UV-blocking Plastic Films and Nets Influence Vectors and Virus Transmission on Greenhouse Tomatoes in the Humid Tropics

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ABSTRACT We studied the effect of UV-blocked greenhouses made from netting and plastics on the movement and pest status of three important pest of tomatoes: whitefly (*Bemisia tabaci*), thrips (*Ceratothripoides claratris*), and aphid (*Aphis gossypii*). Under UV-blocked greenhouses, fewer whiteflies, aphids, and thrips entered the greenhouse compared with the ones having more UV intensity. Similarly, significantly fewer alate aphids and adult *B. tabaci*/leaf were counted in greenhouses with low UV intensity. Although thrips were the most abundant pest, they also were significantly less abundant in greenhouses with lower UV intensity. Consequently, significantly lower levels of leaf infestation were recorded under these greenhouse conditions. During open gates experiments, virus infection levels reached 96–100% under UV nonblocking greenhouses compared with 6–10% infection levels in greenhouses where UV irradiation was blocked. In addition, the appearance of virus symptoms was considerably delayed under greenhouses made from the UV-blocking roof material, although the majority of the plants tested positive for the tospovirus, capsicum chlorosis virus (CaCV; AIT isolate). The results are discussed in context of improved management of sucking insect pests of tomatoes in the humid tropics.

KEY WORDS *Bemisia tabaci*, *Ceratothripoides claratris*, tospovirus, UV-blocking nets and plastic films, humid tropics

Tomato production under protected cultivation in the humid tropics is extremely vulnerable to abiotic stresses (temperature, humidity, air flow, etc.) (Ajwang et al. 2002) and to biotic stresses represented by insects (whitefly, thrips, aphids) and plant virus diseases vectored by these insects (Thongrit et al. 1986, Attathom et al. 1990, Premachandra et al. 2005). The damage that whitefly inflicts on the host plant results from sap sucking, the heavy deposition of honeydew, plant disorders such as uneven ripening (Schuster et al. 1990), and spread of diseases caused by 50–60 different kinds of geminiviruses (Brown et al. 1995). Similarly, thrips (*Ceratothripoides claratris* Shumsher; Thysanoptera: Thripidae) is a serious pest species attacking field- and greenhouse-grown tomatoes in Thailand (Premachandra et al. 2005). Major damage is caused directly by mechanical damage through feeding and oviposition and indirectly by transmitting tospoviruses (Premachandra et al. 2005). Aphids, *Aphis gossypii* (Homoptera: Aphididae), are another pest of tomato in Thailand, causing direct damage by sucking plant sap and reducing the overall quality and productivity. Often plants are attacked by a complex of these pests, which can lead to detrimental infections by more then one type of virus (Summers et al. 2004).

Chemical control is the primary method to manage whiteflies, thrips, and aphids; however, management using pesticides has not been effective, provides only partial control (Denholm et al. 1996, Horowitz and Ishaaya 1996), or fails mainly because of rapid selection of resistant pest biotypes of whitefly (Cahill et al. 1995, Denholm et al. 1996, Prabhaker et al. 1998, Elbert and Nauen 2000), thrips (Kontsedalov et al. 1998, Espinosa et al. 2002), or aphids (Foster et al. 2000). Botanicals like neem can be efficient with lower risk of resistance selection (Thoeming et al. 2003, Kumar et al. 2005) but suffer from rapid dissipation and degradation in presence of UV light under tropical conditions, which reduces persistency (Barrek et al. 2004).

Some species of insects such as whitefly, thrips, and aphids are dependent on UV light (mainly UV A from 320 to 400 nm) to orient themselves during flight. These species may use UV light reflectance patterns as cues for recognizing host plants and flower species (Kring 1972, Rossel and Wehner 1984, Scherer and Kolb 1987, Greenough et al. 1990, Kring and Schuster 1992, Goldsmith 1993, Costa and Robb 1999). Furthermore, *Bemisia argentifolii* and *Frankliniella occidentalis* are attracted to UV light (Mound 1962, Matteson and Terry 1992, Antignus et al. 1996, Antignus 2000). Field studies from Israel showed a significant reduction in crop infestation by *B. tabaci*, aphids, and thrips when UV-blocking plastics were used as greenhouse covers (Antignus et al. 1996, 1998, 2001, Antignus

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2000). These materials are also reported to reduce the incidence of whitefly transmitted geminiviruses.

The aim of protected cultivation is to allow production under otherwise adverse climatic conditions (e.g., heavy rainfalls) and reduce dependency on frequent pesticide use. However, screens as a physical means of control has limitations, particularly with small insects because very small mesh size in nets, or complete cover with plastics, reduces the efficiency of natural ventilation. Good ventilation is a prerequisite for greenhouses without expensive cooling devices (Michelle and Baker 2000, Ajwang et al. 2002). Materials hindering insect invasion but permitting adequate ventilation are desired. UV-blocking materials may be a further advance in greenhouse development. Antignus et al. 1998, Antignus 2000, and others mentioned above used UV-blocking nets/screen or plastics alone to reduce immigration, dispersal, and virus infection. However, none of these studies were performed under the conditions of the humid tropics, where a combination of rain blocking plastic roof materials and well-ventilated side wall covers is necessary to allow year-round production. We undertook this study with UV-blocking and UV-transmissible roof and wall materials in small experimental greenhouses to study the movement pattern of the more serious small plant sucking insects (whitefly, thrips, and aphids) of tomatoes, and the incidence of viruses transmitted by these vectors in the humid tropics.

Materials and Methods

Location

Experiments were conducted on tomato plants [*Lycopersicon esculentum* Mill (Solanaceae), cultivar King Kong II] at the greenhouse complex Asian Institute of Technology, Bangkok, Thailand. No pesticides were used in any series of experiments discussed below. The experiments were conducted during the later part of the spring (March) until end of rainy season (September) 2005.

Treatments and Greenhouses

In all experiments, we measured the effect of UV blocking nets and plastics on the immigration of whitefly, thrips, and aphids and occurrence of tospoviruses and Tomato yellow leaf curl virus (TYLCV). Two nets, UV-blocking Bionet (Klayman Meteor, Petah Tikva Israel) and UV nonblocking (= UV transmitting), Anti-insect nets (50 mesh; Klayman Meteor), along with two plastic films, UV-blocking (Sun Selector Diffused Antivirus; Ginegar Plastic Product, Kibbutz, Israel) and UV-nonblocking (= UV-transmitting), PE-1A (RKW AG, Worms, Germany) were used in the experiments. The spectral transmission properties of these films were analyzed using a Perkin Elmer Lambda 900 UV/ VIS/NIR spectrophotometer (Perkin Elmer Life and Analytical Sciences, Boston, MA; Fig. 1).

These two nets and plastics were permutated in four different combinations: UV blocking nets + UV blocking plastics [B (N+P)]; UV nonblocking nets + UV blocking plastic (NB-N+BP); UV blocking nets + UV nonblocking plastics (BN+N-BP); UV nonblocking nets + UV nonblocking plastic [NB (N+P)]. A total of eight greenhouses (GHs) with vertical side walls (7.5 by 2 by 2 m) were constructed with four GH each placed in identical orientations (either east/west or north/south direction) to avoid any effect of orientation. Furthermore, each greenhouse was provided with two identical doors at the length side. The front and rear end of the door walls were covered with identical nets used for the sidewalls of each greenhouse. The sidewalls of the greenhouses were always covered with either of the nets and the roofs with either of the plastics. Between GH, 1.5-m space reduced shading from each other. The area around the GH complex was cleaned and all weed plants were removed before each series of experiments. Two replications of each treatment were arranged in a complete randomized block design. Between each series, greenhouses were thoroughly washed and cleaned ~1 wk before new experiments. A total of two experimental series each of 6-wk duration were carried out, and each experiment was repeated once. Data collection started 1 wk after transplanting and continued for 5 wk. A total of 30 potted (25 cm high and 27 cm OD) 2-wk-old tomato plants (cultivar King Kong II) were transplanted in a commercial local media composed of clay, sand, and silt in proportions of 31, 30, and 39%, respectively, and 29% of organic matter. Tomato seedlings were grown in an insect free evapo-cooled nursery. Radiation triggered and scheduled drip irrigation combined with dosatron fertigation was provided to ensure the mineral balance and optimal growth and development of the tomatoes. During the period of experiments, each GH was provided with automatic sensors to measure temperature and humidity. The incoming UV-A was measured using Radiometer UV-Sensor (Dr. Grobel UV-Elektronik, Germany).

Capsicum Chlorosis Virus Detection by Double Antibody Sandwich-Enzyme-linked Immunosorbent Assay

Double antibody sandwich enzyme-linked immunosorbent assay (DAS-ELISA) was conducted for the confirmation of Capsicum Chlorosis Virus (CaCV)-Asian Institute of Technology, Bangkok, Thailand (AIT) infection of tomato plants in addition to symptom diagnostics. Polyclonal and monoclonal antibodies raised against N-protein of Watermelon Silver Mottle Virus (WSMV) and Groundnut Bud Necrosis Virus (GBNV; Agdia, Elkhart, ID) were used. Plant leaves were homogenized at a ratio of 1:5 in PBS-T (2.5 mM KCl, 1 mM KH_2PO_4, 8 mM Na_2HPO_4, 0.14 M NaCl, and 0.6 ml/liter Tween 20) containing 0.45 polyvinylpyrollidone (PVP). Leaves from healthy plants were used for the control treatment. Absorbance values were read with a microplate reader (BIO-Tek Instruments, VT) at 405 nm, with PBS-T as a blank. The

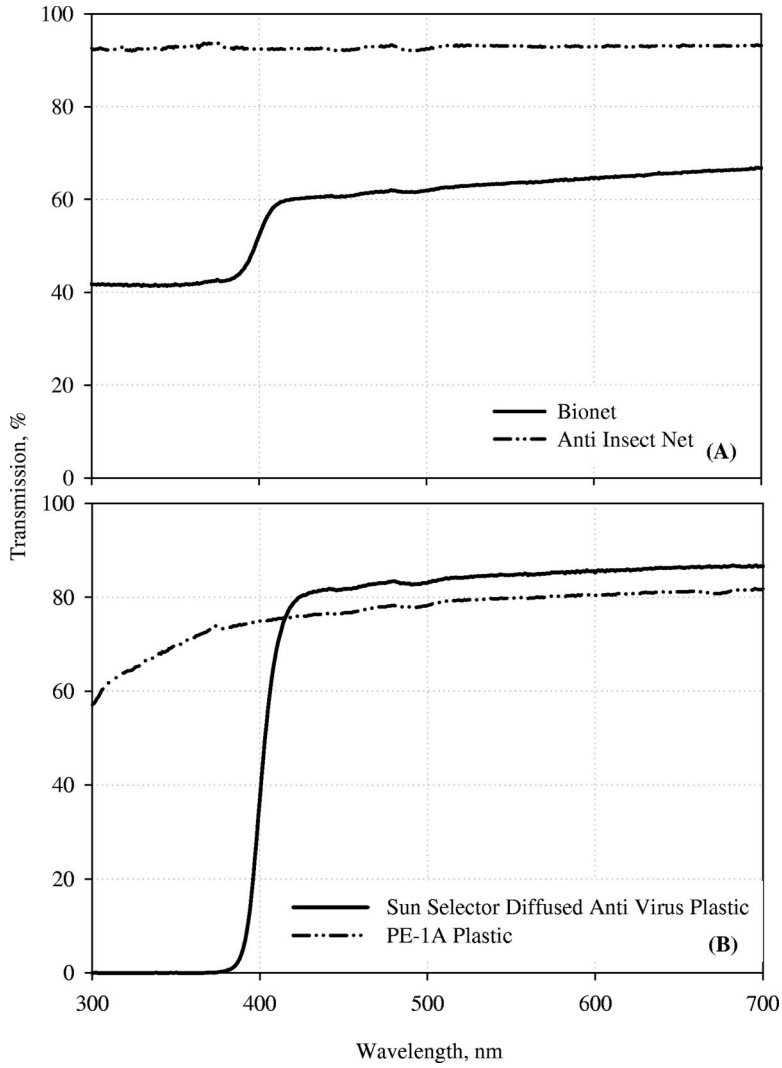

Fig. 1. Spectral transmisson of plastic films and nets measured with a PerkinElmer Lambda 900 UV/VIS/NIR spectrophotometer. (A) Nets: UV blocking net (Bionet, Klayman Meteor) and UV-transmitting nets (Anti-Insect; Klayman Meteor). (B) Plastics: UV-blocking plastic film (Sun Selector Diffused Anti-Virus; Ginegar Plastic Products) and UV-transmitting plastic, PE-1A (RKW AG).

absorbance values were corrected by subtracting the average of three wells of the blank from samples means. Samples having absorbance means three times that of the control was considered as positive. For other viruses (e.g., TYLCV), visual counts were made on the basis of symptoms only.

Partial Ventilation: Experiments 1 and 2

Two experiments were conducted using the eight GHs. The two parallel doors of the GH were simultaneously opened every morning from 0600 to 1000 hours (partial ventilation), coinciding with the peak insect's activities time. The immigrating whitefly population was measured by yellow sticky traps (YSTs; 25 by 15 cm) positioned half at the plant canopy and half above canopy. The YST were made from yellow PVC sheets coated with insect-glue (Kosfix; Kosmix Polymer, Bangkok, Thailand) on both sides. A total of six YST were placed for each GH and changed once a week, and number of WF trapped at both sides of the traps were counted. Each trap was considered as one replication, and this way, a total of five weekly readings were collected on the WF entering inside each of eight GHs during each experiment. Similarly, the numbers of adult WF per plants were counted by selecting one young fully developed leave per plant, gently turning it over, and visually counting the number of adults present on the lower surface. The counting was carried out in the early morning (0700 hours and before) from three randomly selected plants from each greenhouse.

Once a week, number of thrips entering in each GH was counted using Blue Sticky Traps (BSTs) of same dimension simultaneously with YST (12 replications). Additionally, once a week, number of thrips infested leaves were counted from three premarked plants until the fifth week to asses a cumulative weakly leaf damage. Once a week, number of virus infected tomato plants were counted and marked, and toward the end of the experiments at 35 d after transplanting (DAT), DAS-ELISA tests were carried out to distinguish between the tospovirus and other viruses (e.g., TYLCV). Because the tospovirus was the most commonly occurring one, the plants failed to test positive for the CaCV-AIT infection but showing virus symptoms were assumed to be infected with the TYCLV.

The number of immigrating winged aphids was monitored using the same YST placed for the whitefly monitoring in a similar manner as explained above. The immatures and wingless adults (henceforth referred to as immatures) were counted by selecting one young, fully expanded leaf per plant, gently turning it over, and visually counting their numbers present on the lower surface.

Full Ventilation: Experiments 3 and 4

Two experiments (June–July; August–September) were carried out in a similar GH set-up as discussed above with a single exception of timing of GH door opening. Two GH doors were kept open during the entire experiment (full ventilation). The numbers of whitefly and thrips were counted on the YSTs and BSTs as described above (weekly until 35 DAT). Similarly, number of thrips infested leaves and virus infected plants were counted and marked, and plant viruses were monitored. Simultaneously with these two experiments, ability of whitefly and thrips to reach to the experimental GHs were studied by attaching two YSTs and BSTs each at the outer walls (centrally placed). Traps were changed weekly followed by counting of thrips and whiteflies. The position and orientation of the traps on all four GH types were similar.

Data Analyses

Adult whiteflies, thrips, and aphids on traps, alate aphids and whiteflies on leaves, number of thrips-infested leaves, and percentage of virus-infected plants were subjected to HOVTEST = LEVENE option of SAS to account for homogeneity of variance and normality. In case of nonhomogeneity, percent values were transformed using arcsine–square-root (arcsine$\sqrt{}$) transformation. Insects on traps and plants and number of infested leaves count values were transformed by square-root ($\sqrt{}$) transformation before running an analysis of variance (ANOVA) followed by mean separation using Fisher least significant difference (LSD) test (Steel and Torrie 1980, Gomez and Gomez 1984). Data were back-transformed for presentation as mean $\pm$ SE. A significance level of $\propto$ = 0.05 was used for all analysis.

Results

Light Transmission and Temperature

No significant differences in temperatures and humidity inside the four types of tunnels were found during all four experiments. However, the UV light intensity varied under each GH type during either sunny or cloudy days (Fig. 2). The UV levels dropped to almost half during cloudy days. During experiments 1 and 2, ≈20% of the 5-wk-long experiments were cloudy, whereas it was ≈40% during experiments 3 and 4.

Partial Ventilation: Experiments 1 and 2

Whitefly. Significantly fewer whiteflies entered the B (N+P) GH type compared with the other tested combinations during all sampling days. Whiteflies always preferred to enter the NB (N+P) GH type, irrespective of either initial low population (experiment 1) or at relatively higher population (experiment 2; Table 1). Comparing the other combinations, WF preferred to enter GHs with roofs made from the nonblocking plastics. In contrast, GHs with UV-blocking plastic roofs had a significantly lower number of whiteflies on YSTs inside. Moreover, colonization was clearly related to the sidewall net properties (Table 1). Significantly fewer adult whiteflies were recorded on leaves in the B (N+P) GH compared with the other tested GH types. Highest numbers of WF per leaf were recorded from the NB (N+P) type GH (Table 1). During the second round of experiments, settling of whitefly followed the same trends (Table 1).

Aphids. Winged aphids followed the same entry trends as whitefly, and significantly less aphids were trapped inside the B (N+P) GH compared with other tested treatments (Table 2). On 35 DAT, both during experiments 1 and 2, highest counts were recorded on the YSTs. Moreover, for most sampling dates, no significant differences were recorded inside B (N+P) and NB-N+B-P type GH. Significantly higher numbers of aphids per leaf were counted within the GH with more UV light intensity during both experimental periods (Table 2). It is obvious from the results that winged aphids preferred to immigrate into more UV receiving GH compared with the ones with less UV and that denser immatures and wingless adult populations developed on the leaves. Thus, the GHs made from the B (N+P) provided the best protection against the winged as well as the immature aphids.

Thrips and Leaf Damage. Thrips was the most abundant pest and immigration followed similar trends of that of whiteflies and aphids. NB (N+P) GH attracted significantly the highest number of thrips compared with all other GH types (Table 3). During the second round of experiments, more thrips per BST and more thrips damaged leaves were recorded. At 35 DAT, 162 and 176 thrips per BST were recorded under the NB (N+P) material during experiments 1 and 2, respectively, against 0 and 3.75 thrips during same period inside B (N+P) GH types. For over 3 wk, significant differences in numbers of thrips were recorded inside

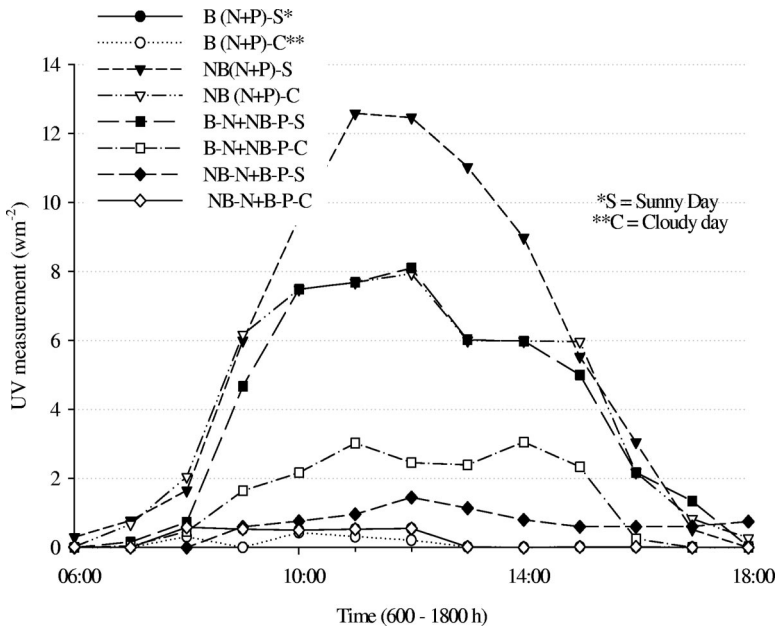

Fig. 2. UV-A measurement (w/m^2) under four greenhouses, UV-blocking net sidewalls with UV-blocking plastic film as roof [B (N+P)]; UV nonblocking nets as sidewalls and UV nonblocking plastic films as roof [NB (N+P)]; UV-blocking nets as side walls and UV nonblocking plastic films as roof (B-N+NB-P); and UV nonblocking nets as side wall and UV-blocking plastics films as roof (NB-N+B − P) using Radiometer UV-Sensor (Dr. Grobel UV-Elektronik).

B (N+P) and NB-N+B-P type GHs during experiments 1 and 2. The higher number of immigrating thrips inside the NB (N+P) caused significantly higher cumulative number of thrips-infested leaves (leaf damage) at 35 DAT compared with the other greenhouses (Table 3).

Table 1. Weekly mean ± SE no. of *B. tabaci* adults per leaf and on YSTs trapped inside GHs during partial ventilation experiments (experiments 1 and 2)

Days after transplanting	Treatments			
	B (N+P)	NB-N+ B-P	B-N+ NB-P	NB (N+P)
Experiment 1				
Whiteflies per leaf				
7	0.00 ± 0.00a	0.50 ± 0.22b	2.50 ± 0.34c	5.00 ± 0.86d
14	0.00 ± 0.00a	0.83 ± 0.40ab	2.00 ± 0.52b	10.33 ± 1.65c
21	0.17 ± 0.17a	1.50 ± 0.22b	5.67 ± 0.71c	15.50 ± 2.28d
28	0.50 ± 0.34a	2.00 ± 0.45a	7.67 ± 1.86b	22.17 ± 3.12c
35	1.50 ± 0.43a	2.83 ± 0.54a	10.00 ± 2.14b	22.67 ± 2.54c
Whiteflies per YST				
7	0.00 ± 0.00a	0.42 ± 0.15b	1.83 ± 0.37c	8.92 ± 1.04d
14	0.17 ± 0.11a	1.00 ± 0.28a	6.75 ± 0.45b	24.83 ± 4.31c
21	0.75 ± 0.41a	2.58 ± 0.56b	10.58 ± 0.69c	25.17 ± 1.97d
28	0.92 ± 0.26a	1.42 ± 0.38a	11.58 ± 0.68b	32.58 ± 3.59c
35	0.08 ± 0.08a	1.92 ± 0.47b	7.50 ± 1.14c	28.58 ± 3.84d
Experiment 2				
Whiteflies per leaf				
7	0.00 ± 0.00a	0.67 ± 0.21b	2.83 ± 0.40c	6.50 ± 1.52d
14	0.00 ± 0.00a	0.83 ± 0.40a	4.33 ± 0.21b	19.33 ± 3.63c
21	0.17 ± 0.17a	2.33 ± 0.33b	7.50 ± 1.06c	30.67 ± 7.79d
28	0.83 ± 0.48a	3.50 ± 0.76b	9.67 ± 1.31c	29.00 ± 4.43d
35	1.50 ± 0.34a	2.33 ± 0.42a	11.17 ± 2.14b	34.67 ± 6.29c
Whiteflies per YST				
7	0.00 ± 0.00a	0.42 ± 0.19a	1.58 ± 0.56b	10.75 ± 1.04c
14	0.17 ± 0.11a	2.58 ± 0.66b	10.67 ± 1.36c	33.33 ± 1.97d
21	0.33 ± 0.22a	1.17 ± 0.39a	6.75 ± 0.86b	47.25 ± 4.26c
28	0.42 ± 0.26a	1.92 ± 0.61b	9.75 ± 1.58c	71.92 ± 5.09d
35	0.08 ± 0.08a	5.25 ± 0.87b	20.00 ± 1.56c	93.17 ± 5.68d

ANOVA for each DAT was performed followed by mean separation using Fisher's LSD test. Means within DAT followed by the same letter(s) are not significantly different at $P = 0.05$.

Table 2. Weekly mean ± SE no. of wingless adults and immature aphids per leaf and winged aphid adults trapped on YSTs inside during partial ventilation (experiments 1 and 2)

Days after transplanting	Treatments			
	B (N+P)	NB-N+ B-P	B-N+NB-P	NB (N+P)
Experiment 1				
Immature and wingless adults per leaf				
7	0.17 ± 0.17a	0.17 ± 0.17a	0.50 ± 0.22a	4.00 ± 0.63b
14	0.00 ± 0.00a	1.33 ± 0.33b	3.50 ± 0.81c	12.00 ± 2.54d
21	0.00 ± 0.00a	0.50 ± 0.22a	4.50 ± 0.56b	15.17 ± 3.72c
28	0.00 ± 0.00a	0.17 ± 0.17a	1.33 ± 0.33b	6.67 ± 0.99c
35	0.00 ± 0.00a	0.50 ± 0.22a	3.17 ± 0.79b	7.83 ± 0.17c
Winged adults per YST				
7	0.00 ± 0.00a	0.00 ± 0.00a	0.75 ± 0.18b	6.08 ± 1.87c
14	0.50 ± 0.19a	1.00 ± 0.35a	3.47 ± 0.42b	10.83 ± 1.09c
21	0.17 ± 0.11a	1.42 ± 0.42b	3.92 ± 0.81c	12.83 ± 1.64d
28	0.42 ± 0.19a	0.67 ± 0.22a	4.75 ± 0.79b	14.50 ± 2.18c
35	0.25 ± 0.13a	0.75 ± 0.18b	3.92 ± 0.71c	15.92 ± 0.90d
Experiment 2				
Immature and wingless adults per leaf				
7	0.00 ± 0.00a	0.00 ± 0.00a	1.50 ± 0.50b	4.17 ± 0.70c
14	0.17 ± 0.17a	1.00 ± 0.37ab	2.67 ± 0.95b	6.50 ± 0.56c
21	0.00 ± 0.00a	0.83 ± 0.40b	2.33 ± 0.80c	7.17 ± 0.54d
28	0.17 ± 0.17a	0.83 ± 0.40a	2.83 ± 0.60b	8.17 ± 0.60c
35	0.00 ± 0.00a	0.67 ± 0.33b	2.50 ± 0.43c	9.33 ± 0.61d
Winged adults per YST				
7	0.00 ± 0.00a	0.00 ± 0.00a	1.08 ± 0.73b	5.08 ± 1.37c
14	0.25 ± 0.13a	0.67 ± 0.22a	4.17 ± 0.95b	11.58 ± 2.76c
21	0.00 ± 0.00a	1.75 ± 0.98b	5.08 ± 1.47c	15.00 ± 2.92d
28	0.67 ± 0.22a	1.58 ± 0.73a	6.42 ± 2.26b	21.33 ± 3.92c
35	0.33 ± 0.22a	2.33 ± 0.92a	9.67 ± 1.71b	25.92 ± 4.29c

ANOVA for each DAT was performed followed by mean separation using Fisher's LSD test. Means within DAT followed by the same letter(s) are not significantly different at $P = 0.05$.

Table 3. Weekly mean ± SE no. of adult thrips per BSTs trapped inside GHs and cumulative leaf infestation during partial ventilation (experiments 1 and 2)

Days after transplanting	Treatments			
	B (N+P)	NB- N+ B-P	B-N+NB-P	NB (N+P)
Experiment 1				
Adult per BST				
7	0.00 ± 0.00a	0.00 ± 0.00a	0.25 ± 0.13a	9.75 ± 0.75b
14	0.25 ± 0.13a	0.67 ± 0.22a	6.75 ± 1.08b	17.42 ± 1.99c
21	0.17 ± 0.11a	1.00 ± 0.35b	11.50 ± 0.89c	33.42 ± 1.59d
28	0.42 ± 0.19a	1.58 ± 0.31b	20.00 ± 0.83c	72.83 ± 4.52d
35	0.00 ± 0.00a	1.75 ± 0.48b	24.08 ± 0.54c	162.67 ± 2.25d
Cumulative no thrips infested leaves/plant				
7	0.00 ± 0.00a	0.67 ± 0.21b	1.00 ± 0.45b	2.00 ± 0.26c
14	0.33 ± 0.21a	1.17 ± 0.40ab	2.17 ± 0.70b	5.17 ± 0.31c
21	0.83 ± 0.31a	1.50 ± 0.50a	3.50 ± 0.72b	9.50 ± 0.34c
28	1.33 ± 0.61a	2.17 ± 0.40ab	4.83 ± 1.17b	12.67 ± 0.33c
35	1.67 ± 0.71a	2.83 ± 0.60a	7.00 ± 1.34b	13.33 ± 0.49c
Experiment 2				
Adult per BST				
7	0.25 ± 0.13a	0.58 ± 0.23a	3.75 ± 0.64b	18.00 ± 1.35c
14	0.17 ± 0.11a	0.75 ± 0.33a	7.67 ± 0.54b	20.08 ± 1.79c
21	0.33 ± 0.14a	1.92 ± 0.42b	17.25 ± 0.99c	53.33 ± 1.45d
28	0.92 ± 0.26a	5.08 ± 0.77b	23.08 ± 1.53c	114.33 ± 4.65d
35	3.75 ± 0.37a	10.92 ± 1.60b	33.50 ± 1.51c	176.75 ± 6.05d
Cumulative no thrips infested leaves/plant				
7	0.00 ± 0.00a	0.50 ± 0.22ab	1.17 ± 0.54b	3.33 ± 0.76c
14	0.33 ± 0.21a	1.17 ± 0.48ab	3.00 ± 0.89b	8.33 ± 0.67c
21	0.83 ± 0.40a	1.33 ± 0.56a	4.17 ± 0.79b	10.17 ± 0.60c
28	1.67 ± 0.61a	2.50 ± 0.62b	5.00 ± 1.00c	13.83 ± 0.48d
35	1.83 ± 0.54a	3.00 ± 0.73b	5.67 ± 1.23c	14.50 ± 0.34d

ANOVA for each DAT was performed followed by mean separation using Fisher's LSD test. Means within DAT followed by the same letter(s) are not significantly different at $P = 0.05$.

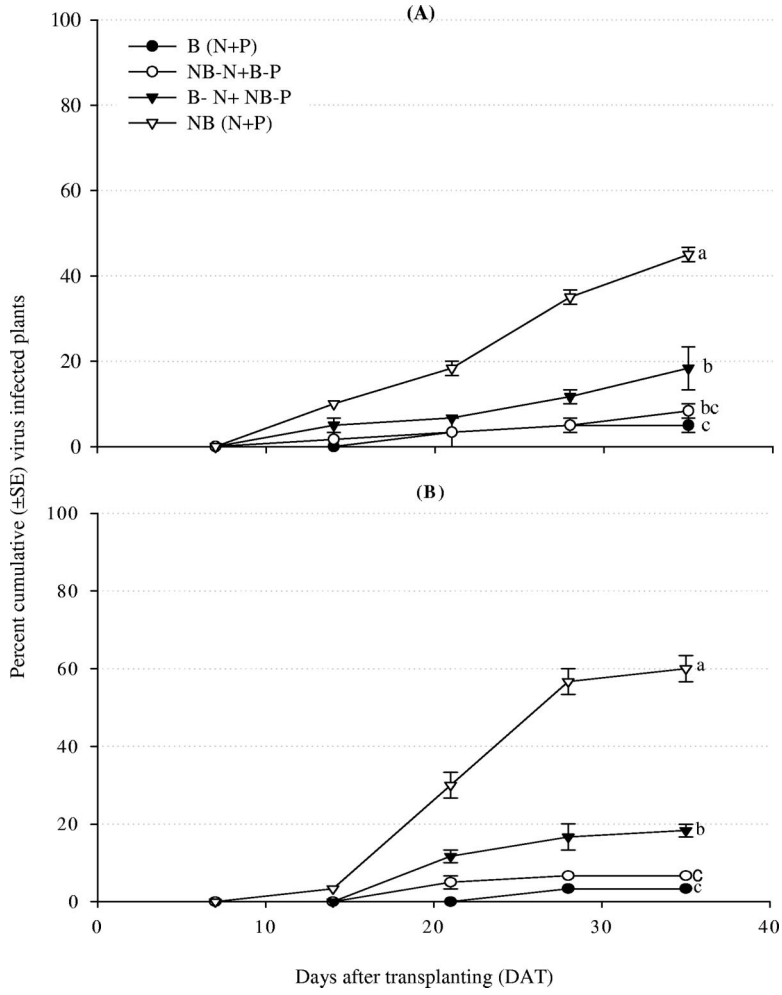

Fig. 3. Percent cumulative virus-infected tomato plants under greenhouses, UV-blocking net sidewalls with UV-blocking plastic film as roof [B (N+P)]; UV nonblocking nets as sidewalls and UV nonblocking plastic films as roof [NB (N+P)]; UV-blocking nets as side walls and UV nonblocking plastic films as roof (B-N+NB-P); and UV nonblocking nets as side wall and UV-blocking plastics films as roof (NB-N+B-P). (A) During experiment 1 and (B) during experiment 2, when greenhouse doors were open from 0600 to 1000 hours. Cumulative percent at 35 d after transplanting sharing a common letter are not significantly different at $P < 0.05$, Fisher LSD.

Virus Spread. Cumulative percent virus (total number of virus infected plants) incidence at 35 DAT was significantly lower with 5.00% recorded inside B (N+P) GH compared with 45% under NB (N+P) GH types ($F = 29.80$; df = 3,7; $P = 0.0034$; Fig. 3A). Tospovirus (CaCV, AIT isolate, constituted the major proportion and reached 88 and 66%, respectively, in B (N+P) and NB (N+P) GH types. Inside the NB (N+P) GH, virus-infected plants were recorded earlier and virus spread at faster rates compared with the B (N+P) GH. During the second round of experiments, more plants showed virus symptoms, but similar to the first experiment, virus spread was significantly higher under NB (N+P) GH ($F = 243.73$; df = 3,7; $P = 0.0001$; Fig. 3B) compared with B (N+P) type GH. However, no significant differences were found in B (N+P) and NB-N+B-P types GHs. Of these, a total of 83.33% plants tested positive for the tospovirus. Percent cumulative infestation with tospovirus was significantly higher under the NB (N+P) type GH ($F = 24.30$; df = 3,7; $P = 0.005$). Similar to experiment 1, virus incidence started earlier at 14 DAT under the NB (N+P) GH types compared with 28 DAT under B (N+P) GH types. During both experiments 1 and 2 under the UV-blocking plastic GH roof, most of the virus affected plants were found near to the doors, whereas in GHs with UV nonblocking roofs, infected plant were dispersed all over the GH. The results clearly indicate that the B (N+P) GH type provided the best protection against the virus infection.

Table 4. Weekly mean ± SE no. of *B. tabaci* adult per leaf on YSTs trapped inside GHs and trapped on the YSTs on the outer walls of the GHs during complete ventilation (experiments 3 and 4)

Days after transplanting	Treatments			
	B(N+P)	NB-N+ B-P	B-N+NB-P	NB(N+P)
Experiment 3				
Whiteflies per leaf				
7	0.17 ± 0.17a	0.50 ± 0.22a	4.33 ± 1.65b	15.17 ± 2.21c
14	2.17 ± 0.48a	3.00 ± 0.37a	9.50 ± 1.63b	37.50 ± 3.80c
21	2.33 ± 0.21a	3.50 ± 0.62a	18.67 ± 1.78b	53.67 ± 9.04c
28	2.67 ± 0.56a	4.00 ± 0.37a	20.17 ± 1.72b	60.00 ± 9.15c
35	3.83 ± 0.54a	5.17 ± 1.01a	15.17 ± 1.76b	36.00 ± 2.18c
Whiteflies per YST inside				
7	1.00 ± 0.33a	2.25 ± 0.39ab	4.92 ± 0.34b	15.00 ± 4.49c
14	0.83 ± 0.24a	3.58 ± 0.98b	19.25 ± 2.75c	43.17 ± 7.64d
21	1.42 ± 0.29a	2.58 ± 0.31a	19.58 ± 2.27b	109.83 ± 6.64c
28	1.58 ± 0.38a	2.50 ± 0.80a	23.33 ± 2.42b	131.25 ± 17.32c
35	1.25 ± 0.28a	2.67 ± 0.61a	25.67 ± 1.32b	133.92 ± 11.42c
Whiteflies per YST trapped on outer wall of GH				
7	1.00 ± 0.42a	1.63 ± 0.60a	4.00 ± 0.68b	22.63 ± 2.90c
14	1.10 ± 0.38a	2.13 ± 0.40b	13.75 ± 1.70c	34.00 ± 2.15d
21	1.88 ± 0.35a	2.63 ± 0.65a	21.25 ± 1.15b	46.88 ± 2.22c
28	3.23 ± 0.53a	3.88 ± 0.79a	21.88 ± 1.61b	52.50 ± 4.23c
35	3.00 ± 0.57a	4.13 ± 0.58a	23.63 ± 1.38b	56.25 ± 3.67c
Experiment 4				
Whiteflies per leaf				
7	0.17 ± 0.17a	0.67 ± 0.33a	5.00 ± 1.39b	17.17 ± 2.69c
14	2.17 ± 0.60a	3.33 ± 0.67a	10.33 ± 0.92b	38.50 ± 5.85c
21	1.67 ± 0.61a	3.50 ± 0.76ab	5.83 ± 0.60b	24.17 ± 4.61c
28	2.33 ± 0.33a	2.17 ± 0.60a	6.67 ± 1.12b	22.17 ± 3.67c
35	2.17 ± 0.31a	3.67 ± 0.56a	6.33 ± 0.84b	18.50 ± 2.78c
Whiteflies per YST trapped inside GH				
7	2.75 ± 0.48a	4.49 ± 0.50a	10.17 ± 0.27b	21.33 ± 3.02c
14	5.33 ± 0.99a	7.67 ± 0.45a	17.42 ± 0.56b	50.00 ± 6.28c
21	5.93 ± 0.84a	7.33 ± 0.83a	20.50 ± 1.02b	52.58 ± 4.09c
28	4.58 ± 1.33a	11.75 ± 0.62b	36.50 ± 1.80c	98.75 ± 11.99d
35	6.83 ± 0.81a	10.75 ± 0.68b	31.50 ± 1.34c	90.92 ± 7.69d
Whiteflies per YST trapped on outer walls of GH				
7	2.00 ± 0.46a	4.13 ± 0.64a	6.00 ± 1.02b	17.50 ± 2.27c
14	3.88 ± 0.81a	5.63 ± 0.53a	13.25 ± 0.67b	35.00 ± 3.26c
21	3.63 ± 0.91a	5.38 ± 0.60a	12.63 ± 2.02b	30.88 ± 1.54c
28	3.38 ± 0.56a	5.88 ± 0.52b	11.13 ± 0.97c	43.63 ± 2.56d
35	3.13 ± 0.58a	6.50 ± 0.19b	14.50 ± 0.80c	35.38 ± 1.25d

ANOVA for each DAT was performed followed by mean separation using Fisher's LSD test. Means within DAT followed by the same letter(s) are not significantly different at $P = 0.05$.

Complete Ventilation: Experiments 3 and 4

Whitefly. In total, a higher whitefly population was observed when gates were kept open to achieve complete ventilation. Similar to the entry trends under partial ventilation, significantly fewer number of WF entered inside the B (N+P) GH compared with other tested combinations during all sampling periods. Similar to the lower number trapped on YSTs, significantly fewer whiteflies were found on leaves under B (N+P) GH over the sampling period (Table 4). These results yet again indicated the preference of whiteflies to immigrate into a UV-rich environment irrespective of the ventilation status under NB (N+P) type GHs. During the second experiment, entry and settling of whiteflies followed the same trends (Table 4). The load of whiteflies measured at outside walls of the NB (N+P) were significantly higher in either round of experiments 3 and 4 (see Table 4) compared with B (N+P) GH types.

Thrips and Leaf Damage. Again thrips was the most abundant pest, and similar to the previously observed trends, significantly higher number of thrips entered and were trapped inside the NB (N+P) GH compared with other GH combinations tested in both rounds of experiments (Table 5). Moreover, significantly higher cumulative leaf infestation was observed under NB (N+P) type GHs (Table 5). Thrips followed the same trends of entry and attraction toward UV-rich environment, and a higher number of thrips focused on sidewalls of NB (N+P) type compared with B (N+P) type GH in either of the two rounds of the experiment (Table 5).

Virus Spread. Cumulative percent virus (total number of plants showing virus symptoms) incidence at 35 DAT during experiment 3 was 8% inside B (N+P) GHs compared with 100% under NB (N+P) GH type ($F = 1588.25$; df = 3,7; $P = 0.0001$; Fig. 4A). Tospovirus (CaCV, AIT isolate, constituted the major proportion and reached >75% infection level under B (N+P) GH type ($F = 96.38$; df = 3,7; $P = 0.0003$). Similar to the trends reported with the partial ventilation experiments, inside the NB (N+P) GH types, virus symptoms appeared early and spread at a faster rate compared with B (N+P) GH types. During the second

Table 5. Weekly mean ± SE no. of thrips on BSTs inside GHs, trapped on the outer walls of the GH, and cumulative leaf infestation during complete ventilation (experiments 3 and 4)

Days after transplanting	Treatments			
	B (N+P)	NB-N+B-P	B-N+NB-P	NB (N+P)
Experiment 3				
Thrips per BST trapped inside GH				
7	3.33 ± 0.66a	4.25 ± 0.93a	16.83 ± 1.70b	60.50 ± 11.13c
14	4.17 ± 1.17a	5.92 ± 1.55a	101.83 ± 20.36b	270.42 ± 37.35c
21	11.42 ± 2.52a	17.08 ± 2.53a	86.67 ± 7.86b	327.92 ± 35.40c
28	17.33 ± 3.32a	27.33 ± 3.76a	102.00 ± 22.99b	442.17 ± 25.95c
35	11.75 ± 2.56a	24.75 ± 3.93a	130.17 ± 19.77b	578.83 ± 32.88c
Cumulative no thrips infested leaves/plant				
7	0.33 ± 0.21a	0.67 ± 0.21a	1.50 ± 0.22b	2.67 ± 0.21b
14	1.33 ± 0.33a	2.00 ± 0.00b	4.17 ± 0.31c	8.67 ± 0.42d
21	1.67 ± 0.42a	2.67 ± 0.21b	5.83 ± 0.40c	11.17 ± 0.48d
28	1.83 ± 0.48a	3.67 ± 0.21b	8.17 ± 0.40c	14.00 ± 0.63d
35	2.33 ± 0.33a	5.00 ± 0.37b	11.33 ± 0.33c	21.00 ± 0.68d
Thrips per BST trapped on outer walls of GH				
7	2.13 ± 0.55a	2.50 ± 0.33a	6.75 ± 0.53b	19.88 ± 1.41c
14	2.25 ± 0.37a	3.63 ± 0.38a	19.63 ± 1.92b	57.63 ± 3.19c
21	3.13 ± 0.30a	4.00 ± 0.38a	33.00 ± 1.34b	120.88 ± 7.84c
28	4.69 ± 0.45a	5.88 ± 0.35a	39.25 ± 3.19b	135.38 ± 9.14c
35	4.75 ± 0.70a	6.50 ± 0.60a	34.25 ± 1.39b	145.88 ± 4.40c
Experiment 4				
Thrips per BST trapped inside GH				
7	5.83 ± 0.86a	11.25 ± 1.32b	22.75 ± 2.05c	61.42 ± 7.58d
14	5.25 ± 1.41a	15.50 ± 1.28b	44.67 ± 2.70c	145.25 ± 12.12d
21	11.33 ± 2.29a	25.42 ± 2.72b	60.17 ± 3.36c	190.92 ± 21.30d
28	12.92 ± 1.89a	24.42 ± 2.67b	76.50 ± 5.75c	296.67 ± 21.09d
35	14.92 ± 2.45a	23.58 ± 3.75a	69.75 ± 6.97b	376.33 ± 23.77c
Cumulative no thrips infested leaves/plant				
7	0.50 ± 0.22a	0.83 ± 0.31a	1.67 ± 0.21b	2.33 ± 0.33b
14	1.17 ± 0.31a	2.33 ± 0.21b	3.83 ± 0.48ab	5.00 ± 0.58c
21	1.33 ± 0.33a	3.17 ± 0.31b	5.67 ± 0.61c	8.00 ± 0.68d
28	2.00 ± 0.52a	3.83 ± 0.48b	8.50 ± 0.67c	12.33 ± 0.67d
35	2.83 ± 0.48a	4.33 ± 0.49b	10.67 ± 0.92c	18.33 ± 0.88d
Thrips per BST trapped on outer walls of GH				
7	2.38 ± 0.60a	5.25 ± 1.44ab	11.63 ± 2.06b	34.75 ± 11.92c
14	4.50 ± 0.91a	14.00 ± 1.64b	28.63 ± 2.21c	47.13 ± 4.84d
21	5.00 ± 0.60a	9.63 ± 1.40a	29.75 ± 0.96b	68.38 ± 8.96c
28	6.00 ± 1.86a	9.13 ± 1.16a	21.50 ± 2.04b	71.25 ± 6.82c
35	2.75 ± 0.73a	9.13 ± 1.30b	17.13 ± 1.42c	73.00 ± 2.43d

ANOVA for each DAT was performed followed by mean separation using Fisher's LSD test. Means within DAT followed by the same letter(s) are not significantly different at $P = 0.05$.

round of experiments, overall slightly less cumulative virus incidence was recorded at 96% under NB (N+P) GH type, with similar trends as reported for the previous rounds ($F = 196.94$; df = 3,7; $P = 0.0001$; Fig. 4B). Similarly, the virus symptoms appeared earlier and then spread at faster rates under NB (N+P) GH type over B (N+P) GH types.

Discussion

These studies are probably the first of its kind from protected cultivation in Southeast Asia.

Whitefly Immigration

The UV-deficient environment in all three experiments reduced entry and attraction of whitefly toward or inside the greenhouses. Strongest differences were observed between greenhouses completely covered by UV-blocking material [B (N+P) type GH] compared with those made from UV-transmitting plastics and nets [NB (N+P) type GH]. This entry trend was true irrespective of the length of the time GH gates were opened for ventilation, but fewer whiteflies immigrated and were trapped under the B (N+P) GH type when gates were opened for 4–5 h/d only in the morning compared with experiments with parallel gates kept open longer for full ventilation. When the attraction of whitefly toward the structures was monitored outside the walls, much lower numbers were trapped around the UV blocking houses compared with the nonblocking ones. The results clearly indicate a very sensitive reaction of whitefly adults to the presence of the total amount of UV inside a GH, irrespective of the individual blocking properties of either nets or plastic used in the experiment.

The reduced immigration and attraction of whiteflies inside UV-deficient GHs or toward sidewalls of UV-blocking material are in agreement with Antignus et al. (1996, 1998, 2001) and Costa and Robb (1999). Similarly Gonzalez (2004), working with *B. tabaci*, and Mutwiwa et al. (2005), working with *T. vaporariorum*, reported significantly lower numbers of whiteflies trapped under UV-low GHs. Most of these studies

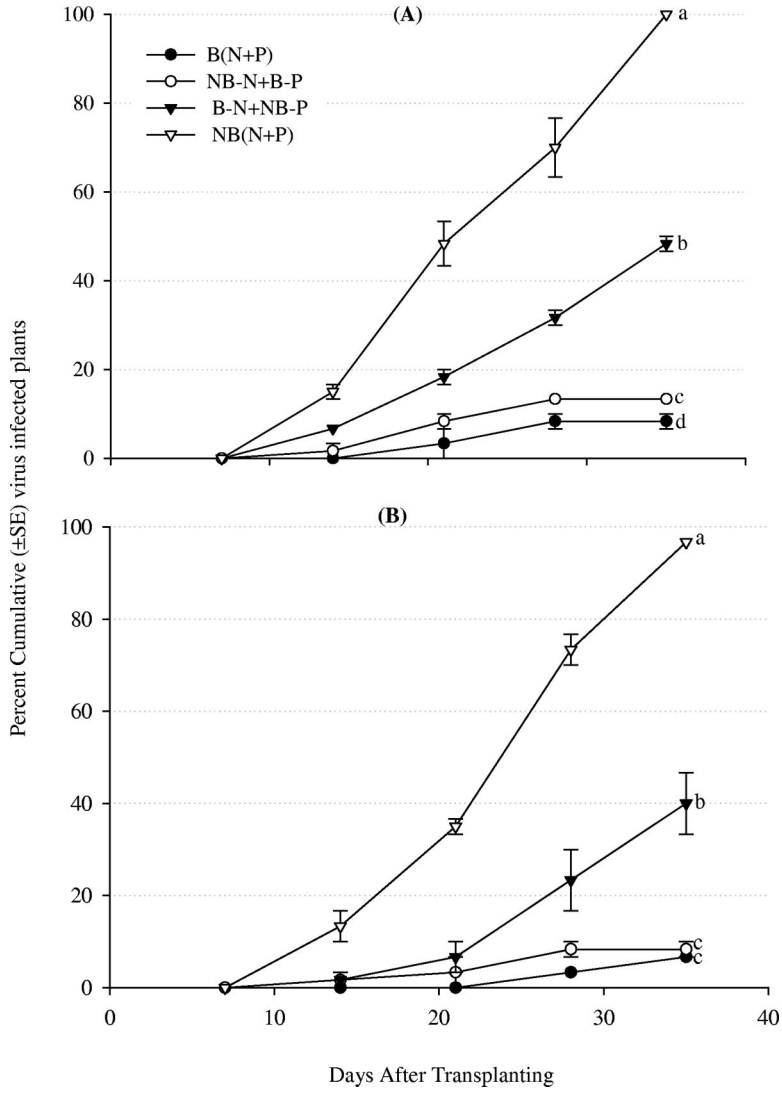

Fig. 4. Percent cumulative virus-infected tomato plants under greenhouses (treatments), UV-blocking net sidewalls with UV-blocking plastic film as roof [B (N+P)]; UV nonblocking nets as sidewalls and UV nonblocking plastic films as roof [NB (N+P)]; UV-blocking nets as side walls and UV nonblocking plastic films as roof (B-N+NB-P); and UV nonblocking nets as side wall and UV-blocking plastics films as roof (NB-N+B-P). (A) During experiment 3 and (B) during experiment 4, when greenhouse doors were kept open (complete ventilation). Cumulative percent at 35 d after transplanting sharing a common letter are not significantly different at $P < 0.05$, Fisher LSD.

showed reduction in WF flight intensity and immigration into UV-poor tunnels/net house/greenhouses. Most used UV-blocking plastics, whereas Antignus et al. (1998, 2001) covered tunnels completely with UV-blocking nets and achieved a long-term protection of plants inside from *B. argentifolii*. When we measured the incoming radiation inside these structures (Fig. 2), we found that plastic roofs of our small greenhouses blocked the UV radiation more efficiently than nets at the sidewalls. Wherever we used the UV-blocking plastic roofs, internal UV radiation was lowest. The immigrating whiteflies showed an UV intensity–dependent behavior. For instance, during experiment 1, on a typical sunny day at 1200 hours, inside GH types NB (N+P), we recorded UV intensity of 12.47 w/m^2 followed by 8.10 w/m^2 in the B-N+NB-P, 1.45 w/m^2 under NB-N+B-P, and 0.55 w/m^2 under B (N+P) type GH (Fig. 2). These levels of UV radiation decreased to half in respective GH types during cloudy days, but the differences in attraction of WF persisted further on between the GH types. This indicates that it is not the absolute UV amount available that triggers WF selection behavior but the relative difference between two light environments. Similar findings on reduced movement, dispersal, and colonization under UV-deficient conditions of another whitefly species in greenhouses, *T. vaporariorum*, have been recently reported by Doukas (2002) and Mutwiwa et al. (2005).

Similar to the trends of trapping with YSTs, significantly higher numbers of whiteflies per leaf were recorded under the NB (N+P) GH either with short opening (4–5 h) or when gates kept open permanently. This indicates that YST trapping is giving a clear picture of whitefly settling and population development on the plants. Reduced population built up of whiteflies under UV-deficient environment is in line with Antignus et al. 1996, 1998. Our results seem to be only in disagreement with Costa et al. (2002), who found insignificant differences in whitefly numbers on plants in greenhouses made of UV-absorbing compared with UV-transmitting plastics. These contradictions could be caused by the fact that, in our experiment, only the gates were opened but not the sidewalls. However, we also found more whiteflies, thrips, and aphids on the tomato plants near the gates under B (N+P) GHs compared with the center of the GHs. Even the virus-infected plants in this type of GH are always recorded near the opening gates. Similar observations were made by Mutwiwa et al. (2005).

Clearly, the UV-reduced GH environment achieved through the combination of the UV-blocking plastics and nets was able to dramatically reduce the number of whiteflies moving to the wall of greenhouses, entering inside, and settling on plants. The exact mechanism of this effect is still unknown, but it is presumed that reduced immigration and dispersal levels result from interference with visual cues that trigger flight activity and orientation to and selection of plants for settlement (Antignus et al. 1996, 1998, Antignus 2000, Mutwiwa et al. 2005). That whiteflies might be able to react to UV is shown by Mellor et al. (1997), who described UV-sensitive photoreceptors for the greenhouse whitefly, *T. vaporariorum.* No such detailed information is available for *B. tabaci.*

Aphid Immigration

Winged aphids followed similar trends considering the different GH types as previously discussed for whiteflies independent of whether they were trapped with YSTs or accounted for on the plants. These results are in line with Antignus et al. (1996, 1998) and Chyzik et al. (2003), who reported trapping 50 times more alate aphids under normal condition over UV-blocked conditions. Recent studies (Kirchner et al. 2005) show that aphids have photoreceptors in their compound eyes sensitive to light in the UV-A range of the light spectrum; however, detailed studies about the importance of light reception in the UV range for aphid behavior are still missing. The increased number of aphid nymphs inside the NB (N+P) GH could well be caused by its increased propagation time over B (N+P) GH types. Propagation time of aphid (*Myzus persicae*) was reported to be 1.5–2 times longer under regular film compared with UV-absorbing films, and UV-exposed aphids gave birth to more new progeny (Chyzik et al. 2003).

Thrips Immigration and Leaf Damage

The thrips, *Ceratothripoides claratris*, gave a very sensitive response to the changes in UV environment. Irrespective of ventilation period (partial or complete), thrips preferred to enter inside UV-rich environment in a concentration-dependent manner. Thrips followed the same trend as whiteflies and aphids in their attraction toward the various greenhouses. Higher numbers of thrips immigrating into NB (N+P) type GHs resulted in higher number of damaged leaves per plant. Because no previous studies with *C. claratris* have been reported, results were compared with other thrips species. Our findings are consistent with findings on Western flower turnips (WFT), *F. occidentalis* (Pergrande) from Israel, where significant reduction of the thrips were found under UV-absorbing plastic tunnels (Antignus et al. 1996). Similarly, in a choice study Costa and Robb (1999) captured 90–98% of released *F. occidentalis* (Pergrande) under tunnels rich in UV over tunnels covered with UV-absorbing plastics. However, Antignus et al. (1998) could not significantly reduce the immigration of *F. occidentalis* with tunnels made of 50-mesh UV-blocking Bionets. The discrepancy to our results could be explained by the different set-ups because we used a combination of UV-blocking plastics and nets with much higher UV-blocking capacity compared with Bionet only. Similar to aphids, the ability of thrips to receive light in the UV range spectrum is well documented (Matteson et al. 1992), including a differentiation between UV-A and UB-B. Mazza et al. (1996, 2002) showed that the thrips *Caliothrips phaseoli* avoids UV-B but is attracted by UV-A, and Vernon and Gillespie (1990) reported that high UV reflectance environment repels thrips. The selective sensitivity of thrips to different UV ranges becomes obvious when we compare our results with reports on the use of UV-reflective mulches against thrips. Some reports are available for tomato and capsicum crops, where use of UV-reflective mulch caused significant reduction in WFT, *F. occidentalis* (Pergrande) population (Scott et al. 1989, Greenough et al. 1990, Brown and Brown 1992, Kring and Schuster 1992, Vos et al. 1995, Costa et al. 2002, Stavisky et al. 2002, Gonzalez 2004). Similarly, other species of thrips were repelled using plastic reflective mulches in outdoor ornamentals and vegetable crops (Csizinski et al. 1995, Terry 1997). It could be speculated that the specific reflection pattern of UV is important in determining whether thrips is attracted to a host or repelled and that relative high amounts of reflected UV-B can "overrule" the attractive properties of UV-A.

Plant Virus

Thrips, *C. claratris*, have recently been reported to be a serious pest of protected cultivation of tomato in the greater Bangkok area and vector of tospovirus, CaCV (isolate AIT) (Premachandra et al. 2005). Number of plants showing virus symptoms, which was later confirmed through ELISA, followed the trends of

the immigrating thrips and WF, which was recorded least under the B (N+P) type GH over NB (N+P) type GH. B (N+P) GH reduced and delayed the virus infection in all experiments. The majority of plants showing virus symptoms was tested positive for the tospovirus (CaCV, AIT isolate), which could be expected because *C. claratris* was the most abundant species. No further attempts were made to identify other viruses by serological testing, but based on the visual symptoms, it could be speculated that TYLCV was another virus present. Furthermore, it is transmitted by whiteflies, and it is very frequently observed in field crops in the study area. In Israel, the spread of TYLCV was significantly reduced using UV-absorbing nets (Antignus et al. 1996, 1998, Gonzalez 2004), the incidence of cucurbit yellow stunting disorder virus in melons was reported to be 70% less under UV-absorbing films, and the same film seemed to be effective against aphid-borne Zucchini yellow mosaic virus (Antignus 2000). UV-reflective mulches can significantly reduce the incidence of thrips vectored viruses as shown with Tomato Spotted Wilt Virus, which was vectored by *Frankliniella* spp (Stavisky et al. 2002). Moreover, the use of aluminum or silver plastics mulches delayed the infection and spread of TYLCV in Jordan (Suwwan et al. 1988) and effectively protected tomato against tomato mottle virus in Florida (Csizinski et al. 1995).

In conclusion, our results show that the greenhouses made from a combination of the UV-blocking nets as sidewalls and roof from UV- blocking plastics are able to significantly limit immigration of whiteflies, aphids, and thrips into such structures, and consequently, tomato plants grown under such GHs had fewer pest populations resulting into less leaf infestation as well as reduced virus infections. Being in the tropics, the major amount of light filters through the roof, hence UV-blocking plastic on the roof can efficiently reduce the incoming UV. Nets on sidewalls, however, are a prerequisite for low-cost noncooled greenhouses to achieve sufficient ventilation. UV-blocking nets, although not as efficient as films in their blocking abilities, can supplement the UV blocking film roof material. Reducing immigration of the pests in greenhouses leads to a lower initial pest population density, which is a key factor for successful and effective control (Xu et al. 1984). Other potential benefits from the reduced UV environment achieved through the use of UV-blocking net and plastics may include improved performance of entomopathogenic fungi (Costa et al. 2001) and baculoviruses (Goulson et al. 2003), improved management of some fungal pathogens (Reuveni and Raviv 1992, Elad 1997), reduced UV-related degradation of botanicals like neem (Barrek et al. 2004), and overall improvements in the microclimate, but that has to be confirmed in further studies.

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