Safe housing ensured by an electric field screen that excludes insect-net permeating haematophagous mosquitoes carrying human pathogens

2015 J. Phys.: Conf. Ser. 646 012002

(http://iopscience.iop.org/1742-6596/646/1/012002)

Safe housing ensured by an electric field screen that excludes insect-net permeating haematophagous mosquitoes carrying human pathogens

Y Matsuda[1], K Kakutani[2], T Nonomura[1], J Kimbara[3], K Osamura[4], S Kusakar[1] and H Toyoda[1]

[1]Faculty of Agriculture, Kinki University, Nara, Japan,

[2]Pharmaceutical Research and Technology Institute, Kinki University, Osaka, Japan,

[3]Research and Development Division, Kagome Co., Ltd., Tochigi, Japan,

[4]Technical Development Unit, Panasonic Environmental Systems and Engineering Co., Ltd., Osaka, Japan

E-mail: ymatsuda@nara.kindai.ac.jp

Abstract. An electric field screen can be used to keep mosquitoes out of houses with open windows. In this study, doubly charged dipolar electric field screens (DD-screens) were used to capture mosquitoes entering through a window. The screen had two components: three layers of insulated conductor iron wires (ICWs) in parallel arrays and two electrostatic direct current (DC) voltage generators that supplied negative or positive voltages to the ICWs. Within each layer, the ICWs were parallel at 5-mm intervals, and connected to each other and to a negative or positive voltage generator. The negatively and positively charged ICWs are represented as ICW(–) and ICW(+), respectively. The screen consisted of one ICW(+) layer with an ICW(–) layer on either side. The Asian tiger mosquito (*Aedes albopictus*) and house mosquito (*Culex pipiens*) were used as models of vectors carrying viral pathogens. Adult mosquitoes were blown into the space between the ICWs by sending compressed air through the tip of an insect aspirator to determine the voltage range that captured all of the test insects. Wind speed was measured at the surface of the ICW using a sensitive anemometer. The result showed that at ≥1.2 kV, the force was strong enough that the ICWs captured all of the mosquitoes, despite a wind speed of 7 m/s. Therefore, the DD-screen could serve as a physical barrier to prevent noxious mosquitoes from entering houses with good air penetration.

1. Introduction

Electric field screens have been used to create spore-free and pest-free spaces for crop production and preservation [1]. The first electrostatic spore precipitator that we reported was a screen that created a non-uniform electric field around insulated copper conductor wires arranged in parallel [2]. The electric field generated an electrostatic force that could be harnessed to attract fungal conidia entering the field. Unfortunately, the spore precipitator was ineffective at trapping major insects that fly into greenhouses. The second device used to solve this problem was a three-layered version of the electric field screen, in which grounded metal mesh was placed on both sides of the original spore precipitator to make dielectric poles; it captured insects that were blown into the inner space of the screen [3]. In this system, a negative charge released from the insects to the grounded net is detected immediately after they enter the electric field [4,5]. We postulated that the strong attraction between the insects and insulated conductor iron wire (ICW) was a result of this release. In fact, this postulate held for different insect pest species, including mosquitoes [6]. Successful insect capture depends on the formation of an electrostatic barrier with no spaces through which the insects can pass. However, parallel ICWs with negative charges create a static electric field with no electricity transfers between the ICWs or insects, which is not effective for attracting insects to enter the field. In a survey of screens installed on greenhouse windows, we observed that insects rarely entered such a static electric field. Therefore, we constructed a doubly charged dielectric electric field screen (DD-screen) in which the ICWs were oppositely charged with equal voltages using two voltage generators to provide an insect exclusion screen with multiple gap-free electric fields [1].

We are especially interested in ways to exclude hematophagous mosquitoes from houses. In tropical and subtropical countries, these noxious mosquitoes transmit various viral and bacterial pathogens and malarial plasmodia that cause severe diseases in humans. The current standard countermeasure is the use of an insecticide-impregnated woven net with larger mesh sizes (mesh diameter 5 mm) for increased air-permeability [7]. However, this method has some potential risks, including the development of insecticide-resistant pests [8] and continuous contact with exuded neurotoxic insecticides by the users [9]. Our electrostatic technique should create pest-free living spaces in houses by installing the screens on windows because its strong electrostatic force captures insects while allowing good air penetration.

2. Materials and methods

2.1. Electric field screen

A three-layered DD-screen [10] was used in this study (Fig. 1). An iron conductor wire was insulated by passing it through a transparent insulator vinyl sleeve and was used to construct the electric field screen. The screen had two components: three layers of ICWs in parallel arrays and two electrostatic DC voltage generators that supplied negative and positive voltages to the ICWs. Within each layer, the ICWs were parallel at 5-mm intervals and connected to each other and to a negative or positive voltage generator. The negatively and positively charged ICWs are represented as ICW(–) and ICW(+), respectively. The screen consisted of one ICW(+) layer with an ICW(–) layer on either side. The layers were parallel and 2 mm apart, and the ICWs in the different layers were offset from each other. The generators were linked to each other to make an electric circuit producing electric fields between ICW(–) and ICW(+). Both generators were operated with 12 V storage batteries, with power supplied by a 15-watt solar panel, to supply equal negative and positive voltages (0.4–1.4 kV) to the ICWs. In this system, free electrons from ICW(+) were pushed out to ICW(–), and the opposite surface charges on the ICWs acted as dipoles that form an electric field between them.

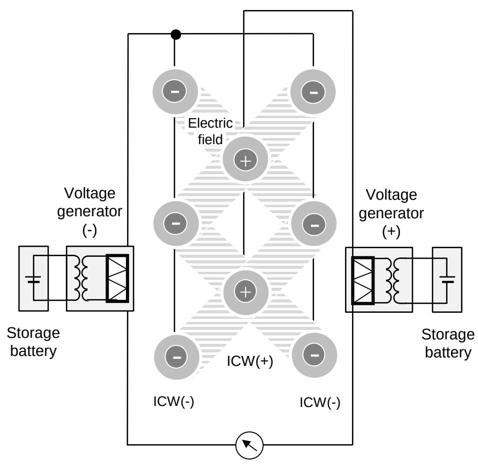

Fig. 1. Construction of a three-layered electric field screen.

2.3. Test mosquitoes and insect-capturing assay

The Asian tiger mosquito (*Aedes albopictus*) and house mosquito (*Culex pipiens*) were used as model vectors of viral pathogens. Adults of both mosquitoes were purchased from Sumika Technoservice (Hyogo, Japan) and maintained in a growth chamber (25.0 ± 0.5°C, 12-h photoperiod of 4000 lux), using our standard method.

Adults of the test insects were collected with an insect aspirator and blown into the space between the ICWs by sending compressed air through the tip of an insect aspirator to determine the voltage range that captured all test insects. Wind speed was measured at the surface of the ICW using a sensitive anemometer. To confirm the successful capture of mosquitoes with the ICW, we directed a blower (max. wind speed 7 m/s at the ICW) at the captured insects for 10 minutes. Twenty adults were used for each voltage tested. The experiments were repeated three times, and the data are presented as the mean ± SD, with a statistical analysis.

3. Results and discussion

Females of both the Asian tiger mosquito and house mosquito invade houses nocturnally and diurnally, respectively, to suck blood from humans [11]. The prevention of entry by these mosquitoes is a fundamental approach to protect humans from the diseases transmitted by pest mosquitoes. For this purpose, the ability of the electric field screen to trap the mosquitoes blown into the field at different wind speeds was examined. Different wind speeds were achieved by changing the distance between the tip of an insect aspirator and the surface of ICWs; wind speeds of 1, 2, and 3 m/s were created at distances of 5, 10, and 15 cm, respectively. **Table 1** lists

Table 1. Percentage of Asian tiger mosquito and house mosquito adults captured by ICWs of three-layered DD-screen

Pest insects tested	Wind speed (m/sec)	Negative and positive voltages (kV) applied to ICWs						
		0	0.4	0.6	0.8	1	1.2	1.4
Asian tiger mosquito	1	0	0	42.1 ± 5.3 a	76.4 ± 4.7 a	100 a	100	100
	2	0	0	41.4 ± 2.3 a	75.9 ± 3.4 a	100 a	100	100
	3	0	0	45.0 ± 3.1 a	77.2 ± 5.6 a	100 a	100	100
House mosquito	1	0	0	25.7 ± 3.1 b	56.1 ± 1.4 b	99.2 ± 0.6 a	100	100
	2	0	0	27.1 ± 3.9 b	55.6 ± 2.4 b	98.6 ± 0.5 a	100	100
	3	0	0	35.8 ± 4.5 b	50.8 ± 2.2 b	99.8 ± 0.1 a	100	100

Twenty adults were used for each voltage and wind speed, and the means and standard deviations were calculated from five replicates. The different letters on the mean values in each vertical column indicate significant differences ($p < 0.05$) according to Tukey’s method.

the percentages of the two species of mosquito captured by the screens at different voltages (0.4–1.5 kV) for each wind speed. The mechanism of insect capture by the DD-screen has been described in our previous paper [1]. Stronger forces of ICWs were necessary to capture mosquitoes carried at higher wind speeds, and the force increased with the voltage applied to the ICWs. In addition, there was no significant difference in the capture rate between the two mosquito species for any combination of wind speed and voltage. At ≥1.2 kV, the force was strong enough that the ICWs captured all of the mosquitoes, regardless of the wind speed. The mosquitoes were attracted to the near ICW. Both ICW(–) and ICW(+) were similarly effective at capturing approaching mosquitoes; in fact, the force at both sites was strong enough to capture the mosquitoes despite a wind speed of 7 m/s. At lower voltages, however, the force was insufficient to capture the mosquitoes permanently; the captured mosquitoes waved their legs, twisted their bodies, and then flew away from the ICWs; otherwise, they were blown away from the ICW by the blower. Therefore, this study provides an experimental basis for the practical application an electric field screen in house windows.

In addition to its ability to capture mosquitoes, the low electric power consumption of our screen system is important for practical use. In the electric field screen, the voltage generator is the only driving part requiring an electric power supply, and its electric power is 0.5W, equivalent to that of a small LED pilot lamp. This enabled the use of a photovoltaic power generation method for supplying electric power to the voltage generators. Using this system, we continuously operated four DD-screens attached to a house window for 1 month.

4. Conclusion

The offset arrangement of ICWs in the DD-screen results in gap-free electric fields to ensure the complete prevention of entry by mosquitoes and wider spaces for good air penetration. More importantly, it is possible to place major parts (the voltage generator, current flow-controlled storage battery, and electric wires connecting the ICWs to the generator) inside the aluminium window frame and seal them with silicon resin to waterproof the screen. In addition, the solar panel used for photovoltaic power generation can be attached on the frame surface. This self-sufficient electric structure of the DD-screen enables installation of the screen on house windows in areas with no electrical infrastructure. Therefore, this study strongly supports the possibility that safe housing that eliminates pathogen-carrying insect pests can be realised with the installation of DD-screens on house windows.

Acknowledgement

This work was supported in part by JSPS KAKENHI Grant Number 25450375 from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

References

[1] Matsuda Y, Kakutani K, Nonomura T, Kimbara J, Kusakari S, Osamura K and Toyoda H 2012 *Journal of Applied Physics* **112** 116103

[2] Matsuda Y, Ikeda H, Moriura N, Tanaka N, Shimizu K, Oichi W, Nonomura T, Kakutani K, Kusakari S, Higashi K and Toyoda H 2006 *Phytopathology* **96** 967

[3] Matsuda Y, Nonomura T, Kakutani K, Takikawa Y, Kimbara J, Kasaishi Y, Osamura K, Kusakari S and Toyoda H 2011 *Crop Protection* **30** 155

[4] Kakutani K, Matsuda Y, Haneda K, Sekoguchi D, Nonomura T, Kimbara J, Osamura K, Kusakari S and Toyoda H 2012 *Journal of Electrostatics* **70** 207

[5] Nonomura T, Matsuda Y, Kakutani K, Kimbara J, Osamura K, Kusakari S and Toyoda H 2014 *Journal of Electrostatics* **72** 1

[6] Kakutani K, Matsuda Y, Haneda K, Nonomura T, Kimbara J, Kusakari S, Osamura K and Toyoda H 2012 *Annals of Applied Biology* **160** 250

[7] Bobanga T, Ayieko W, Zanga M, Umesumbu S, Landela A, Fataki O, Mandoko AS, Tshibamba J and Nyabola L 2013 *Journal of Vector Borne Disease* **50** 206

[8] N'Guessan R, Corbel V, Akogbéto M and Rowland M 2007 *Infectious Diseases* **13** 199

[9] Sharma SK, Tyagi PK, Upadhyay AK, Haque MA, Mohanty SS, Raghavendra K and Dash AP 2009 *Acta Tropica* **112** 181

[10] Takikawa Y, Matsuda Y, Nonomura T, Kakutani K, Kimbara J, Osamura K, Kusakari S and Toyoda H 2014 *Aerobiologia* **30** 435

[11] Bowen M F 1991 *Annual Review of Entomology* 36 139