THE ROLE OF CONVECTION CURRENTS IN MOSQUITO ATTRACTION TO HUMAN SKIN

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INTRODUCTION. Previously we quantitated the effect of heat, moisture and carbon dioxide individually and combined in a specially constructed tower, on the approach, landing and probing by *Aedes aegypti* (L.) (Khan *et al.*, 1966; Khan and Maibach, 1966). The human palm was tested as a natural source of attractive stimuli. Maximal attraction was obtained with the palm at all heights of the tower. At 12 in. from the stimulus, however, heat plus moisture were also attractive. At this short distance, the high attraction to the palm could have been due to: (1) additional response of the mosquitoes to the stimuli of heat and moisture per se; (2) greater concentration of odor in a smaller volume or; (3) faster transport of odor to the mosquitoes by the convection currents (the distance being short) or due to all three combined. In this study we have manipulated convection currents to study their effect on mosquito attraction to the human palm.

METHODS AND MATERIALS. Experiments were conducted in a 1 cu. ft. cage with a wooden frame. The cage was lined with 20 mesh nylon net on the sides and the top. The bottom was fitted with cardboard having a 9 cm. diameter hole in the center covered with net. The cage's sides were covered with polyethylene outside the net. A flap of polyethylene sheet was attached to one side of the top to cover the cage top completely when desired.

Fifty *A. aegypti* females, 6–8 days old and fed previously on 5 percent sugar solution only, were released in the cage through a small hole in the top. They alighted on the net lining. The palm was exposed under the bottom hole and the mosquitoes flying, landing or probing on the net over the palm were counted each min. for 20 minutes. A 20-minute rest period was allowed between replicates. The polyethylene on the side of the cage protected the mosquitoes from cross currents from outside the cage and from the subject. Two sets of experiments were made with this method. The first set consisted of experiments made at room temperature ($27\pm1^\circ$ C) and 55–60 percent RH. Mosquitoes flying, landing or probing on the palm were counted first when the cage top was open and then with the cage top covered. Results are given in Table 1.

The second set of experiments was made at an ambient temperature equal to that of the palm (34° C.) and 55–60 percent RH. The cage top was kept open. A control was first run at 27° C. to check the activity of the mosquitoes. The cage was then moved to a room at 34° C. and the experiment repeated. To ascertain whether or not higher ambient temperature affected the avidity of the mosquitoes, a hand was introduced into the cage at the end of the experiments for 10 min. and the number of mosquitoes engorged with blood was counted. The responses of the mosquitoes to the palm at the two ambient temperatures are given in Table 2.

RESULTS AND DISCUSSION. In this study we examined the role of the convection currents in two ways. In the first experiments we muffled and diffused the convection currents by sealing the top of the

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TABLE 1.—Mean responses of *Aedes aegypti* females to the human palm in open and closed cages.*

Top open			Top closed		
Landing	Probing	Flying	Landing	Probing	Flying
1.3±0.2	11.0±0.9	6.2±0.5	1.1±0.3	5.3±0.4**	4.4±0.4

* Figure are means with S. E. of 10 replicates each of 20 1 min observations.
** Significantly low ($P<.01$).

cage with the polyethylene flap. Recording of the temperature and relative humidity in the cage above the palm and at the top in the open and covered cage showed a fall in the temperature gradient by 1° and an almost complete elimination of the moisture gradient in the covered cage. The sharpness of the heat and moisture gradient as well as that of the odor was therefore blunted by covering the cage. As a consequence, the total response to the palm decreased about one half (Table 1). The mosquitoes that probed in a covered cage were less than half in number compared to those probing in an open cage, the difference being highly significant ($P<.01$).

The lack of any significant difference in the number of mosquitoes flying in the open and covered cages is curious and important. It suggests that fewer mosquitoes took off in the first place in a covered cage compared to those in the open, rather than that as many mosquitoes flew, but only half the number found their target. We had shown previously (Khan and Maibach, 1966) that at short distances dry heat activates the mosquitoes to fly and moist-heat induces some landings. Odor, however, induces take-off at far greater distances (Khan *et al.*, 1966) and is also the chief stimulus inducing landing and probing. Since heat acts through generating convection currents, any muffling of the convection currents would not only suppress the activation of mosquitoes but would also suppress and diffuse the transport of odor for which convection currents serve as vehicles of transport. This could be the reason for a significant decrease in the take-off by mosquitoes in a covered cage though the explanation is not entirely satisfactory to us.

In the second set of experiments the convection currents from the palm were neutralized by raising the ambient temperature to 34° C, which was the temperature of the palm. The mosquitoes did not land or probe. The same mosquitoes gave about 28 percent landings and probings on the average at 27° C (Table 2). The higher ambient temperature, however, had no significant adverse effect on the avidity of the mosquitoes since 54 percent mosquitoes fed in 10 minutes when the hand was introduced into the cage at the end of the experiment. Bishop and Gilchrist (1946) observed 19 percent feeding at 37° C. in 30 min. when they reduced the temperature gradient to 0°. It is not valid, however, to compare the two experiments because of several dis-

TABLE 2.—Mean response of the *Aedes aegypti* female to the human palm at different ambient temperatures.

27° C.*			34° C.**		
Landing	Probing	Flying	Landing	Probing	Flying
2.4	11.8	6.8	0.0	0.0	1.9

Each figure is a mean of 20 1 min observations per replicate.
* 2 replicates.
** 5 replicates.

similarities in the method and material.

Another aspect of this study that begs for explanation is that at 34° C. the mosquitoes had no difficulty in finding the hand inside the cage, but the same mosquitoes were not attracted when the hand was placed under the hole in the bottom of the cage. It could be the short distance, since the hand, when placed inside the cage obviously came much closer to the mosquitoes compared to its position under the bottom of the cage. Though the stimulus of convective heat was still lacking, at such close proximity, perhaps the slow diffusion of odor from the skin in all directions and a better visual stimulus contributed to the attraction of mosquitoes to the hand. At very short distances the mosquitoes apparently can find the host without the help of convective currents.

The importance of convection currents to the host-seeking behavior of mosquitoes has been emphasized by many workers. Howlett (1910) showed in his simple experiment with a warm test tube that heat was effective through the formation of warm convection currents. Peterson and Brown (1951) confirmed this and showed that radiant heat was not an important factor in mosquito attraction. Christophers (1960, pp. 538, 540) thinks that sensitiveness of *A. aegypti* to convection currents is very highly developed, amounting almost to a special sense, and that convection currents arising from the object are the chief stimulus to attract to feed. The findings of these workers emphasize the importance of convection currents per se and not as a vehicle for odor transport in the host-finding by mosquitoes. Though the importance of convection currents in the host-seeking behavior is not discredited, this study has shifted the emphasis from their importance per se to their more important role as a vehicle of transport for odor.

SUMMARY. The role of convection currents in mosquito attraction to human skin was examined. Diffusion of the convection currents and blunting the odor gradient reduced the approach of mosquitoes to the human skin by one half; neutralizing the convection currents by raising the ambient temperature equal to that of the skin (34° C) eliminated the approach of the mosquitoes to the human palm at the bottom of the cage completely. The higher ambient temperature did not, however, affect the avidity of the mosquitoes significantly as 54% fed when the hand was introduced inside the cage. The findings of this study confirm the importance of convection currents in the host-seeking behavior of mosquitoes as emphasized by several workers, but shifts the emphasis from their importance per se to their more important role as a vehicle of odor-transport.

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