THE EFFECTS OF SURFACE TENSION ON MOSQUITO DEVELOPMENT

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It has been known for many years that surface tension phenomena play an important role in the development of aquatic insects. Mosquitoes, which undergo most of their developmental cycle in water, are likewise known to be affected by changes in the surface tension of their aquatic environment. It appears however, that the limited number of studies on this subject have been confined largely to larvae (Renn, 1941; Russell and Rao, 1941), and that little attention has been given to the subsequent developmental stages and their responses to a wide range of surface tensions.

The present report compares the effects of different surface tensions upon the development of a variety of genera and species of mosquitoes.

MATERIALS AND METHODS. The pupae of five mosquito species, *Aedes aegypti, Culex fatigans, Culex molestus, Culex pipiens* and *Anopheles quadrimaculatus,* used in these experiments were taken from laboratory colonies reared at 25° C. on a standard diet of dog chow. Also included was a strain of *Culex fatigans* (F) collected from a local sewage drainage ditch as fourth stage larvae and pupae. Using Tween 80 to lower the surface tension and magnesium chloride to raise it, solutions with a surface activity of 31, 41, 45, 53, 72, 73.5, 76 and 78 dynes/cm were prepared. Fifty newly-formed pupae

of each species were placed in cups containing 100 cc. of the test solution. Two days later, all cups were checked for pupal mortality and adult emergence. The results were tabulated in terms of pupal mortality and degree of emergence of the adults (complete and incomplete). All experiments were done twice on different days at 25° C.

RESULTS. The results are summarized in Figure 1 according to the degree of development reached in water at different surface tensions. The data are given in terms of (1) pupal mortality rates, (2) incomplete emergence of the adults (unable to leave the water surface) and (3) complete or normal emergence. All figures not designated in the text as percent refer to dynes per centimeter of surface tension.

It is evident from Figure 1 that none of the species studied can emerge when the surface tension is 41 or less, or 78 or more. At 31 and 78 there was total pupal mortality. However, at 41, *A. aegypti, C. fatigans, C. fatigans* (F), *C. molestus* and *C. pipiens* showed some emergence although it was incomplete. At 45, *C. fatigans* was the only species which exhibited more than 50 percent emergence. There was 69 percent pupal mortality and 31 percent incomplete emergence in *A. quadrimaculatus* at this same surface tension. *Culex fatigans, C. fatigans* (F), *C. molestus* and *C. pipiens* developed well at 53 with only 1, 0, 3 and 8 percent pupal mortality respectively and 7, 8, 19 and 14 percent incomplete emergence. At this same surface tension *A. aegypti* and *A. quadrimaculatus* exhibited 38 and 36 percent emergence respectively. While *A. aegypti* showed no pupal mortality, *A. quadrimaculatus* exhibited 41 percent. At 72, which is the normal surface tension of water at 25° C., there was 100 percent emergence of *A. aegypti, C. fatigans, C. fatigans* (F) and *C. molestus*. However, somewhat fewer of the *C. pipiens* and *A. quadrimaculatus* (92 and 82 percent respectively) underwent normal development. Above 72 the species behaved differently. For example, at 73.5, *A. aegypti* developed well with 96 percent normal emergence. On the other hand, *C. fatigans, C. pipiens* and *C. fatigans* (F) with 82, 82 and 76 percent emergence respectively, showed some inability to adapt to this same surface tension. *Culex molestus* and *A. quadrimaculatus*, exhibiting 53 and 58 percent emergence respectively were even more adversely affected. Significantly more *A. aegypti* completed development at 76 than any other species.

DISCUSSION. Pupae of the six mosquito strains tested, *A. aegypti, C. fatigans, C. fatigans* (F), *C. molestus, C. pipiens* and *A. quadrimaculatus* seem to differ in their ability to withstand different surface tensions. *A. quadrimaculatus* evidently is the least adaptable, having a very limited range (53–73.5) in which normal development is possible. These findings are in accord with those of Renn (1941), who observed that the surface tension of natural breeding water of *A. quadrimaculatus* and *A. crucians* ranged from 65 to 73. Similarly, forty *Anopheles* breeding places studied by Russell and Rao (1941) ranged in surface tension from 65.5 to 70.6.

The four *Culex* strains reacted similarly to a variety of surface tensions. They are more capable of surviving in water having a lower surface tension (45 to 53) than the other species. On the contrary, *A. aegypti* evidently does better at a higher surface tension (73.5 to 76) than any other species tested.

These differences in the behavior of the three genera towards the surface tension seem to be in accord with their natural habitat. It has been pointed out that *A. aegypti* and *A. quadrimaculatus* prefer clean water for development whereas *C. fatigans, C. molestus* and *C. pipiens* all generally breed in polluted water (Horsfall, 1955). Since the surface tension of polluted water tends to be comparatively low, it is not surprising that *Culex* mosquitoes are capable of withstanding lower surface tensions than *A. aegypti* and *A. quadrimaculatus*. It can readily be seen from the results that there is no significant difference in the reaction of the two *fati-*

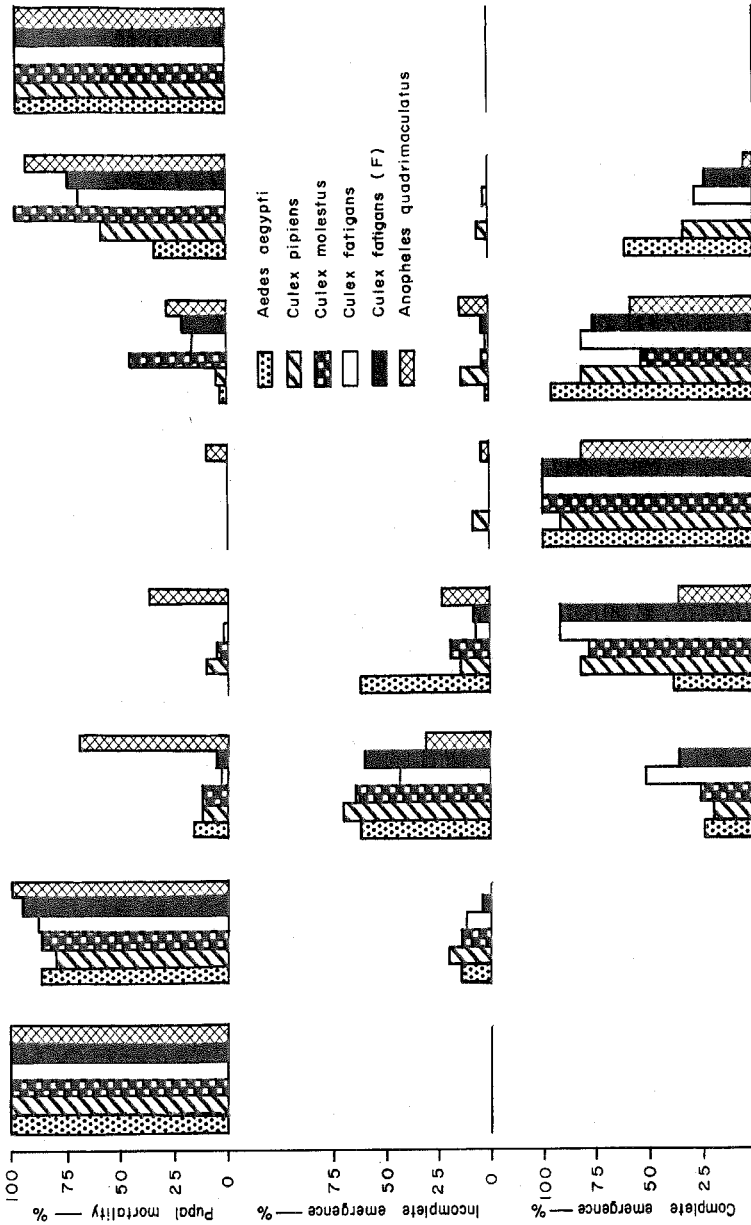

FIG. 1.—Six strains of mosquitoes are compared as to their ability to survive as pupae and complete development while subjected to a wide range of surface tensions.

gans strains to different surface tensions. This finding suggests that factors governing the surface tension requirements of the species are probably inherent rather than a matter of adaptation to a particular environment.

In examining the effects of surface tension on the degree of development, it is interesting to note that it is only at the lower surface tensions, particularly 45, that the largest numbers of all species fail to emerge completely and leave the water surface (see Figure 1). The reason for this may be that at a lower surface tension, the pupae manage to remain at the surface and emerge, but there is very little support for the adult to spread out its wings and body in a normal manner. The adult, therefore, may develop normally, but may lack the necessary support to leave the water surface. On the other hand, at higher surface tensions, the pupae cannot get through the water surface and thus die in the pupal stage. Even though the surface tension of the water at any given time may be optimum for larval growth and development, it may change radically during the pupal period, and interfere with the emergence of the adults.

SUMMARY. The effects of various surface tensions upon pupal development and adult emergence were studied in six strains of mosquitoes. *Culex pipiens, Culex fatigans, Culex fatigans* (F) and *Culex molestus* were found to develop normally in water with lower surface tensions whereas *Aedes aegypti* was found to prefer higher ones. *Anopheles quadrimaculatus* was the least adaptable to changes in surface tension, showing a limited range (53–73.5 dynes/cm) in which normal development could occur.

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