EFFECT OF ELECTROSTATIC FIELDS ON INSECTS: THE HOUSEFLY AND CABBAGE LOOPER

by

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INTRODUCTION

Insects cause a great amount of damage to crops of agricultural importance each year. Reduction in this damage would cause an increase in the quality and quantity of products available for consumption. A large variety of pesticides are in use to control insect populations, and since the use of pesticides has had negative effects on the quality of the environment, there is an increasing concern over their continued use.

In 1968, Cecil H. Wadleigh, Director, Soil and Water Research Division, Agricultural Research Service said the following on the use of insecticides:

> The potential contamination of the environment by pesticides, particularly the chlorinated hydrocarbons, has been a matter of public and private discussions. Within a few years after DDT began to be used extensively as a field and forest insecticide, DDT and its metabolites were found in the fatty tissues of fish and wildlife, both living and dead. Newspapers carried features on fish and wildlife losses with an implicit indictment of agriculture and forestry for having used insecticides.
>
> The use of these chemical tools has made a tremendous contribution to man's health and welfare over the past 25 years. Unfortunately, in some instances, they have also been abused and misused without due consideration to their impact on the nontarget organisms.
>
> The application of certain insecticides to cotton, corn, or other crops may lead to insecticide residues in soybeans or peanuts grown in the soil a year or more later. Certain chlorinated hydrocarbons can persist in soil for many years. In one experimental study 50 percent of the original high-level application of DDT was found in the soil 8 years after the material had been applied.
>
> Over the long pull, research efforts towards avoiding the adverse effects of insecticide residues in the environment must continue to receive major attention.
>
> Far better information is needed on insect population trends with the objective that emergency use of chemicals may be avoided.

Mr. Wadleigh's direction on finding alternatives to pesticides in the scope of physical attractants is as follows:

> The use of physical attractants to aid in non-chemical control of economic insects needs to be more fully explored. All possible support should be allocated to research for completely selective methods of controlling major insect pests. These techniques include the use of predators and dissemination of specific insect diseases; development of specific insect attractants...

In recent years the use of different stimuli for insect control has been studied extensively. Many have investigated the possible use of stimuli such as sound, radiation, magnetic fields and pheromone. Even though certain stimuli listed show some promise, it is important that possible use of other stimuli be explored. Information available from different studies show that electrostatic fields have varied effects on biological systems. However, its effect on insects has not been studied extensively to determine whether electrostatic fields can be used for insect control. Therefore, the overall objective of this study was to determine the response of certain insects to electrostatic fields so that its possible use for controlling insects can be evaluated.

OBJECTIVES

The specific objectives of the study were as follows:

1. To determine the locational preference of houseflies when given a choice between regions with and without an electrostatic field.
2. To determine the effect of electrostatic fields on the wingbeat frequency of cabbage loopers.

REVIEW OF LITERATURE

Electrostatics

Coulomb's Law states that the force between two point charges varies directly as the magnitude of each charge and inversely as the square of the distance between them (Schaum, 1961). Written mathematically

$$F = \frac{K\, q_1\, q_2}{r^2} \qquad [1]$$

where: F = the force exerted on each charge by the other in newtons (nt).

K = a dimensional proportionality constant (9×10^9 nt·m^2/coul^2).

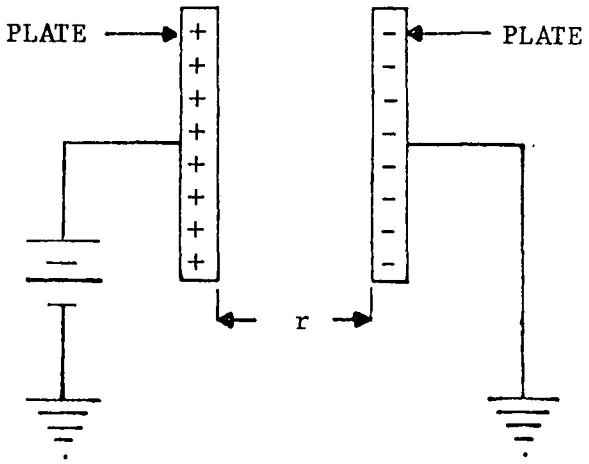
q_1= charge on point one in coulombs (coul).

q_2= charge on point two in coulombs.

r = distance between the two charges in meters (m).

When two parallel plates are connected to a potential source, charges build up as shown in Figure 1. This arrangement is commonly known as a parallel plate capacitor. After a short period of time the system will reach equilibrium and the charges on the plates will be equal but opposite. If the magnitude of charges on the positive and negative plates is q, using Coulomb's Law

$$F = \frac{-K\, q^2}{r^2}\,. \qquad [2]$$



+ positive charges

- negative charges

Figure 1. Charges on Parallel Plates due to an Applied Voltage.

The electric field intensity (e.f.i.) at a point is numerically equal to the force exerted by the field on a unit charge placed at that point. Unit field intensity is the field which exerts a force of one newton on one coulomb of charge or

$$E = F/q \qquad [3]$$

where: E = electric field intensity (nt/coul).

F = force (nt).

q = charge (coul).

Substituting for F from Equation [2]

$$E = \frac{-Kq}{r^2}. \qquad [4]$$

The minus sign in Equation [4] indicates that the force is tending to bring the plates together and is due to the opposite charges on the plates. For a uniform field between parallel plates one newton per coulomb is equal to one volt per meter. Therefore,

$$E = V/r \qquad [5]$$

where: E = electric field intensity in volts per meter (v/m).

V = potential difference between plates in volts (v).

r = distance between plates (m).

If two large parallel plates are located close to each other the field between them will be fairly uniform as shown in Figure 2 (Moore, 1968). The lines in Figure 2 starting from the positively

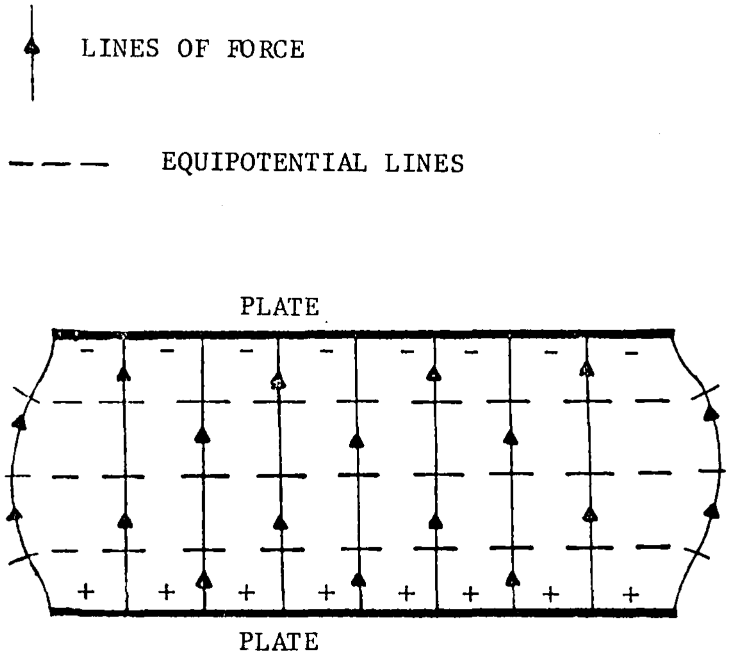


Figure 2. Electrostatic Field Between Two Parallel Plates where Plate Dimensions are Large as Compared to Separation Distance.

charged plate and ending on the negatively charged plate are called lines of force. The e.f.i. is constant in the region within the uniform field. Nonuniformity in the field occurs at the edge of the plates due to the high concentration of lines. The planes perpendicular to the lines of force and parallel to the plates are the equipotential surfaces.

The maximum potential difference that can be applied between two parallel plates is dependent on the dielectric constant of the material separating the plates. The dielectric constant is a measure of the insulating properties of the material, where the higher the dielectric constant the better are the insulating properties of the material. Air has a dielectric constant of one (Moore, 1968).

Electrostatic Fields in Nature

The planet we live on has a natural electrostatic field with the earth negative and the surrounding atmosphere being positive. The average gradient under fair weather conditions in this natural electrostatic field is of the order of 1.0 volt per centimeter (v/cm) (Vonnegut, 1973). This gradient can change in a very short period of time and go up to 10,000 volts per meter under a thunder-cloud (Moore, 1968).

Biological Systems and Electrostatic Fields

Investigation of the effects of electrostatic fields on mammals has been conducted. Novitskiy et al. (1971) reviewed the reports of Russian investigators concerning the effects of electrostatic fields on mammals. The biological effects noted include a change in respiration of rabbits when exposed to an e.f.i. of 82 v/cm for a period of fifteen minutes. No effect was observed on the EKG, arterial pressure or respiration rate of cats for a fifteen minute exposure to an e.f.i. of 10 v/cm. Rats exposed to an electrostatic field ranging from 195 v/cm to 400 v/cm showed changes in their blood indices (hemoglobin, number of erythrocytes), in pulse rate and rate of respiration. In a prolonged test with an electric field intensity (e.f.i.) of 20 v/cm for four hours, six times a week for six weeks the rats showed no significant effects. Some researchers found no effect on human beings when they were subjected to an e.f.i. of 10,000 v/cm for a period of two hours daily for fifty to sixty days.

Brown (1962) found that the planarian *Dugesia* can perceive a change of 2 v/cm electrostatic gradient in the surrounding air. The degree of response as measured by the planarian's turning tendency in the field was related to the "right angled potential", time of day, and orientation of the worm in the "earth's geographic field". A similar response measuring turning tendency was demonstrated by snails to an e.f.i. of 2 v/cm (Webb et al., 1961).

While using a black light trap to catch insects, Maw (1964) noticed that one section of the rotating trap being used consistently caught fewer insects than any of the other sections. This section was coming in contact with a leaf from a nearby tree as it rotated, and as a result a negative charge built up. Through further testing it was found that a negative electric charge on an individual section of a light trap significantly reduced the insect catch of that section. Suspecting that charges and associated electric fields possessed by living plants may influence insect activity, tests were conducted to study the effect of isopotentials of up to 100 volts on insect travel (Maw, 1961). Tests showed that different isopotentials acted as temporary barriers to the insect's movement. However, the levels necessary to impede travel were greater than those would be found in nature.

Control of mosquito populations utilizing electrostatic fields in water was studied by Riordan (1971). He investigated the aggregation of mosquito larvae in a trough filled with water when an electrostatic field was imposed. The larvae were released in the center of the trough and allowed to migrate under e.f.i. from 0.1 v/cm to 13.3 v/cm. Migration of the larvae did occur with direction depending upon larval instar. Pupae were not attracted to the anode and only reached the cathode with e.f.i. above 6.7 v/cm.

Pupation and oviposition of moths of the phantom hemlock looper and the fruit fly were affected by the superimposition of an electrostatic field upon rearing cages (Edwards 1961, Levengood and Shinkle 1960). The superimposed electrostatic field appeared to reduce the variations in progeny yields found outside the field. The progeny yields in the electrostatic field were on the average higher than those outside the field.

Edwards (1960) conducted tests using fruit flies in contact with one plate of an electrostatic field and with fruit flies suspended between the plates of an electrostatic field. A reduction in insect activity during application of electrostatic fields with e.f.i. of 10 v/cm to 540 v/cm was observed with the insects in contact with one plate of the field. There was no suggestion of an effect upon the activity of the insects suspended between the plates of the field.

Edwards (1962) found that insects develop body charges from contact with different materials. Tests were conducted with dead flies. Body charges on the flies were produced by rubbing them with the different materials. Carlton (1971) measured the quantitative electrostatic charge on a housefly. The charge on dead flies was different from that on live flies. Among live flies the charge was variable. The capacitance of individual live flies appeared oscillatory.

EXPERIMENTAL INVESTIGATION

Locational Preference Test

Insects Tested

The insect species used in this study was the housefly or *Musca domestica* L. Pupae were supplied by the Entomology Department of VPI & SU. They were reared in screen cages kept in an incubator maintained at 90° F and 80% RH with a twelve hour light period starting at 6:00 A.M. The pupae in each cage were allowed to emerge for twenty-four hours. At the end of this period the remaining pupae were removed from the cages to keep track of the age of the adults. Each cage was provided with water and a mixture of powdered eggs and dry milk in separate containers. Flies used for tests were between twenty-four and forty-eight hours old.

Apparatus

To obtain the desired information on the locational preference of houseflies, a test chamber with inside dimensions of 3 inches by 5 1/2 inches by 11 1/2 inches was constructed of 1/4 inch plexiglas (Figure 3). It had removable ends for access to the interior, guide rails to hold a mechanical transfer cage, an opening for the introduction of test specimens and a drop gate to divide the chamber into two equal sections at the end of each test.

Two pairs of smooth aluminum plates 5 1/4 inches square were attached to the inner walls of the chamber (Figure 4). The aluminum plates acted as two air gap parallel plate capacitors. A description

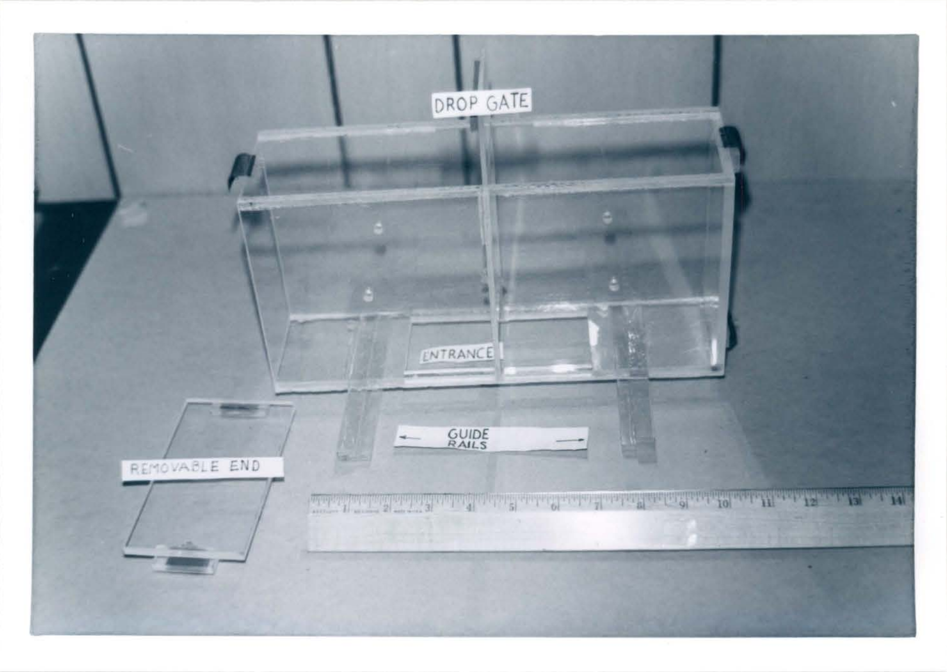


Figure 3. Chamber Used for Locational Preference Test Without Plates.

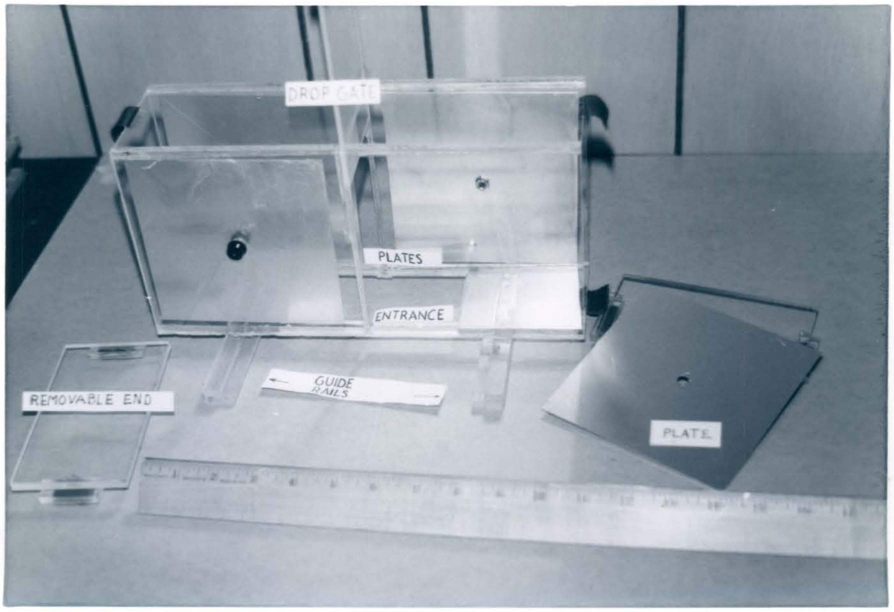


Figure 4. Chamber Used for Locational Preference Tests with One Plate Removed.

of the electrostatic field between the plates is given in Appendix I. Plate voltage for the capacitors was provided by a Universal Voltronics Portable High Voltage Power Supply. A diagramatic representation of instrumentation used for these tests is shown in Figure 5.

A mechanical transfer cage for flying insects (Kranzler 1970) was used to introduce the specimens into the chamber (Figure 6). The transfer cage consisted of a 7 inch by 7 inch by 6 inch wooded frame with two curved sheets of clear plastic positioned concentrically between flat screened sides. The enclosed column took the shape of a 90 degrees sector of an annulus, in vertical cross section, with a rectangular radial cross section. A moving flap pivoted at the geometric center of the annulus could be passed through the volume to expel the insects into the test environment. The flap had two set positions, "load" or "transfer". In the "load" position an opening was provided to collect a test sample. Moving the flap to the "transfer" position confined the test sample and allowed the transfer cage to be moved about freely. To eject the test sample, a latch was released mechanically allowing the flap to pass through the loaded cage "shooing" the insects through a synchronized exit. To facilitate loading of the transfer cage a stop gate was developed to fit directly between the bulk storage cage and the mechanical transfer cage (Figure 7). By opening the gate, flies could be loaded directly into the transfer cage with minimal loss.

All testing was conducted in a screened room to reduce stray electromagnetic radiation and electrostatic charges. It was 6 feet by

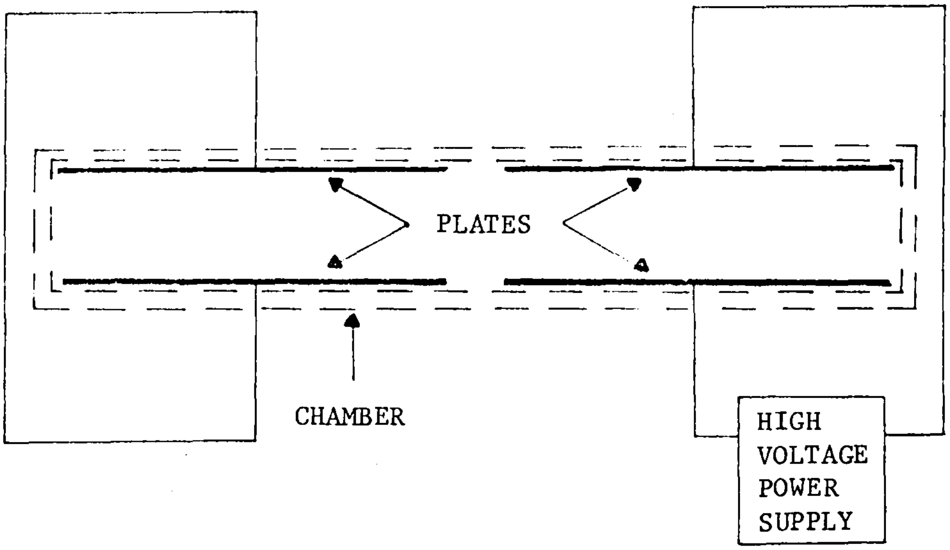


Figure 5. Diagramatic Representation of the Equipment Used in the Locational Preference Tests.

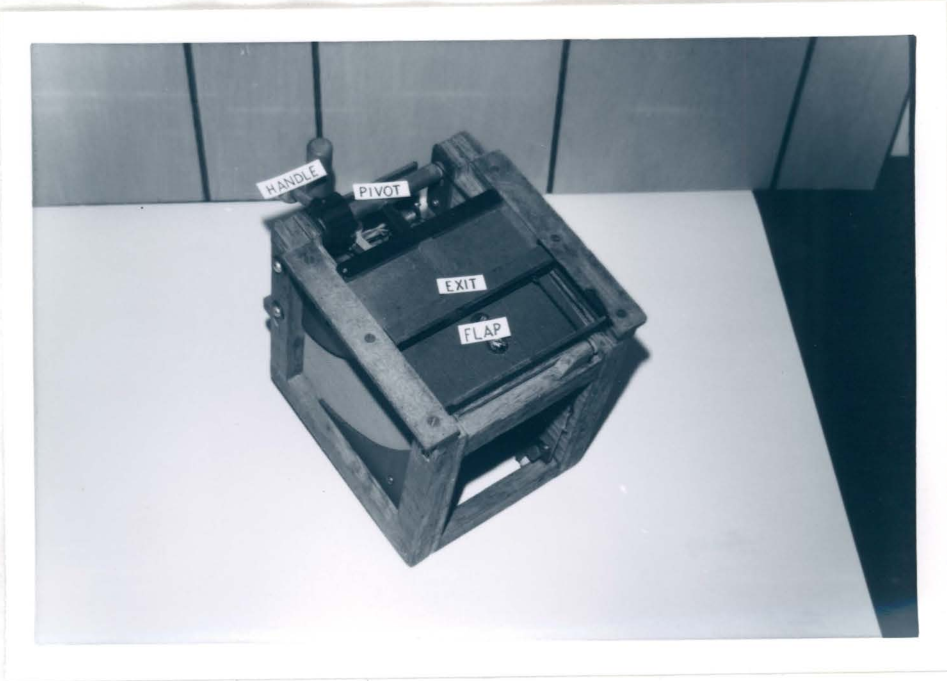


Figure 6. Mechanical Transfer Cage Used to Introduce Housefly Samples into the Locational Preference Chamber.

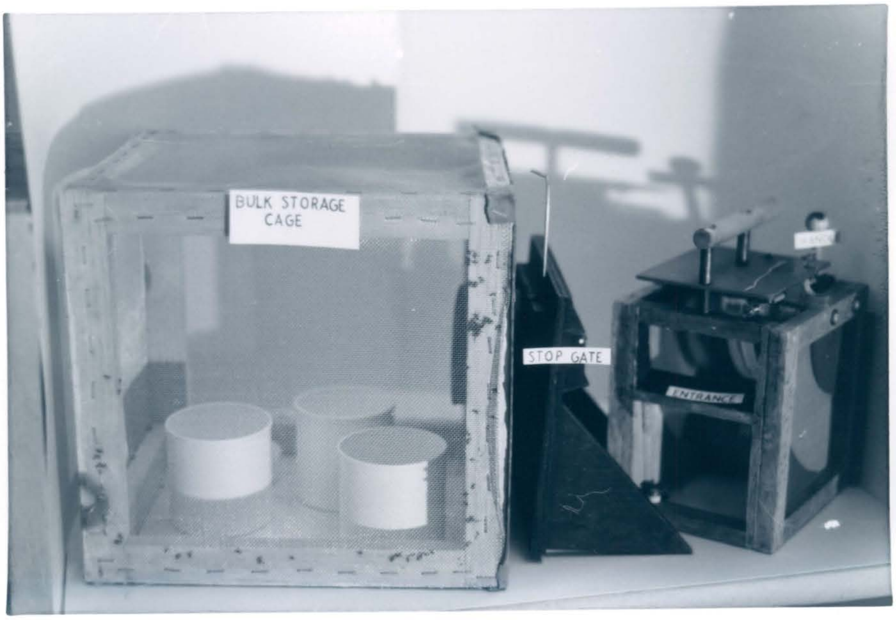


Figure 7. Rearing Cage for Houseflies, Stop Gate and Mechanical Transfer Cage.

9 feet by 8 feet and was located in an air-conditioned laboratory maintained at 75 ± 1° F. The room was covered with black polyetheline film to restrict laboratory light from the interior during testing.

Procedure

To insure that an adequate number of insects introduced into the test chamber were subjected to the applied stimulus and to determine the experiment duration several preliminary tests were conducted. Samples of houseflies were introduced into the chamber and given free access to the entire volume. At one minute intervals the drop gate was lowered and the flies in one section were removed. The gate was then raised and the remaining flies allowed access to the entire chamber. The drop gate was lowered again at the end of one minute. Flies in one section were removed and counted. This procedure was repeated three times. An average of forty-five percent of flies, remaining in the chamber moved to the empty section in each one minute interval. This was considered adequate movement. A series of twenty tests were then run to determine the orientation of houseflies in the absence of electrostatic stimulant and to determine whether there was any bias in the test chamber. During these tests the plates were interconnected to insure 0 e.f.i. between them.

For test, a sample of 80 to 180 flies was collected in the mechanical transfer cage. The transfer cage was then attached to the test chamber and placed in the test position in the screened room (Figure 8). The transfer cage was then illuminated by four 40 watt

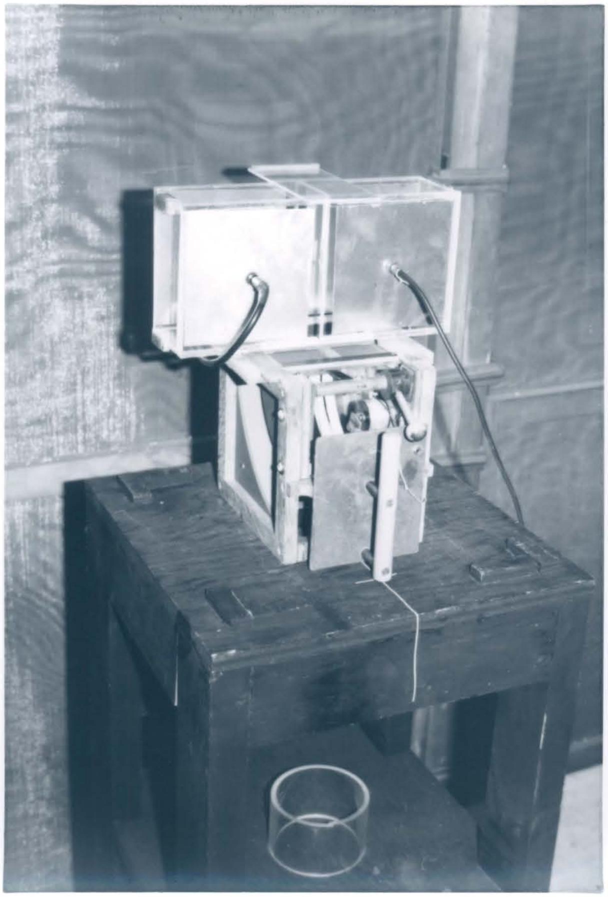


Figure 8. Locational Preference Chamber Mounted in Test Position on the Mechanical Transfer Cage.

fluorescent bulbs for 1.5 minutes to reduce any bias induced during the collection of the test sample. The lights were then turned off and the remainder of the test conducted under low level red light illumination provided by two 25 watt red bulbs located three feet apart and centered one and one half feet above the test chamber. After 1.5 minutes adaptation to the red light, the flies were injected into the test chamber. Three minutes later the dividing gate was lowered, the voltage source was disconnected, the flies were anesthetized with carbon dioxide while in the test chamber, and were then placed in test tubes for counting.

Studies were conducted at e.f.i. of 200, 500, 750, 1000, 1250, and 1500 v/cm with positive polarity, and replicated twenty times. Both the order of treatment and the section of the chamber to which the stimulant was applied were randomized. Except for the application of the electrostatic stimulant prior to the introduction of flies into the test chamber, the procedure was the same as that followed during the test described in the preceding paragraph.

Results and Discussion

The data included the number of flies in the two sections of the test chamber (Appendix II). These numbers were then expressed as percentages of the number of flies introduced for each replication. The percentages were transformed utilizing an arcsine transformation to produce an approximately constant variance for both sections. The transformed data was analyzed using the F statistic in an analysis of variance for two way classification with a 95% significance level.

Cell totals and F ratios are shown in Table 1. For test with 0 e.f.i. the statistical analysis was carried out by comparing the distribution of flies in the left section against the right section to determine if there was a bias. There was no significant difference in distribution between the two sections of the chamber. Data from all other tests were analyzed by comparing the number of flies in the section with the stimulus against the number in the section with no stimulus.

The houseflies did not appear to have a preference between regions with and without electrostatic field for e.f.i. of 200 or 500 v/cm. A significant difference in distribution did occur for e.f.i. of 750 to 1500 v/cm. At 750 v/cm, flies showed a preference for the section of the chamber with electrostatic field. For 1000, 1250 and 1500 v/cm they preferred not to be in the section with an electrostatic field. This observation to some extent agrees with the observation made by Maw (1964). During experiments with black light traps, Maw observed that the light trap which had an electrical charge caught fewer insects indicating that the insects preferred not to be in a region with an electrostatic field. Measurements showed that the light trap had an e.f.i. of 40 v/cm with a negative polarity. The e.f.i. used during this study was considerably higher in magnitude and was of positive polarity.

Table 1. Summary of Results of Locational Preference Tests Showing Total Number of Houseflies in Chamber Sections with and without Stimulus and Resulting F Ratios.

e.f.i.	Total Number of Houseflies in each Section		F
(v/cm)	No Electrostatic Field	Electrostatic Field	(95%)
0[†]	1262	1214	1.770
200	1395	1403	0.0304
500	1729	1609	3.655
750	1320	1451	5.048*
1000	1509	1274	58.415*
1250	1532	1358	10.363*
1500	1256	1081	16.311*

[†] For 0 e.f.i. test, the distribution of flies in the Left Section of the chamber was compared against the Right Section to check for bias.

* Indicates significance at the 95% level.

Effect of Electrostatic Fields on Wingbeat Frequency

Insects Tested

The insect species used for this study was the cabbage looper moth, *Trichoplusia ni* (Hubner). Pupae were supplied by the Insect Attractants, Behavioral, and Basic Biology Research Laboratory, USDA-ARS, Gainesville, Florida. They were sexed and placed in separate wire mesh cages for emergence. A vial containing sugar water and a brown paper wick was placed in each cage for moth's nourishment. The cages were kept in an incubator maintained at 80° F and 60% RH by an Aminco air-conditioning unit.

The pupae were removed from the cages each day in order to keep track of the age of the adults. The age of moths used in this study is referred to by two numbers with a hyphen. The first and second numbers represent the minimum and maximum age in days respectively. Moths used for the test were 3-4 days old.

Apparatus

A tether apparatus used to study the response of loopers to sonic energy (Kranzler and Earp, 1972) was modified and used in this study. The modification included the addition of two parallel aluminum plates 1 1/4 inches by 2 inches to form an air gap parallel plate capacitor (Figure 9). An approximate mapping of the electrostatic field between the plates is in Appendix I. Included in the apparatus was a platform, a tether clamp, and a ceramic phonograph cartridge. The platform was hinged and could be raised or lowered by a remote control solenoid.

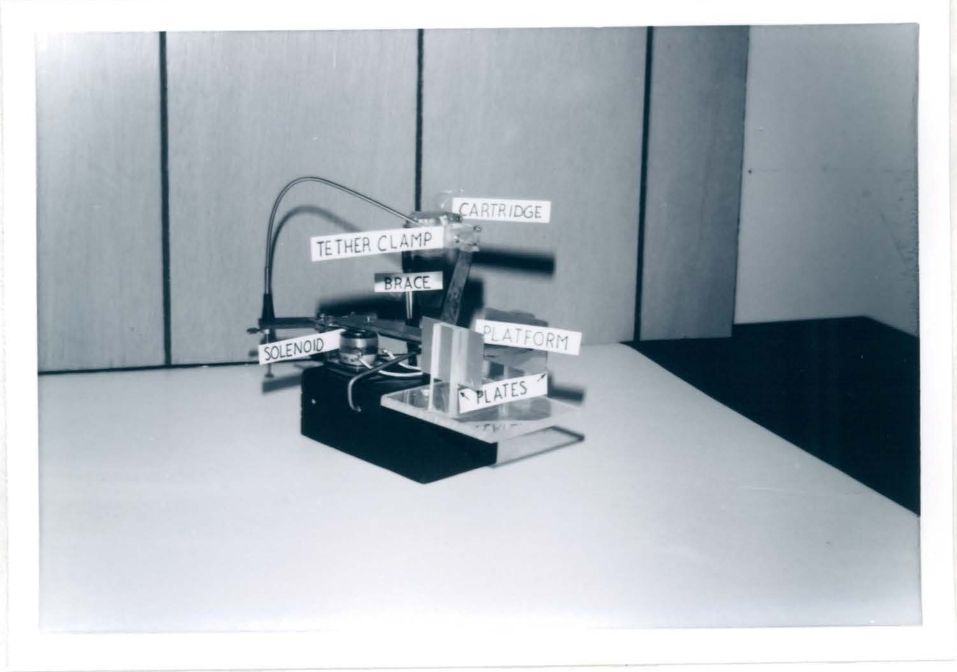


Figure 9. Modified Tether Apparatus Showing Parallel Plates Added to Form an Air Gap Parallel Plate Capacitor.

The ceramic phonograph cartridge was attached to the end of a brace that could be moved in any direction. The tether clamp was attached to the phonograph cartridge and as it vibrated the cartridge would produce a voltage signal.

A short stainless steel wire with a plastic bead attached to one end was used as a tether. To the free end of the tether a cabbage looper could be attached by placing a drop of molten beeswax on the looper's thorax and placing the end of the tether in the molten wax (Frings, 1946) and allowing it to cool. The mounted specimen could be located on the tether apparatus by placing the bead end of the tether in the tether clamp. The specimen's position could be adjusted so that it could rest on the platform when it was in the "up" position. When the platform was dropped to the "down" position, flight was initiated and the resulting thoracic movement was transferred through the tether and tether clamp to the ceramic cartridge. The voltage output of the ceramic cartridge was taken as an analog of the wingbeat. This signal was displayed on one channel of a Textronic Type 502A Dual Beam Oscilloscope. Recordings of the oscilloscope trace as shown in Figure 10 were made with a Textronic Model 125 Camera. From these, the wingbeat frequency could be determined easily. The amplitude of the signal was not directly proportioned to the wingbeat amplitude. The entire tether apparatus was mounted on a tripod whose legs were set on 6 inch cubes of foam rubber to reduce vibrations from external sources.

The parallel plates added to the tether apparatus were positioned such that when a cabbage looper was attached to the tether and the

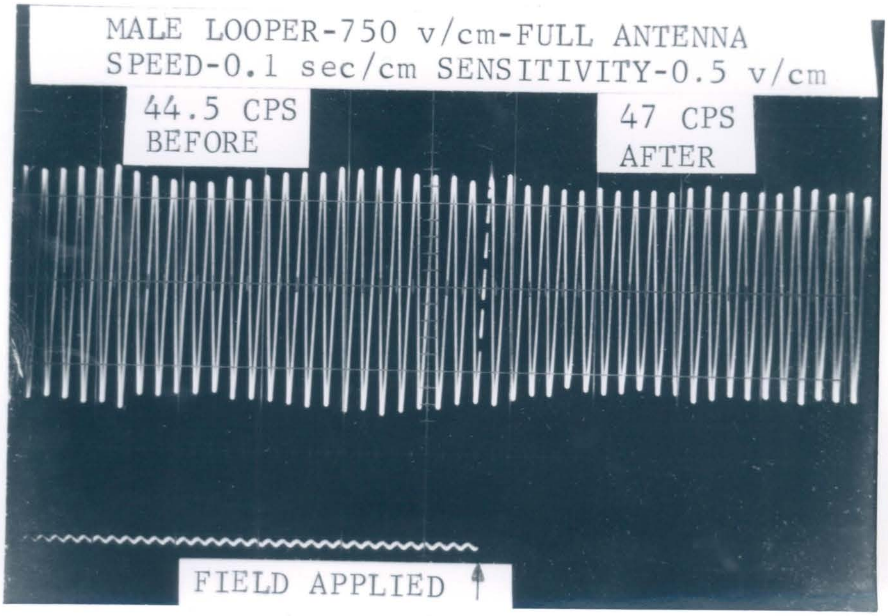


Figure 10. Oscilloscope Trace of a Cabbage Looper During a Test with Electrostatic Stimulant.

platform was in the "down" position, the flying looper was centered between the plates and no part of the looper extended past the edges of the plates (Figure 11). A Universal Voltronics Portable High Voltage Power Supply was connected to the plates through a double pole knife switch. With the knife switch in the open position the test voltage could be preset on the power supply and then applied to the plates and the test looper instantly by closing the switch. A twenty-seven megaohm resistance in series with a one-hundred ohm resistance was hooked in parallel with the plates. The voltage drop across the one-hundred ohm resistance was displayed on the lower channel of the oscilloscope. This gave an indication of when the stimulus was applied. A diagrammatic representation of the apparatus is given in Figure 12.

All tests were conducted in an air-conditioned walk-in chamber maintained at 75 ± 1° F during testing. The chamber employed a double room concept, the test specimen being located in the smaller inner room (test chamber) and the person conducting the test being located in the surrounding room. The test chamber was padded with acoustical insulation on the walls and ceiling and the floor was covered with carpet to reduce reverberations and standing waves. For this series of tests all observation windows were covered to prevent any light from the outer room to reach the test specimens during testing.

Light in the test chamber was supplied by a single 25 watt red bulb located approximately one foot above the test specimen. The light could be controlled from the outer room. Power for the remote control platform was supplied by a General Radio Adjustable Regulated Power

Figure 11. A Mounted Looper Showing Relative Position Between the Plates During Tests.

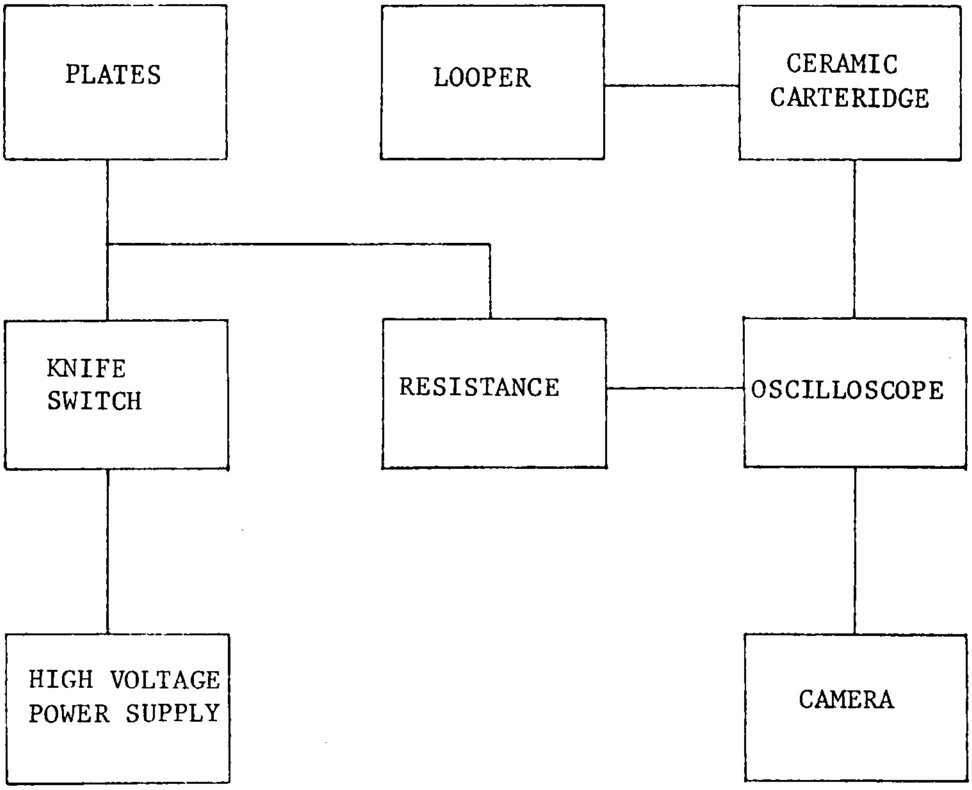


Figure 12. Diagramatic Representation of Instrumentation Used in the Wingbeat Frequency Tests.

Supply Type 1205-B.

Procedure

Since the cabbage looper is a nocturnal insect, specimens were reared on an altered photoperiod to facilitate testing during their period of activity. The incubator light was turned on daily at 6:00 P.M. for twelve hours. All testing in this study was done between 9:00 A.M. and 3:00 P.M. which coincided with the looper's period of activity.

Initially, a cabbage looper of the desired sex was selected at random from a cage containing 3-4 day old moths. The moth was immediately placed in a one pint ice cream carton and anesthetized with carbon dioxide. It was then taken from the carton and the scales on the thorax removed with a small bristle brush. A stainless steel tether was then attached with a drop of molten beeswax. The mounted specimen was placed in the tether clamp and with the platform in the "up" position so that the moth sat. The double doors to the chamber were closed and all lighting therein was cut off to allow a five minute dark adaptation period before the test began.

Electric Field Intensities of 500, 750, 1000, 1250 and 1500 v/cm with positive polarity were used with four replications for each sex. The order of application of e.f.i. was randomized for each specimen and the plate with the high potential was randomized within each sex.

After the period of dark adaptation the red light in the test chamber was turned on and the platform was dropped to the down position to initiate stationary flight. With the knife switch open, the stimulant voltage settings were made on the power supply. After one minute of flight the knife switch was closed applying voltage to the plate and exposing the looper to an electrostatic field. The camera was triggered simultaneously to photograph the oscilloscope trace (Figure 10). This provided a record of the looper's wingbeat frequency immediately before and during the application of stimulus. After the picture was taken the voltage source was disconnected from the plates, the red light was turned off and the platform was raised to the "up" position to provide a two minute rest period before the next test. After the rest period the test procedure was repeated for the next e.f.i.

An observation made during preliminary test was that the antenna movement of the loopers increased when they were located in an electrostatic field. The question then was whether they are using their antennas as a sensing mechanism. To determine whether the antennas are used as a sensing mechanism for the electrostatic fields, a second series of test was conducted. In this series, wingbeat frequencies of the loopers with and without electrostatic stimulant were recorded under three conditions; with full antenna, with half-antenna and with no antenna. The procedures followed for these tests were the same as that described before. A total of six male and six female moths were tested in the second series. The data from both series of test is included in Appendix III.

Results and Discussion

To determine the effect of electrostatic fields on wingbeat frequency, the change in wingbeat was determined from the data

(Appendix III) and was analyzed statistically using F statistic in one way analysis of variance and trend analysis. Results of the statistical analysis using data from the first series of test show that at five percent significance level, the wingbeat frequency of male loopers is found to increase significantly in response to an applied electrostatic field. Analysis also indicated that a linear relationship exists between the average increase in wingbeat and the applied voltage (Figure 13). No significant change in wingbeat was observed among the female moths in response to electrostatic fields.

Analysis of test results from the second series under three conditions (full antenna, half antenna and no antenna) indicated that the responses were the same as those described above (Figure 14). Thus from the available results it appears that the moths were not using their antenna as a sensing mechanism for sensing electrostatic fields.

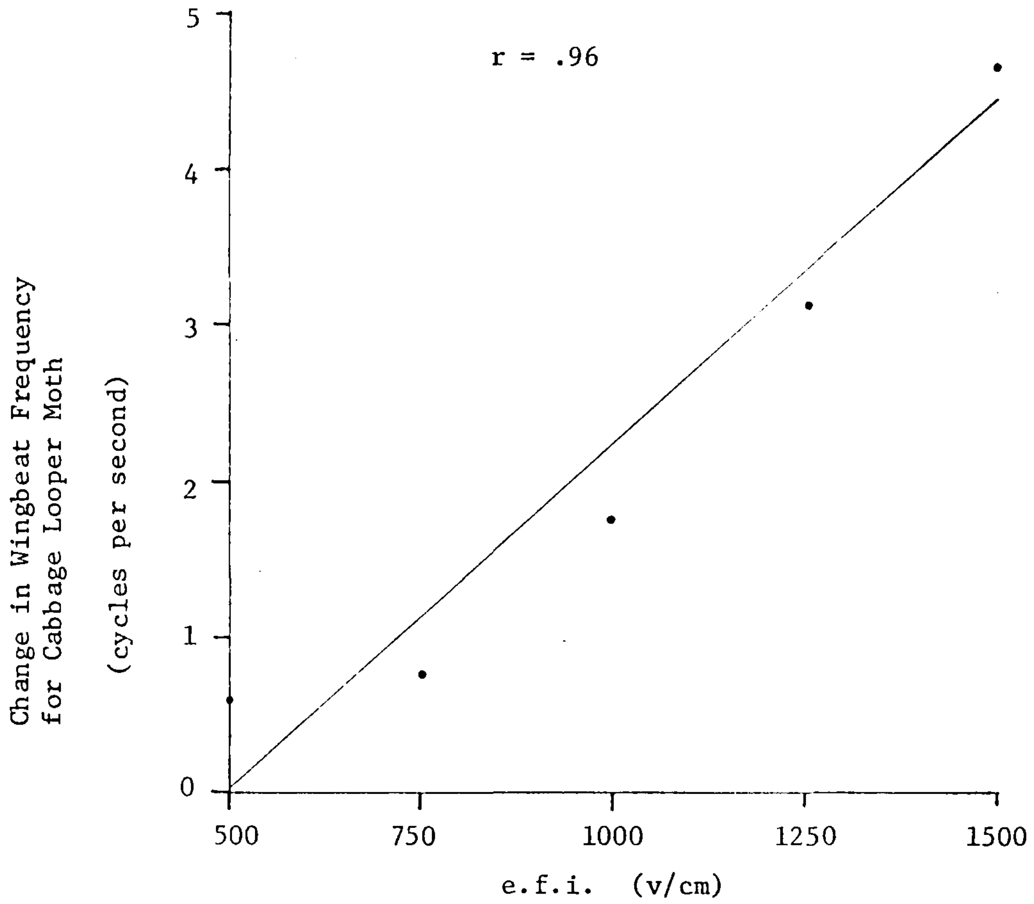


Figure 13. Plot of Average Increase in Wingbeat Frequency for Male Loopers in the First Series of Tests.

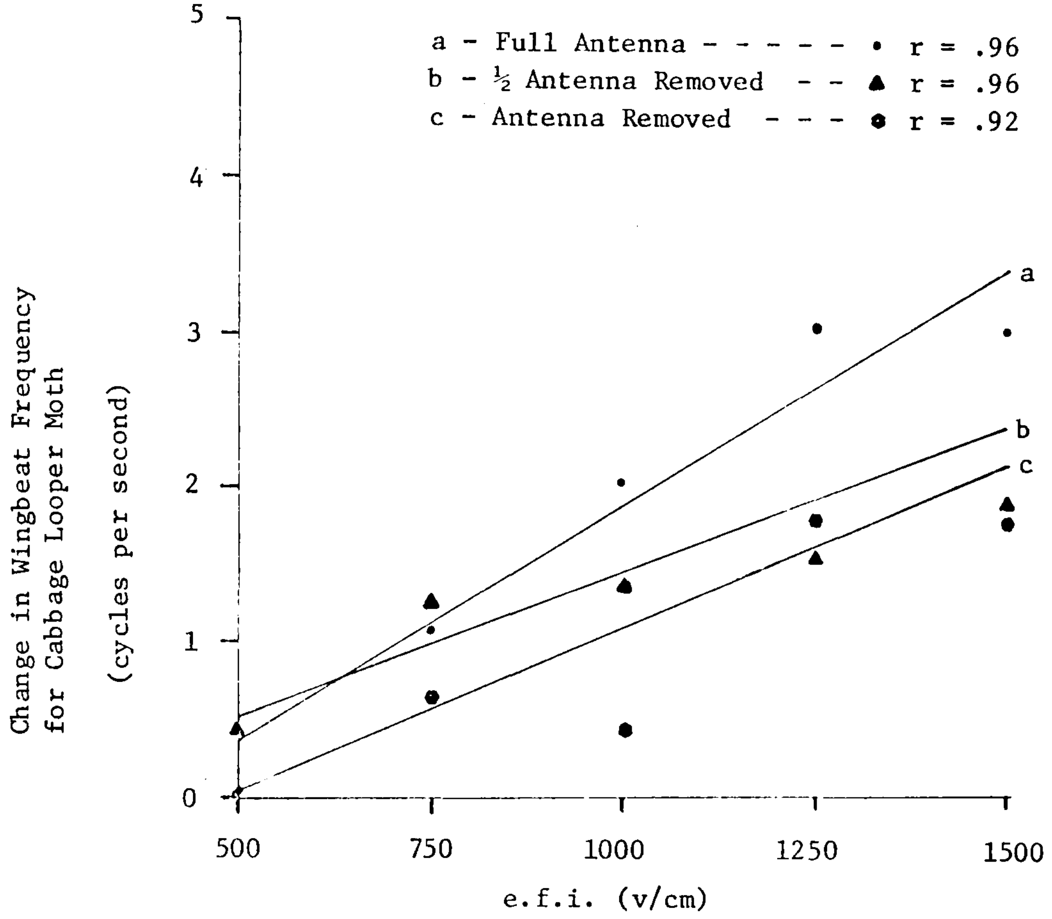


Figure 14. Plot of Average Increase in Wingbeat Frequency for Male Loopers in the Second Series of Tests for the Three Conditions.

CONCLUSIONS

1. Electrostatic fields of intensities up to 500 v/cm did not appear to have any influence on the locational preference of houseflies.
2. Locational preference of houseflies was significantly affected by the electrostatic fields ranging from 750 to 1500 v/cm. At e.f.i. 750 v/cm the houseflies preferred a region with field. For 1000, 1250, and 1500 v/cm they preferred not to be in the section with field.
3. The wingbeat frequency of male cabbage looper moths increased in response to an applied electrostatic field. The change in wingbeat increases linearly with the e.f.i. ranging from 500 to 1500 v/cm.
4. The wingbeat frequency of female cabbage looper moths did not change in response to an electrostatic field between 500 to 1500 v/cm.
5. The removal of part or full antenna had no effect on the response of loopers to electrostatic fields.

RECOMMENDATIONS

The author recommends that further locational preference test with houseflies be conducted for e.f.i. in the 750 v/cm range. Smaller incremental steps in e.f.i. should be used to determine the optimum field intensity in this range for maximum insect response. The locational preference test should also be conducted with other insect species to determine whether other species will behave similarly or not.

Investigation of changes in wingbeat frequency of cabbage looper moths should be conducted in the 0 to 500 v/cm e.f.i. range. Emphasis should be placed on determining the looper's sensing mechanism for electrostatic fields. The wingbeat frequency test should be extended to other insect species to determine the effect of electrostatic fields on flight activity.

Both locational preference and wingbeat frequency tests should be repeated with negative polarity to determine the insect response to a negative electrostatic field.

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APPENDICES

APPENDIX I

Electrostatic Field Between Parallel Plate Capacitors

During this study, the electrostatic fields between the parallel plates used were assumed to be uniform. To determine the accuracy of this assumption, a mapping of the field between the plates was desired. The mapping of the actual field between the plates was not possible since needed equipment was not readily available. Hence, an approximation technique was employed to plot the field between the plates. Step by step procedure involved in plotting the field is as follows:

1. A piece of masonite board was cut with dimensions that were large (approximately 10 times) in comparison to the field to be mapped.
2. Two holes were drilled near the center of the board. The distance between the holes was equal to the distance between the plates under consideration.
3. A wire was then fixed in each hole with one end flush with the surface of the board.
4. The board was then given three coats of graphite in aqueous solution and allowed to dry.
5. A cross section image of the plates being considered was then painted on the board with a conducting paint. Care was taken to insure that each plate image made good contact with one of the wires.

6. A dry cell battery was hooked to the plates (Figure 15). A series of resistors was then hooked in parallel with the plates.
7. One lead of a galvanometer was attached between two of the resistors. The other lead was moved about the surface of the board until a null balance was reached. At these points on the board the potential was equal to the potential between the resistors. By joining these points a line of equipotential could be drawn. By varying the galvanometer attachment between resistors different equipotential lines could be drawn.
8. Lines of force of the electrostatic field were then drawn. These lines are perpendicular to equipotential lines.

For the plates used during the locational preference test with houseflies, the field is shown in Figure 16. The plates were 5 1/4 inches square and 3 inches apart. Since the plates were square one plot gave the field in both vertical and horizontal planes. The field between the plates was relatively uniform and as such supports the initial assumption of a uniform field. The small deviations of the equipotential lines is due partly to uneven coat of graphite on the board.

Two field plots were necessary for the plates used during the wingbeat frequency tests. The plates were 1 1/4 inches by 2 inches and separated 2 inches. The plots for the horizontal and vertical planes are in Figures 17 and 18 respectively. The small difference in plots in the two planes is due to the difference in dimensions of the plates.

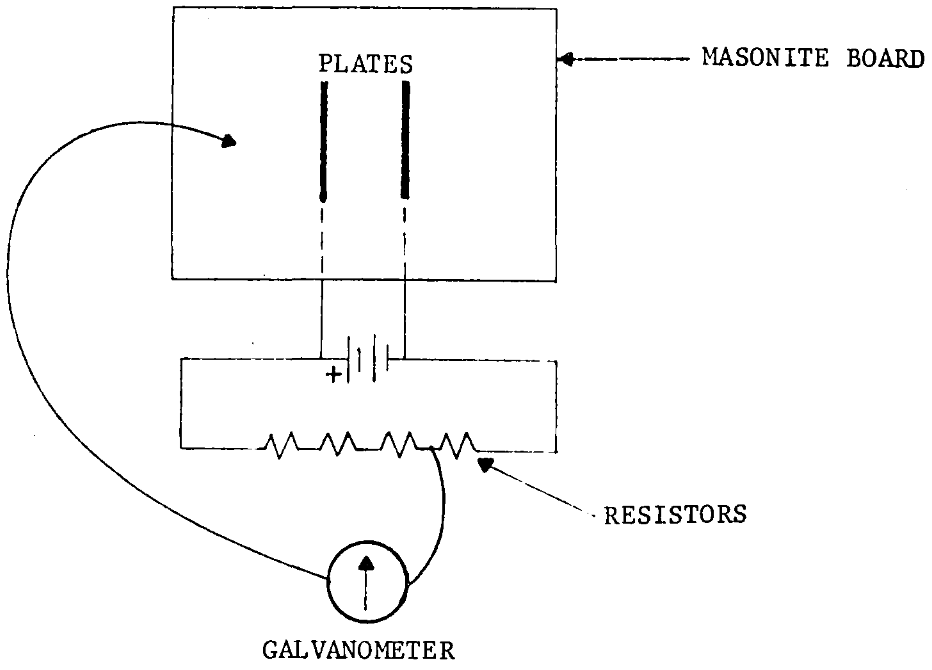

Figure 15. Schematic Representation of Apparatus Used to Plot Electrostatic Fields.

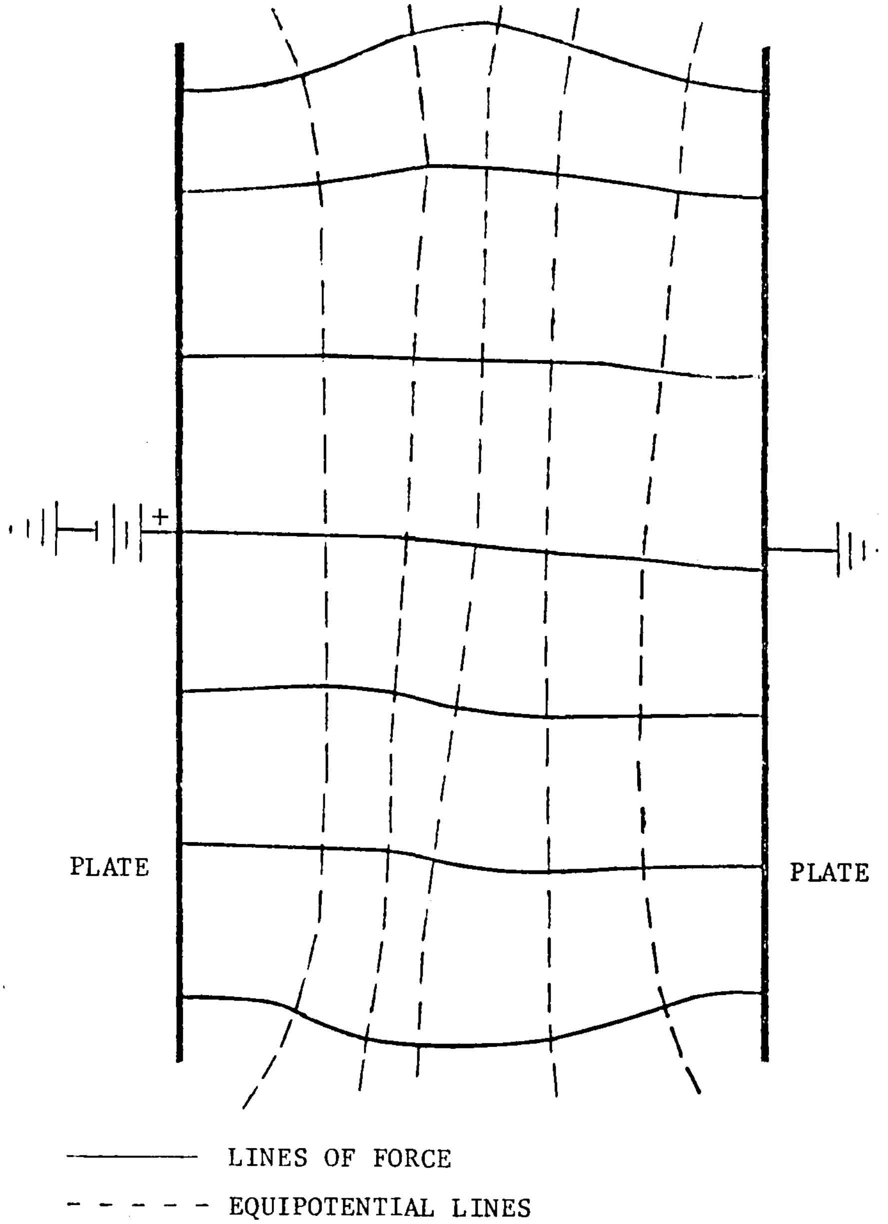

Figure 16. Lines of Equipotential and Lines of Force for the Plates Used in the Locational Preference Test for Houseflies.

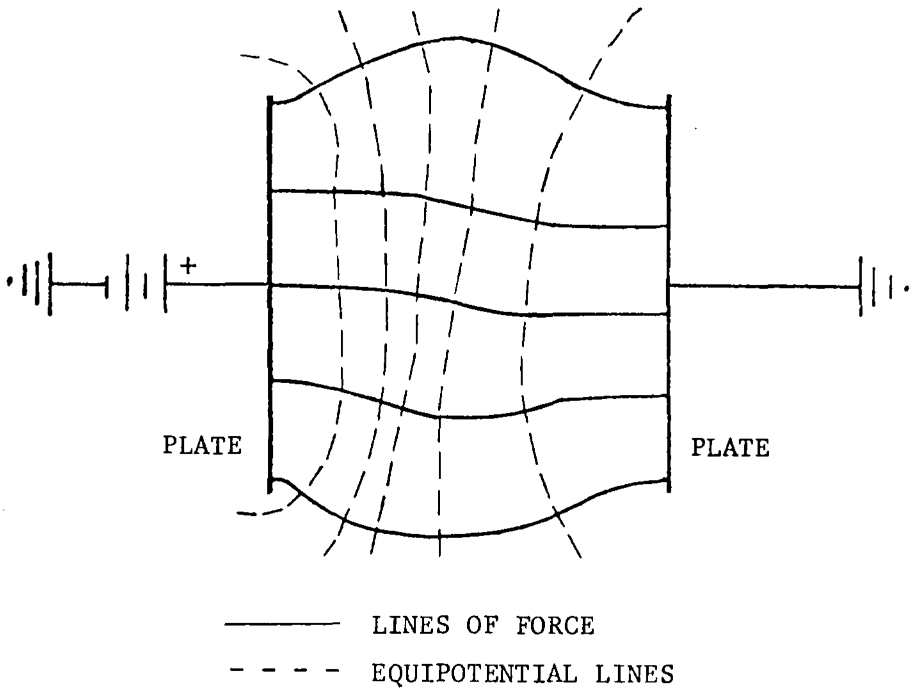

Figure 17. Lines of Equipotential and Lines of Force for the Horizontal Plane of the Plates Used for Wingbeat Frequency Test with Loopers.

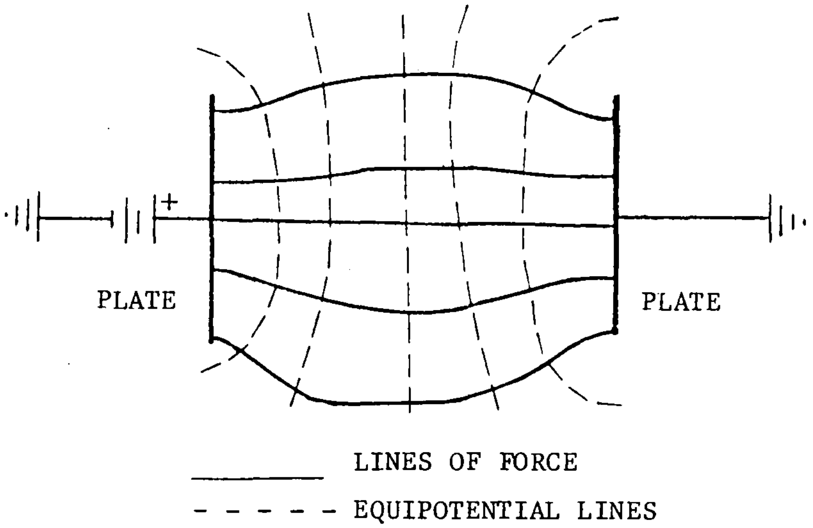

Figure 18. Lines of Equipotential and Lines of Force for the Vertical Plane of the Plates Used for the Wingbeat Frequency Test with Loopers.

APPENDIX II

Locational Preference Test Data

The data includes the number of flies in each section of the chamber at the end of each test.

	0 v/cm e.f.i.	
	No Field	No Field
	69	54
	42	44
	84	65
	48	45
	44	57
	52	48
	60	53
	56	70
	42	54
	64	70
	69	71
	57	72
	67	46
	61	40
	76	99
	65	56
	82	74
	70	52
	76	69
	78	75
Totals	1262	1214

APPENDIX II (CONTINUED)

	200 v/cm e.f.i.		500 v/cm e.f.i.	
	No Field	With Field	No Field	With Field
	66	43	106	81
	76	91	112	57
	84	57	113	78
	71	61	97	91
	83	76	84	58
	67	47	77	81
	98	54	80	77
	75	62	64	67
	95	52	99	99
	93	92	84	79
	76	106	114	106
	54	47	106	91
	56	80	78	83
	68	104	86	68
	62	83	58	63
	73	85	91	107
	38	92	78	77
	56	49	75	84
	57	61	51	87
	47	61	76	75
Totals	1395	1403	1729	1609

APPENDIX II (CONTINUED)

	750 v/cm e.f.i.		1000 v/cm e.f.i.	
	No Field	With Field	No Field	With Field
	57	61	74	65
	64	61	82	44
	89	64	64	40
	76	70	78	38
	48	68	81	58
	85	69	96	69
	58	66	92	63
	38	43	109	65
	51	51	69	55
	70	69	78	57
	34	92	52	65
	57	68	48	46
	152	160	66	56
	58	120	63	65
	81	69	65	76
	50	52	77	77
	98	83	79	95
	42	63	80	78
	63	47	74	88
	49	75	82	74
Totals	1320	1451	1509	1274

APPENDIX II (CONTINUED)

	1250 v/cm e.f.i.		1500 v/cm e.f.i.	
	No Field	With Field	No Field	With Field
	83	63	71	28
	90	57	52	23
	76	71	63	39
	107	87	53	35
	80	81	86	59
	82	64	42	49
	76	47	52	34
	86	51	107	69
	88	56	96	53
	42	42	69	68
	48	70	70	47
	67	78	47	39
	49	73	55	67
	80	54	26	26
	60	72	64	70
	93	82	100	113
	104	102	62	89
	57	62	54	56
	97	74	54	67
	67	72	33	50
Totals	1532	1358	1256	1081

APPENDIX III

Wingbeat Frequency Test Data

Wingbeat frequencies recorded before and during application of electrostatic stimulant.

A. First series of tests.

e.f.i. (v/cm)	Specimen Number	Wingbeat Frequency (Hz)			
		Male		Female	
		No Stimulant	With Stimulant	No Stimulant	With Stimulant
500	1	40	40	40	40
	2	40	40	37.5	39
	3	43	43	42.5	43
	4	36.5	39	45	45
750	1	40	41	40.5	42.5
	2	40	40.5	39	39.5
	3	44	45	40.5	40.5
	4	40	40.5	45	45
1000	1	44	44	44	45
	2	39	41	39	41
	3	37.5	39	45	45
	4	39	42.5	45.5	45.5
1250	1	40.5	43	37.5	40
	2	40	44	37.5	40
	3	40.5	42	40	44
	4	42.5	47	45	45.5
1500	1	40.5	43	37.5	40
	2	40	44	37.5	40
	3	40.5	42	40	44
	4	42.5	47	45	45.5

APPENDIX III (CONTINUED)

B. Second series of tests.

a. Full antenna.

e.f.i. (v/cm)	Specimen Number	Wingbeat Frequency (Hz)			
		Male		Female	
		No Stimulant	With Stimulant	No Stimulant	With Stimulant
500	1	48.5	48.5	38	38
	2	40	41	41	41.5
	3	40	40	40.5	41
	4	45.5	45.5	41	41
	5	39.5	39.5	40.5	40.5
	6	44.5	44.5	41	41
750	1	40	44.5	42.5	42.5
	2	40	40.5	42	42.5
	3	44	47.5	43.5	43
	4	45	45	39.5	40
	5	40.5	41	45	45.5
	6	41	43	40	40
1000	1	45	46	37	39.5
	2	41.5	45	42	44
	3	45	48	41	41.5
	4	46.5	47	40	41
	5	40	41	41	42
	6	41.5	44.5	40.5	43
1250	1	43	45	40	47
	2	40	45	40	44
	3	40.5	46	41	44.5
	4	45	45	40	40
	5	40	44	43.5	44
	6	42	44	40.5	44
1500	1	44.5	46.5	40	45
	2	40	45	49	46
	3	41	45.5	44	45
	4	44	45	41	41
	5	41	43	40	41.5
	6	41	44	39	40

APPENDIX III (CONTINUED)

b. One-half antenna removed.

e.f.i. (v/cm)	Specimen Number	Wingbeat Frequency (Hz)			
		Male		Female	
		No Stimulant	With Stimulant	No Stimulant	With Stimulant
500	1	43.5	45	45	45.5
	2	40	40	40	40
	3	41	41	41	41
	4	44.5	44.5	40	41
	5	43.5	44	45	46
	6	45	45.5	43	43.5
750	1	42	44	45	45
	2	41.5	44	42	42
	3	41	41.5	42	43
	4	50	50	39.5	39.5
	5	42.5	44	45.5	45.5
	6	45	45	43	45
1000	1	44	45	37.5	36.5
	2	41	43.5	40	42
	3	40	42	40	45
	4	49	50	40.5	41
	5	42.5	44	46	47
	6	45	45	42	45
1250	1	45	46	45	45
	2	40.5	44	44	44
	3	40	45	41	45
	4	45.5	45	46	46.5
	5	44	44.5	46	48.5
	6	45	45	42	45
1500	1	44	44.5	35.5	39
	2	42	45	40	41
	3	41	44.5	43	45
	4	41	45	39	41
	5	43	44	45.5	45.5
	6	45	47	42	43

APPENDIX III (CONTINUED)

c. Antenna removed.

e.f.i. (v/cm)	Specimen Number	Wingbeat Frequency (Hz)			
		Male		Female	
		No Stimulant	With Stimulant	No Stimulant	With Stimulant
500	1	43	43	44	44
	2	46	46	52.5	54
	3	45	41	41	44
	4	50	50	39.5	39
	5	44	44	45	45
	6	45.5	45.5	39.5	40
750	1	45	45.5	44.5	45
	2	44.5	45.5	40.5	42
	3	46.5	47.5	40	42
	4	46	46	43.5	44
	5	44	44.5	45	45.5
	6	46	46.5	41	41
1000	1	45	45.5	40	41
	2	46	47.5	44	44
	3	45	46	40	41
	4	46	45	40	40
	5	44	44	45	45.5
	6	45	45.5	40	40.5
1250	1	45	45	46	44
	2	45	49	53	54
	3	47.5	49.5	40	43
	4	45	48	45	45
	5	44	44.5	45	45
	6	45	46	42.5	44.5
1500	1	45	47	44	44
	2	45.5	49	51	53.5
	3	44	46	40	44.5
	4	48.5	50	40	44.5
	5	45	45	45	45
	6	45.5	47.5	44.5	45

ELECTROSTATIC FIELD EFFECTS ON INSECTS: THE HOUSEFLY AND CABBAGE LOOPER

BY

ROBERT ANGELL RIDOUT

(ABSTRACT)

Effects of electrostatic fields on insects were studied using cabbage loopers, *Trichoplusia ni* (Hubner) and houseflies, *Musca domestica* L. Two series of tests were conducted; one to determine the electrostatic field effect on the locational preference and the other to determine the field effect on wingbeat.

Among the field gradients examined (250, 500, 750, 1000, 1250, 1500 v/cm), those with 750 v/cm and up had significant influence on the locational preference of houseflies at the five percent significance level. With a choice between two regions, having no field and with field at an e.f.i. of 750 v/cm, houseflies preferred to be in the field. For gradients above 750 v/cm the houseflies preferred the region with no field.

Electrostatic fields with gradients 500, 750, 1000, 1250, and 1500 v/cm had significant effect on the wingbeat frequency of male cabbage loopers and no effect on females. The change in wingbeat among males was found to increase linearly with increasing e.f.i. Removal of part or full antenna did not effect the response of loopers to electrostatic fields.