FURTHER EXPERIMENTS SEEKING EVIDENCE OF NONTHERMAL

BIOLOGICAL EFFECTS OF MICROWAVE RADIATION

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Abstract

Carpenter and Livstone's[1] experiments on beatle pupae were repeated and extended. Increased incidence of abnormal development occurred due to exposure to microwave energy, both c.w. and pulse. Measurements are reported which specify the microwave environment encountered by the insect.

I. Introduction

This investigation verified and augmented the observations of Carpenter and Livstone[1] on teratological damage inflicted upon the darkling beatle *Tenebrio molitor* by low power microwave irradiation.

We first repeated the Carpenter and Livstone study at 20 mW c.w. irradiation level with a much larger sample population and confirmed their results. Next several of the experimental parameters - c.w. power level, absorbed energy, pulse power level, orientation and pupa age - were varied to determine their effect. Finally measurements were made to specify the microwave environment encountered by the insect.

II. Experiment

One to two day old pupae were mounted in a polyfoam block along the center line of X-band waveguide (with matched termination) with their anterior portion towards the power source. They were irradiated at 9 GHz, then allowed to pupate. Upon completion of pupation, they were categorized for gross morphological defects.

Pupae were irradiated in waveguide instead of free space because power absorption and reflection measurements are more easily made, much less power is required for the same power density and to conform to Carpenter and Livstone's original setup.

Pupae were harvested daily from larva and divided arbitrarily among experimental and three control groups. Some controls were placed directly in vials while others were first mounted as if for irradiation. The third group was placed in a 29°C oven for two hours. The temperature increase was 8°C compared to the measured temperature increase of 2°C under irradiation.

A fine thermocouple junction was placed in the abdomen of a sample pupa to monitor the temperature during irradiation.

III. Phenomenological Experiments

A. 20mW c.w. irradiation for 2 hours.
B. Pulsed Field irradiation for 2 hours with pulse width of 0.25μsec, 20mW average pulse power, and peak powers of 50W and 5KW.
C. Alignment of pupae parallel to E field in expanded height waveguide.[2]
D. Five day old pupae irradiated at 20mW c.w. for two hours.[3,4]
E. Reduced Power Level. 10 mW for four hours.
F. Reduced Dosage. 10mW for two hours.

IV. Results and Statistical Analysis

The categories of morphological damage used both by us and by Carpenter and Livstone are as follows:

D - Insect died during pupation
G1 - Head and thorax of adult, but abdomen of pupa
G2 - Adult insect, but rumpled and grossly distorted elytre (wing covering) or shredded wings
G3 - Normal adult except for small holes in elytra
N - Normal adult

The incidence of abnormality increases more than threefold with irradiation while the death rate remains essentially unchanged (See Table 1). The percentage of G3 abnormalities showed a particularly dramatic difference between experimental and control groups.

The data was subjected to the chi squared test[5] to rule out change occurance. When compared to each other, the control groups showed no significant differences. This also proved true for comparisons between the results of experiments denoted by III A, III B, III C, and III E. However, significant differences did exist between the control groups and the irradiated groups.

V. Microwave Measurements

Insertion loss and input match were measured for the two orientations of the pupa. One third of the incident microwave power is absorbed in each case. The electric field above the pupae was probed with a slotted line and the results plotted in Figure 1.

The complex dielectric constant was measured via the method of von Hippel[6] to be $\varepsilon/\varepsilon_0=30 -j\ 18$. Once the complex dielectric constant is known, the transverse field distribution and hence the power density in the region of the pupa can be approximated.[7,8]

VI. Discussion

We confirm the finding that low power microwave irradiation causes teratological damage at a waveguide power level of 10 mW ($8.6\ mW/cm^2$ at the center of the waveguide).

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TABLE 1

Effect of 9.0 GHz Radiation on Tenebrio Molitor Pupae

Group	D	G1	G2	G3	N	Total
20 mW c.w. 2 hours (Section IIIA)	40(21.7%)	25(13.5%)	58(31.3%)	18(9.7%)	44.(23.8%)	185
Pulsed, 50W peak (Section IIIB)	9(21.4%)	7(16.7%)	16(38.1%)	2(4.8%)	8(19%)	42
Pulsed 5 kW peak (Section IIIB)	21(22.1%)	10(10.5%)	30(31.6%)	8(8.4%)	26(27.4%)	95
Aligned II to E Field (Section IIIC)	9(24.3%)	5(13.5%)	12(32.4%)	4(10.8%)	7(18.9%)	37
Five Day Old (Section IIID)	11(21.6%)	7(13.5%)	11(21.6%)	3(5.9%)	19(37.2%)	51
10mW c.w. 4 hours (Section IIIE)	24(29.3%)	14(17.1%)	18(21.9%)	6(7.3%)	20(24.4%)	82
10mW c.w. 2 hours (Section IIIF)	19(31.1%)	5(8.2%)	17(27.9%)	2(3.3%)	18(29.5%)	61
Untreated Controls (Section II)	48(20.7%)	10(4.3%)	23(9.9%)	0(0%)	151(65.1%)	232
Waveguide Controls (Section II)	18(20.8%)	4(4.4%)	11(12.2%)	1(1.1%)	56(62.2%)	90
Temperature Controls (Section II)	11(20.8%)	2(3.8%)	7(13.2%)	0(0%)	33(62.3%)	53
Total of Control Groups	77(20.5%)	16(4.3%)	41(10.9%)	1(0.3%)	240(64.0)	375

This damage is not due to handling nor to the increase in temperature of the pupa under irradiation.

For our experiments the incidence of damage is independent of specimen orientation, irradiated power level or whether the microwave power is pulse or c.w. The incidence of damage does depend on the energy absorbed and the pupa age when irradiated.

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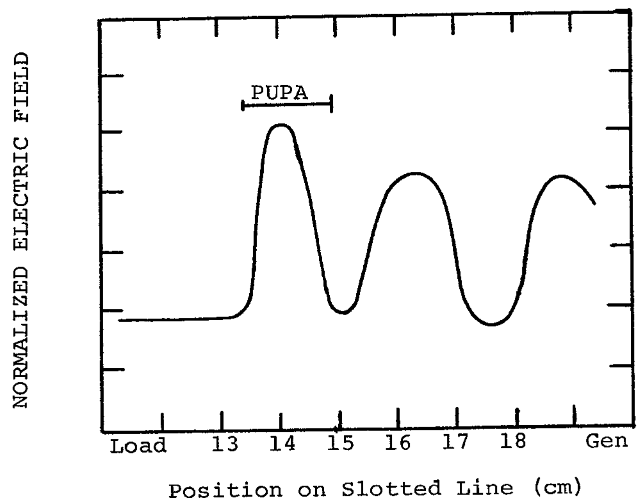

Fig. 1. Electrical Field Intensity In Region of Pupa Normalized to Field From the Generator