MORTALITY AND STERILITY OF THE CIGARETTE BEETLE, *LASIODERMA SERRICORNE* (F.), DUE TO EXPOSURE TO ATMOSPHERIC PLASMA

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Experiments were carried out on the atmospheric plasma device, PALADIN, at maximum operating power of 500 W with oscillating plasma between 5 kHz and 20 kHz. Figure 1 shows the setup for the PALADIN device. During typical operation, the PALADIN device generates atmospheric plasma composed of helium gas and air at 14 kV_{rms} with an active electrode area of 320 cm^2 and a dielectric separation of 3 cm. The helium reduces the electrical requirements for the generation of the plasma and suppresses the production of undesirable chemical by-products such as ozone. The plasma has an electron temperature between 1 eV and 5 eV with electron densities ranging from 10^{12} to 10^{15} m^{-3}. The ions in the discharge have a similar density, but their temperature remains near ambient temperature. Temperature measurements using water and PCA agar show exposure times less than five minutes remain below 40 °C. Since the temperature remains near ambient, insect population reduction associated with the increased temperature is small. Even with increased temperature, current thermal treatments operate on the order of hours so an exposure on the order of a few minutes to even 50 °C has a minimal effect on the population of insects.

Test Insects Laboratory-reared cigarette beetles (CBs) (1 to 4 day-old eggs, 3rd and early 4th instars, 3 to 5 day-old pupae, and <1 week-old adults) were tested. For each treatment, 25 individuals of each CB stage were placed into a 60 x 15 mm glass Petri® dish. At the time of treatment, the top of the dish was removed, CBs in the dish were placed inside a chamber with an altered atmosphere of helium and air, and the top was then replaced. CBs were returned to the laboratory where they were incubated at 26 °C and 75% relative humidity. Mortalities of adults and larvae were determined within several days by direct observations, and mortalities of eggs and pupae were determined over several weeks by observing whether they developed into larvae and adults, respectively. Sterility of surviving treated adults, defined here as "the inability to produce adult progeny", was determined by placing those adult survivors on a rearing medium of ground tobacco and counting the number of adult progeny produced.

Treatments Each CB stage was exposed to the plasma for 0 (control), 5, 10 and 20 sec. Immediately after exposure, it was obvious that adults exposed to the plasma for 5 and 10 sec had not suffered significantly mortality. Therefore, within minutes the adults originally exposed for 5 sec were exposed to an additional 40 sec of treatment, and adults originally exposed for 10 sec were exposed for an additional 60 sec. No other adults nor CBs of any other stage received any such extended treatment.

Results There was essentially no mortality of control adults or pupae, and mortality of pupae and eggs was similar to what is routinely observed in the laboratory (Table 1). Plasma treatment induced significant larval mortality, with the dose effect being apparent However, treatment up to 20 sec induced no pupal mortality, and little or no significant egg or adult mortality. Significant adult mortality was achieved at the 45 and 70 sec exposures. Larvae were possibly the most susceptible CBs because plasmas are thought to be effective only at the surface of the target, and the other stages have either a hard exterior, puparium or chorion for protection.

Although adults placed on the rearing medium for sterility testing were not sexed, sex ratios have routinely been approximately 50:50 in past checks which are conducted frequently. Only 14 adults survived treatment at 45 sec, but 22 to 25 adults were available to be used to seed the 20 sec and control cultures (Table 2). Plasma treatment greatly reduced the ability of surviving adults to produce adult progeny. Adults that survived the 20 and 45 sec treatments produced only 68% and 25%, respectively, as many progeny per adult as did the controls.

The relative size of all larvae was determined by visual inspection. The size distribution of the total number of larvae tested did not differ from the size distribution of the dead larvae (Table 3). Though not conclusive, this suggests that larval size did not affect efficacy of the plasma.

Summary This was an early test on one beetle species, but results demonstrate that plasma treatment can kill and sterilize insect pests such as those in post-harvest commodities. Plasmas are generally effective only at the surface of the target, so plasma systems alone would probably be effective only on species that spend critical portions of their lives on the surface of commodities. Internal feeders or species that otherwise are not clearly exposed would require an additional control component. Additional research is underway to test the potential of this technology.

Table 1. % of cigarette beetles to survive plasma treatment.

Exposure (sec)	Survival Adults	Exposure (sec)	Survival Pupae	Larvae	Eggs
0	100	0	80	96	73
20	92	5	76	60	81
45*	56	10	72	36	65
70**	8	20	72	28	52

* Adults surviving the 5 sec exposure were exposed for 40 sec longer.
** Adults surviving the 10 sec exposure were exposed for 60 sec longer.

Table 2. Number of progeny produced by surviving adults placed on rearing medium (Test of sterility).

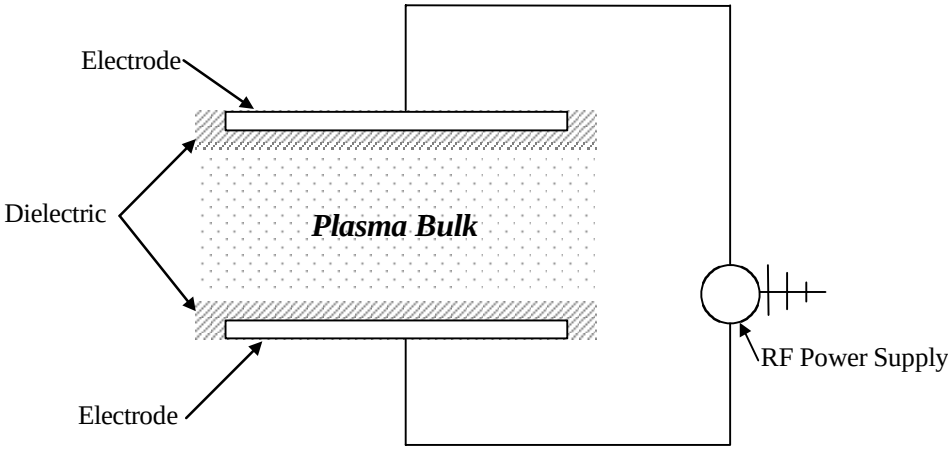
	Controls (No exposure)	20 sec exposure	45* sec exposure
Adults	25	22	14
Total progeny	487	291	68
Progeny/adult	19.5	13.2	4.9

* Adults surviving the 5 sec exposure were exposed for 40 sec longer.

Table 3. Relative sizes of tested and killed larvae.

	% Small	% Medium	% Large
Total larvae tested	42	42	17
Dead larvae	46	34	20

Figure 1.


Electrode
Dielectric
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