Electrical impedance's effects of flying insects on selectivity of electrical insecticides

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ABSTRACT

The history of controlling destructive insects in the twentieth century makes it clear that the difficulties we encounter today in dealing with these types of insects come from our almost total reliance on one single controlling method, namely the use of chemical insecticides. These toxic and suspected carcinogenic products pose a serious threat to agriculture and the environment. However, the possibility of directing researchers in developing a new way considered as more efficient, more selective and less toxic has proved to be possible. The principle of this approach is based on an attractive effect and an electric effect. Nevertheless, the development of a bio and selective electrical system requires taking into account certain parameters involved in the attraction of insects and electrical discharge such as the electrical impedance. The results showed that the threshold at which the insect is disturbed depends on its conductivity.

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1. INTRODUCTION

In the agricultural/ecological context, insects can be grouped in terms of beneficial and non-beneficial organisms. Even though beneficial insects play a considerable role in the balance of nature, the development of plants, and some families, in particular, are leading indicators of the biodiversity of ecosystems and their evolution, some of them are considered pests that we must get rid of [1]. Their extreme densities and voracity pose many threats to agriculture: they ravage crops and are responsible for the transmission of certain viral diseases [2]. As an alternative to non-beneficial insects, we used different methods: cultural, biological, and chemical. The intensive uses of these products have led, within the short term, to the elimination of pests but, have also affected negatively on the environment: water and air pollution, the appearance of certain diseases (autism, allergies, and other congenital malformations) [3]. Moreover, insects have developed a strong resistance against chemicals which has created a new problem for researchers [4], [5]. Although this problem is already widely known, it has not yet been resolved. In this article, we propose an organic electric approach that can be described as a new way to control harmful flying insects that are damaging agriculture [6], [7]. This later has several advantages as such being mobile, non-polluting, and non-toxic. Its geometric and electrical construction presents a selective effect. This technique is already used for indoor insects [8], [9].

2. THE PROPOSED APPROACH

The devise is placed in a protective cage of grounded metal bars witch cannot drive a dangerous current through the body of human. A high voltage power supply powered by mains electricity generate a high voltage to conduct through the body of insect. The device is protected by an external mesh allowing the target insect to penetrate inside according to the configuration and the species/space. Any insect larger than the size selected is unlikely to get inside (>a). Furthermore, a light source is fitted inside composed of two fluorescents lamps designed to emit both ultraviolet and green light which is visible to insects and attracts a variety of them to the device. An electrification system is placed inside the device allowing the destruction of targeted insects from an electric shock. This later determines the minimum size of the insect to be electrified (≤b). It is very important to determine the size as it is considered as the cause behind any air rupture that may occur between inter-electrodes which may not take place if the size of the insect is smaller. The electrified insects are collected in a bac. The device is placed at a certain height and it can be powered by a photovoltaic generator GPV 12 V-DC.

Firstly, the insect is trapped from the light, when it gets between the two electrodes that constitute the mechanism of destruction: there is a rupture of the air gap. The paralysis might occur as long as the current does not exceed a certain threshold of intensity depending on the power used and the conductivity of the tissue as shown in Figure 1. However, there are several types of insects with different characteristic that's why it is difficult to control the target ones [10]. The characteristics of the system can be affected by several parameters such as: types of lights used in attracting insects, conductivity of the insects.

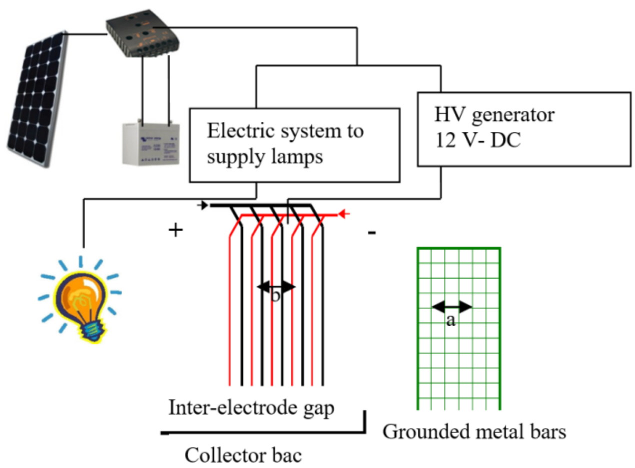
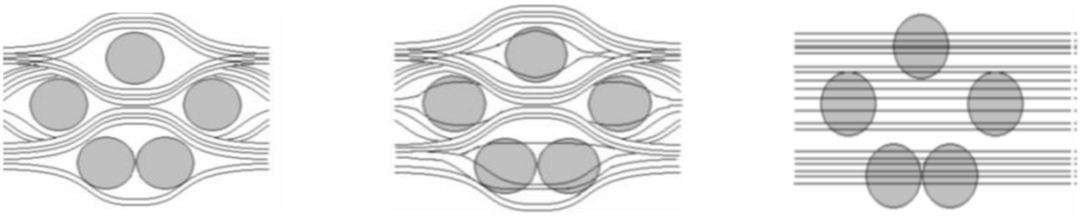


Figure 1. Principle devise

Insects are sensitive to light. They have a primitive vision of shapes and colors, a good judgment of distances, a large field of vision and they see much further than us in the ultraviolet. This light is considered to be more efficient as it emits waves with a wavelength between 340 nm and 370 nm that only flying insects perceive. Nevertheless, the attractive effect can vary greatly from one species to another. Some insects are attracted to other wavelengths such as that of green light which has a spectrum in the range of 560-575 nanometers. In comparison with us, insects perceive colors which are unknown to humans but, are unable to perceive all the red we see [11], [12].

Concerning the conductivity of the insects, very limited research has been undertaken. The biological tissues of the insects depend on the conductivity [13]. The surface of the body of almost all insects is not only made up of high-strength sclerites that accumulate charges but also of membrane structures of different conductivities that can be grounded through the electrolyte system [14], [15].

In humans, surface conductivity occupies a special position because of the high-density distribution of sweat glands throughout the body. Changes in temperature, variations in relative humidity can be the cause of considerable variations in the Ohmic resistance. Also, the current conduction paths through the tissue can be controlled by suitably changing the frequency which helps us to calculate the impedance of the tissue for different current paths [16], [17]. It creates a transition frequency that is involved in the conductivity that depends on the characteristics of the biological tissue [18], [19]. Figure 2 shows the current path in a cell suspension at different frequencies. At low frequencies, the plasma membrane acts as an insulator and the current is not able to enter the cell in Figure 2(a). The insulated effect of the cell membrane decreases, and part of the current is able to flow indiscriminately in the intracellular medium in Figure 2(b). At higher frequencies, the capacity of the membrane is no longer an obstacle in front of the current and the current can flow indiscriminately in Figure 3(c).



(a) (b) (c)

Figure 2. Current path in a cell suspension at different frequencies (a) low frequencies, (b) frequency increases, and (c) high frequencies

3. RESEARCH METHOD

The ionic conductivity of the electrolytes is measured by an alternating current complex impedance over a wide range of frequencies [20], [21]. To know the influence of the geometric part on the electrical initiation, a simulation was carried using a software calling COMSOL version 2 (multiphysics). On second hand, an experimental study was carried out to measure the insect's electrical impedance. In this case, we used live locusts which belong to the Orthoptera order of insects. All locusts used in this study had the same weight and size. To determine the impedance of insects, we calculate the impedance according to Ohm's law states Z=U/I Ohm's law determines the relationship between the current (I) and the voltage (U). The effect of parameters simultaneously, was determined by the design of experiments method [22], [23].

4. RESULTS AND ANALYSIS

4.1. Influence of a conductive body on the electric field

The results of the simulation proved the influence of the geometric part on the air interval initiation. An electric discharge is created in the shortest interval. The more the distance is shorter, the more the discharge is produced. There is a relationship between current density and insect’s conductivity [24], [25]. Figure 3 shows the lines of the electric field with presence of a conductive particle. The applied voltage is sufficient to cause a breakdown interval in Figure 3(a). There is no effect if the particle is smaller than the inter electrode distance as shown in Figure 3(b).

(a) (b)

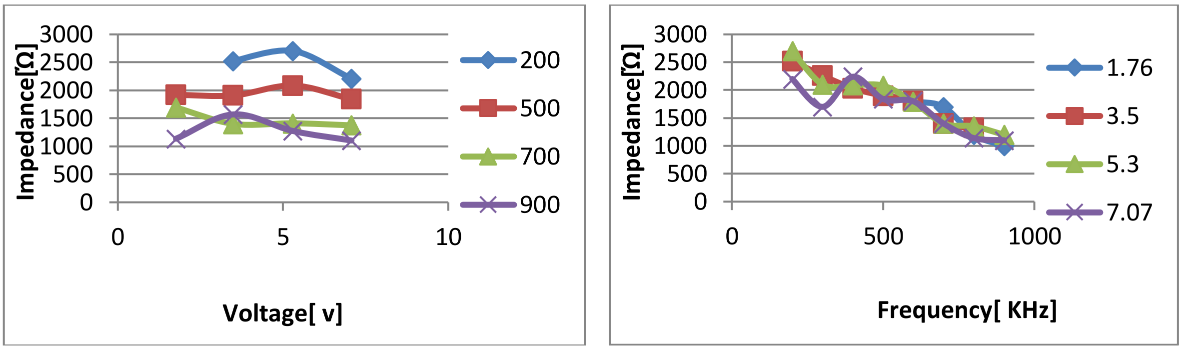
Figure 3. Influence of air gap on electrical initiation (a) total electric discharge and (b) no effect

4.2. Influence of frequency and voltage on electrical impedance

Table 1 shows the electrical impedance measured for different frequency values and voltage. The values indicated in the Table 1 were recorded on live locusts following the various measurements carried out for voltages between 1.76 V, 3.5 V, 5.3 V, and 7.07 V and frequencies from 200 to 900 KHz between two points of the insect’s body. The current allowed us to calculate the impedance according to ohm's law: Z=U/I. Figures 4(a) and 4(b) show that the impedance decreases with voltage and frequency. The current applied through the electrodes passes predominantly through the high conductivity compartments. The threshold at which the insect is disturbed depends on its conductivity. This threshold is the criterion that is appropriate for different insect’s reactions on electrical current.

Table 1. Electrical impedance according to voltage and frequency

	Impedance (Ω)			
Voltage (V)	Frequency (KHz)			
	200	500	700	900
1.76	No effect	1920	1693	1136
3.50	2525	1909	1401	1571
5.30	2704	2086	1412	1274
7.07	2209	1842	1375	1104



(a) (b)

Figure 4. Electrical impedance according to (a) voltage and (b) frequency

4.3. Effect of parameters simultaneously

Table 2 shows the field of study of frequency and voltage simultaneously. On the second aim, the estimated coefficients obtained by using calculation have a positive effect on the impedance, i.e., when, one of them decreases, the impedance is reduced and the effect of the frequency on the impedance is more influential than the voltage as shown in Figure 5. The applied mathematical model is:

$$Y_{imp} = 1975.75 - 877.25x_1 + 161.25x_2 - 155x_1x_2$$

moreover, the residue diagram shows clearly the most influential parameter, therefore, the model gives a good account, the closer the point is to the curve, the less influential it is depending on whether it is positive or negative as shown in Figure 6.

Table 2. The frequency and voltage simultaneously

Trials	Frequency (KHz)	Voltage (V)	Current (mA)	Impedance (Ω)
1	200	3.5	1.38	2536
2	900	3.5	3.2	1093
3	200	7.07	2.23	3170
4	900	7.07	6.4	1104
5	550	5.3	2.54	2086
6	550	5.3	2.96	1790

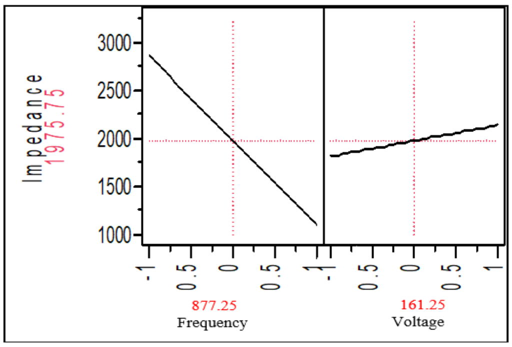


Figure 5. Effect of parameters

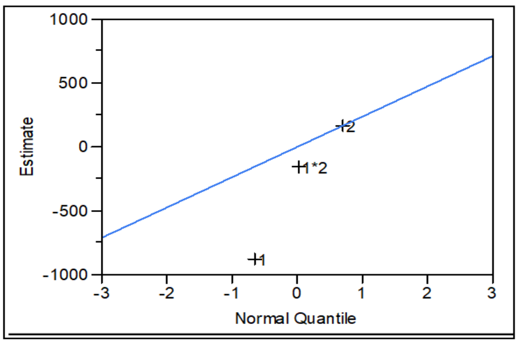


Figure 6. Residue diagram of impedance

5. CONCLUSION

The problems with chemical insecticides force us to change our current insects' controlling strategies: it is not to criticize insecticides but to seriously question their usage competencies. The development of a bioelectrical approach could be used successfully in agriculture. This "green technique" deserves to be the subject of numerous studies. What remains now is to make certain provisions as to the relativity of certain parameters in order to be able to define-subsequently-with relative accuracy the optimum of these parameters on the domains of variation of these with respect to the selected criterion. The results confirm the effect of frequency and voltage on the electrical impedance. Thus, the insects collected become useful reference sources for subsequent verifications. At the end of this work, we plan to: Development of a system with several extermination bigrils to control the arrival of a group of insects at the same time; optimization of geometric parameters to evaluate the system in terms of design according to the target insect. This has been our choice, it goes without saying that we are still in the research stage and any choice is subject to scientific falsifiability that only the field of experimentation invalidates or subsequently confirms.

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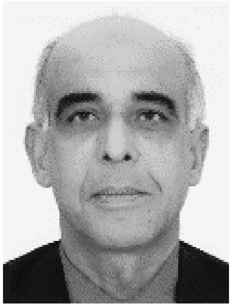

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