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Effect Of Nd:YAG Laser On Ants (*Camponotus consobrinus*)

Estabraq Mahmood Mahdi[1], Sahar Naji Rashid[2]*, Awatif SabirJasim[2]

[1]*Department of Biology, College of Science, University of Tikrit, Tikrit, Iraq*

[2]*Department of Physics, College of Science, University of Tikrit, Tikrit, Iraq*

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Abstract

The subject of biophysics is interdisciplinary and covers various fields of biology and physics. In this research the effect of some parameters of Nd:YAG laser on ants (*Camponotus consobrinus*) has been studied . This includes the effect on its external shape, as well as the percentage of the killing rate obtained. A laser radiation of a wavelength (1.064 µm) with different energies: (300, 320, 340, 360, 380 and 480 mJ) was used to irradiate ants placed at a distance of (10 cm) distance from the laser source . The irradiation times were (15 and 20 sec) for each energy. The obtained results showed an increase in the rate of ant mortality, as well as an increase in deformations, as the laser energy and the irradiation time increased. These results were recorded after different time periods (12, 24, 48 and 72 hours) after laser treatment.. The thermal diffusion within the tissues resulting from laser radiation causes increased death rates due to damage of internal structures.

Keywords: Nd:YAG laser, Ants (*Camponotus consobrinus*), Biophysics, Irradiation, Thermal effect.

تأثير ليزر Nd:YAG على النمل (*Camponotus consobrinus*)

استبرق محمود مهدي[1] ، سحر ناجي رشيد[2*] ، عواطف صابر جاسم[2]

[1]قسم علوم الحياة، كلية العلوم، جامعه تكريت ، تكريت، العراق

[2]قسم الفيزياء، كلية العلوم، جامعه تكريت، تكريت، العراق

الخلاصة

إن موضوع الفيزياء الحيوية متعدد التخصصات ويغطي مختلف مجالات علم الأحياء والفيزياء . في هذا البحث تم تجربة تأثير بعض معلمات ليزر Nd: YAG على النمل (Camponotus consobrinus) والذي يتضمن التأثير على شكله الخارجي ، وكذلك النسبة المئوية لمعدل القتل الناتج عن إشعاع الليزر بطول موجي (1.064 µm) وبالطاقات: (300, 320, 340, 360, 380 and 480 mJ) وعلى مسافة (10 cm) بين مصدر الليزر والحشرة ، وبأوقات التعرض (15, 20 sec) لكل طاقة . وأظهرت النتائج التي تم الحصول عليها زيادة في معدل قتل النمل ، وكذلك زيادة في التشوهات ، كلما زادت طاقة الليزر وزمن التشعيع . تم تسجيل هذه النتائج بعد فترات زمنية بعد المعاملة بالليزر وهي كالتالي: (12, 24, 48 and 72 hour) . أدى الانتشار الحراري داخل الأنسجة الناتج عن إشعاع الليزر إلى زيادة معدلات القتل بسبب تلف البنية الداخلية.

*Email: s_n_r83@yahoo.com

Introduction

The subject of biophysics is interdisciplinary and covers various fields of biology and physics. Scientists and specialists in this subject strive continuously on the most important aspects of biophysics, which resulted in the growth of various technologies and applications in this field [1]. One of the most important of these technologies is laser because of its wide applications in various fields of life [2], also it has been widely used for many biological purposes [3].

There is worldwide suffering from health and economic risks caused by insects, whether in quantity or quality when attacking storage grain and materials [1]. Insects identification and mitigation are critical to the health of humans and crops worldwide. The insects' ability to move and adapt to human control methods makes this difficult [4]. Ant colonies contain thousands of ants. They are non-vertebrate animals and are the most complex in terms of morphology, organ functions, behavior, and social organization, but morphologically they are the most evolved Hymenoptera [5]. Different ant species often exhibit varying behavioral characteristics as well as different feeding preferences [6]. Ants have a great role in ecosystems, as they can be predators, eaters of grains, weeds, debris, and litter [7]. Soil-living ants' colonies size varies depending on the types of ants [8].

Ants adapted to an urban environment cause inconvenience, such as falling into our drink, for example, and this may be a small problem, but it may cause a serious public health problems because ants are creatures that can develop multiple interactions with animals, plants, fungi and bacteria because they have many parasitic and mutual relations. Because of this, they are known to be a potential threat as carriers of pathogenic microorganisms found in our body, such as (*Staphylococcus*, *Klebsiella*, *Acinetobacter Streptococcus*, *Enterococcus* and *Enterobacter*). According to a study of ants as a vector for the spread of bacterial resistance in university hospitals, ants do not only carry bacteria but also act as a major route of dispersion of drug resistance in intrahospital ambiance [6].

Control of disease-carrying insects is of critical importance to global health. Health care and food resources are under global pressure due to these pathogens [9]. Chemical, biological and mechanical methods are used to control insects. But without knowing the exact location of insects, the use of these techniques remains ineffective in addition to its high cost [10]. These techniques have undesirable effects because of the use of toxic chemicals or biological agents [9]. One of the main disadvantages of chemical pesticides is that their effectiveness can decrease due to insect resistance to the active ingredients. This will require the increase of the concentrations of the active ingredients of the pesticide which is harmful to humans. For this reason, many researchers have begun to search for alternative ways, that are environmentally friendly and safe, to control insects in the hope of eliminating these diseases. Several studies investigating the extermination of small insects such as mosquitoes, aphids, and whiteflies using laser systems have been conducted. Some researchers have developed a laser system to determine the different wavelengths, intensities and pulses needed to kill a type of insect [4]. In this work, Nd:YAG laser was used to find out the effect of its radiation on ants (*Camponotus consobrinus*).

Theoretical

Lasers have been used in biology and medicine either as a diagnostic tool or for irreversible change in the cell or living tissue. Due to its many properties, it has been used in a variety of technologies taking advantage of its interaction with materials and the rapid changes it causes. This technique is also used in studying the function of the cell after the effect of laser on a specific area of the cell, and the mutual effect between light and matter, then the energy resulting from this effect can be directed precisely from the use of biological materials [2]. he penetration depth of laser beam inside tissue is related to its wavelength, e.g. IR laser has higher tissue penetration, followed by the visible spectrum laser in the red region.

Several studies have demonstrated the catalytic effects of laser beam at the molecular and cellular level [3]. Rays that reach living tissues can be reflected, scattered, absorbed, or transmitted to the surrounding tissues. The mechanism of ray reflection, absorption, refraction and propagation within the tissue can be illustrated in Figure 1, [1].

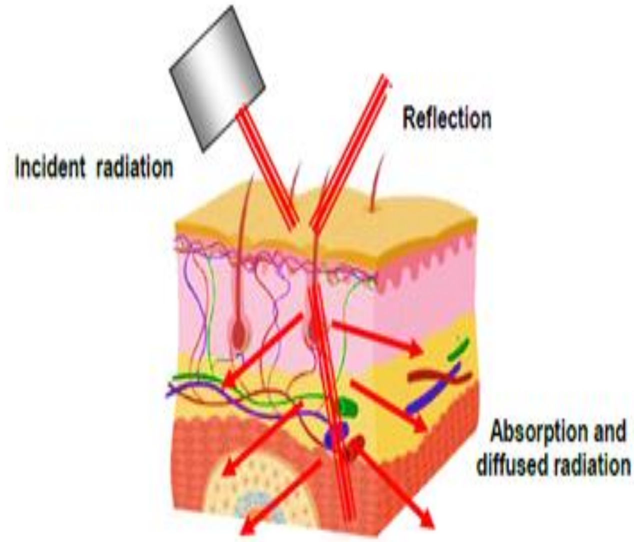


Figure 1-Mechanism of I\interaction laser with the tissue

The most widely used laser types to affect tissues are CO_2, Nd:YAG, Er:YAG and diode laser. Figure 2 shows the rate of approximate absorbance curves for various tissue components [11].

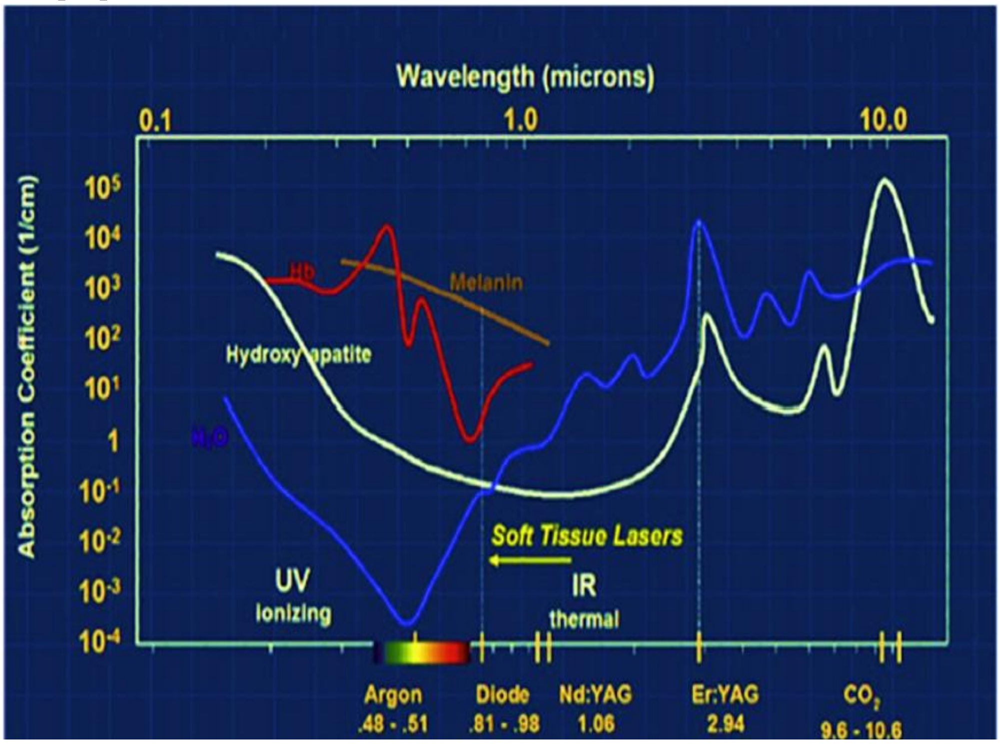


Figure 2-Approximate net absorption curves of various tissue components

Nd:YAG laser can be used in various applications taking advantage of its interaction with materials and the rapid changes it causes. The interactions of laser with tissue are emphasize in two effects : the optical effect and the thermal effect the first depends on the wavelength of the laser used,the extent of its interaction with the tissue and its compatibility with it in terms of absorption. While the second effect is the direct effects of the thermal energy that the laser produce. These effects are effective and fast due to the large increase in temperature affecting small areas [1]. In order for laser to have an effect on the material it must be absorbed by it. [12]. This absorption is essential for the reaction of laser with the material. It is the primary source of energy within the material and is represented by laser beam emitted from the source [13]. The basis of the process of laser interaction with matter includes the absorption of the laser energy and its distributing inside, which will result in heating the material. The falling beam pulse warms up the target material quickly, resulting in waves of stress in the irradiated target [1]. The thermal interaction between laser and the material occurs as a result of the ability of the material to absorb the laser energy and the amount of changes that can occur from the thermal properties, evaporation and melting [14]. Laser parameters affecting its interaction with the fabric are wavelengths, exposure time, energy intensity, spot size and exposure distance. The study of the interaction of electromagnetic radiation with matter in a physical system has led to significant improvements in laser technology [15].

Laser has different effects on biological tissues and cells. The respiratory chain of mitochondria in a biological cell is affected by laser, also it changes the electrical potential of cell membranes affects their selective transmittance to some ions, or the activity of some enzymes may increase. It may also double the DNA and lead to collagen production, cell proliferation or alteration of their motor properties [3]. The characteristics of the tissues as well as the properties of laser source are the two factors that depend on how laser affects the tissues themselves [16]. Coagulation, evaporation, solubility and carbonization can be distinguished depending on the highest value of tissue temperature and duration of heating. Nd:YAG laser beam has a large depth of optical penetration, hence, in dermatology, this laser gives major indications of some diseases in skin. Some thermal effects of laser inside living tissue are illustrated in Figure 3, [3].

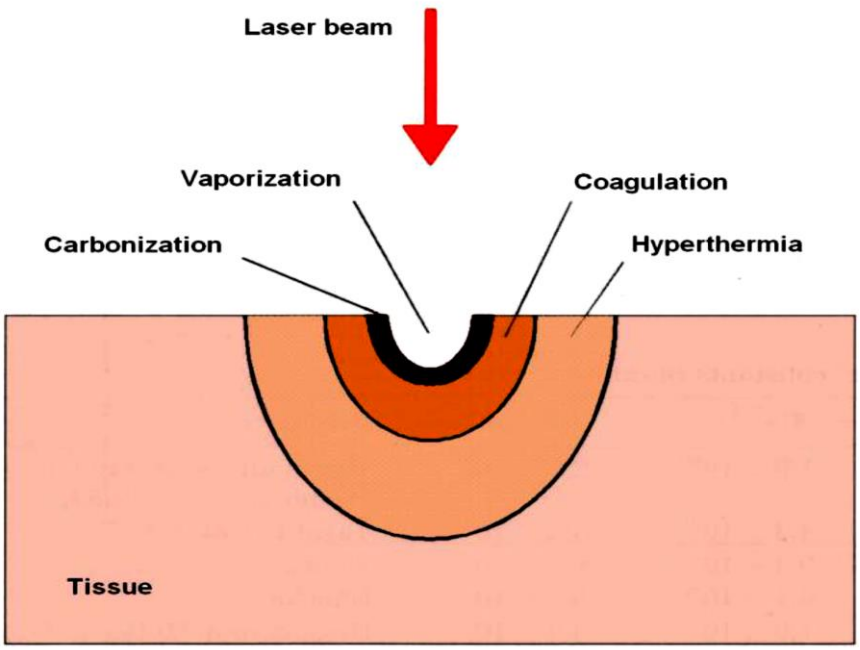


Figure 3- The location of laser thermal effects inside biological tissue

Experimental

Samples of domestic ants were collected and placed in petri dishes. They were divided into six groups with two petri dishes per group. In this work, the pulse laser Nd:YAG of wavelength (1.064 µm) was used. The collected ants were placed at (10 cm) distance from the laser source. Some parameters of the laser such as energy and irradiation time were changed and their effect on the ants were monitored. All six groups were irradiated with laser of energies (300, 320, 340, 360, 380, and 400 mJ) and with two irradiation time periods (15 sec) and (20 sec). Then the external shapes of the ants were examined by a microscope with a zoom camera (Sony) (12 MP). All the samples were examined after (12, 24, 48, and 72 hours).

Results & Discussion

Figure 4 shows the type of ants whose external shape changes were studied, in addition to the killing rates resulting from laser irradiation with specific energies and time periods.

Figure 4-Ant insect

- Laser Effect On The External Shape Of Ant:

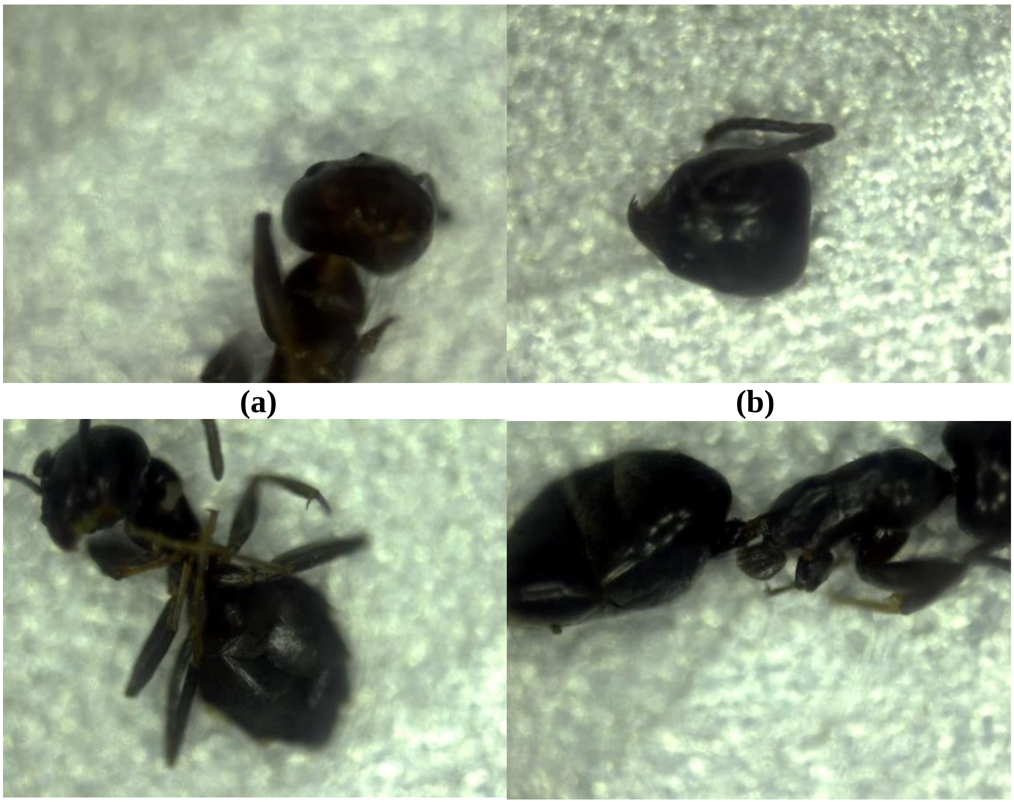
The results showed clear distortions of the ants after being exposed to laser beam of all energies, which was very clear at the highest energy (400mJ) and the longest exposure time (20sec). These changes included:

1) loss of sensor horns: as shown in Figure (5-a), the percentage of sensor losses reached 95% of the ants.

2) color change: Figure (5-b) shows the upper region of the head showing a change in the color of the outer layer with high percentage, as well as, loss of one of the sensor horns.

3) broken legs: as shown in Figure (5-c), and this happened in 70%.

4) Figure (5-d) shows the occurrence of shattering and erosion in the chest and abdomen areas which was in about 70%.



(a) (b) (c) (d)

Figure 5-Ant insect exposed to laser show the changes in: (a): sensor horns, (b): head, (c): color and legs, (d): chest and abdomen

- **Laser Effect On Ant Life:**

The averages of death percentages of ant are showed in Table (1) after laser treatment.

Table 1-Averages of death percentage of ant insect treated by laser

Irradiation energy (mJ)	Duration of irradiation (sec)	percentage of death after 12 hours (%)	percentage of death after 24 hours (%)	percentage of death after 48 hours (%)	percentage of death after 72 hours (%)
300	15	16.66	30	43.33	50
	20	23.33	45.5	50	68.5
320	15	25	45.5	55.5	58.5
	20	30.33	57.5	60.5	70
340	15	30.33	55.5	60.66	70.5
	20	55.5	66.66	73.33	75.5
360	15	40	58.5	73.33	83.33
	20	60.66	68.5	80	83.33

380	**15**	**55.5**	**60.66**	**83.33**	**85.5**
	20	**63.33**	**70**	**88.5**	**90**
400	**15**	**55.5**	**73.33**	**90.5**	**93.33**
	20	**73.33**	**75.5**	**93.33**	**95.5**

The death percentages shown in Table 1 indicate some differences of the laser effect on ants life. The results showed that mortality increases slowly at low laser energies and short irradiation times. Followed by a gradual increase in mortality rates when the energies and the time of irradiation was increased, as in Figure 6. After 24 hours of treatment (Figure 7), mortality percentage was higher and mortality was very clear for all energies and irradiation times. The death rates were higher after (48 hours) after treatment has passed as in Figure (8). I It was more than (95 %) after (72 hours), when the irradiation power was (400mJ) at 20sec of irradiation time., as shown in Figure 9.

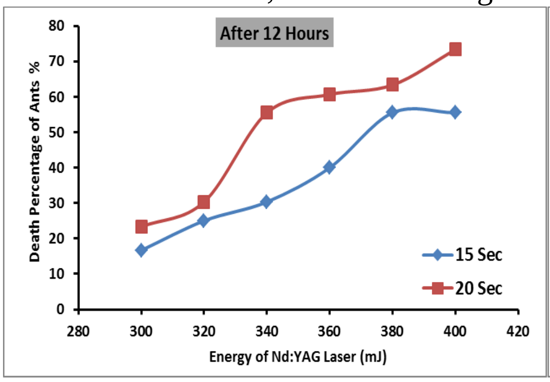


Figure 6- Death percentage of ants after (12 hours) of laser treatment

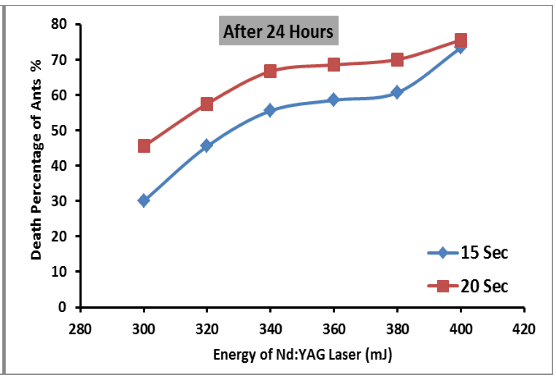


Figure 7-Death percentage of ants after (24 hours) of laser treatment

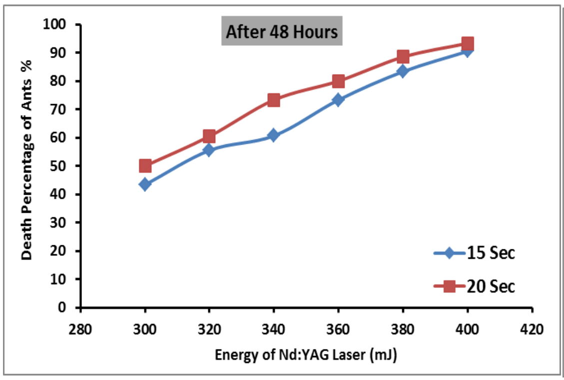


Figure 8-Death percentage of ants after (48 hours) of laser treatment

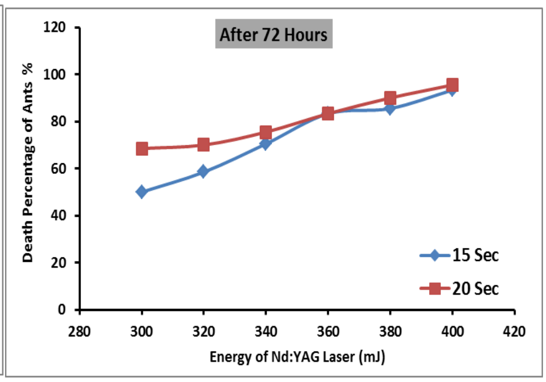
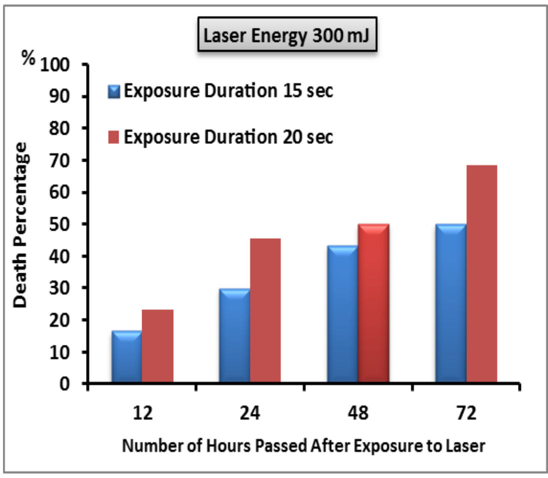


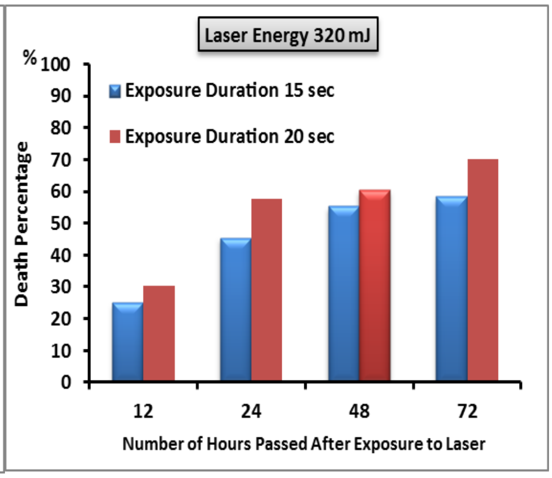
Figure 9-Death percentage of ants after (72 hours) of laser treatment

The obtained results are similar to those of previous studies [1,3]. It is clear that laser has a real and fast effect, especially at high energies and long exposure time.

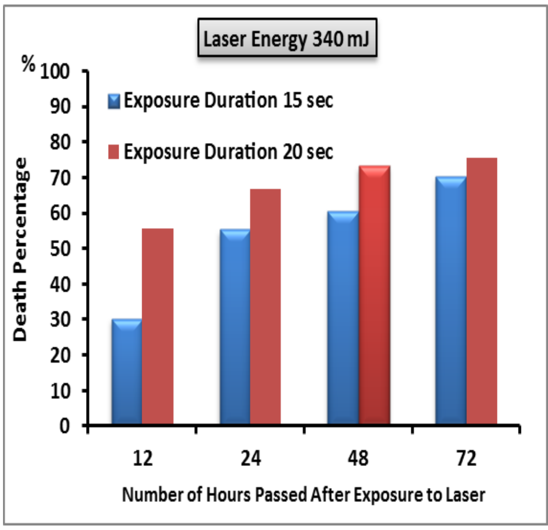
Exposure to laser energy causes the surface area of the insect to heat up over time. The resulting sharp changes in temperature cause direct effects on ant, such as dehydration of the body due to water loss and misalignment of gases inside it. The insect body tissues perform rapid breathing that leads to a high energy exchange. The proximity of the laser source to the insect led to a significant increase in the energy of laser per unit area of the insect body, which led to an increase in temperature in a very short time, leading to severe harm to the insect internal frame as well as to its appearance. Figure 10 shows the change of the death rates of ants based on the passage of the number of hours after the laser treatment according to the exposure energies.



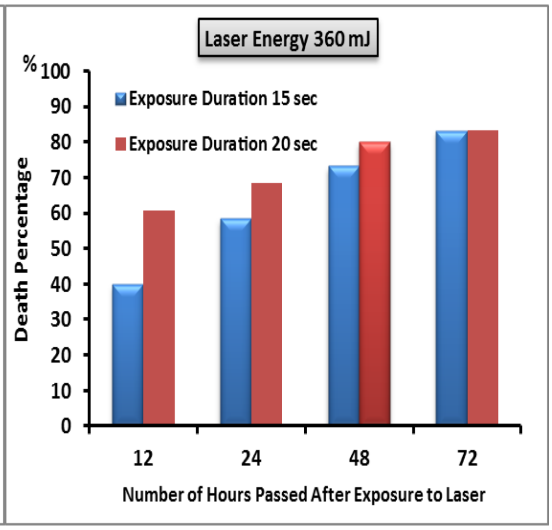
(a)



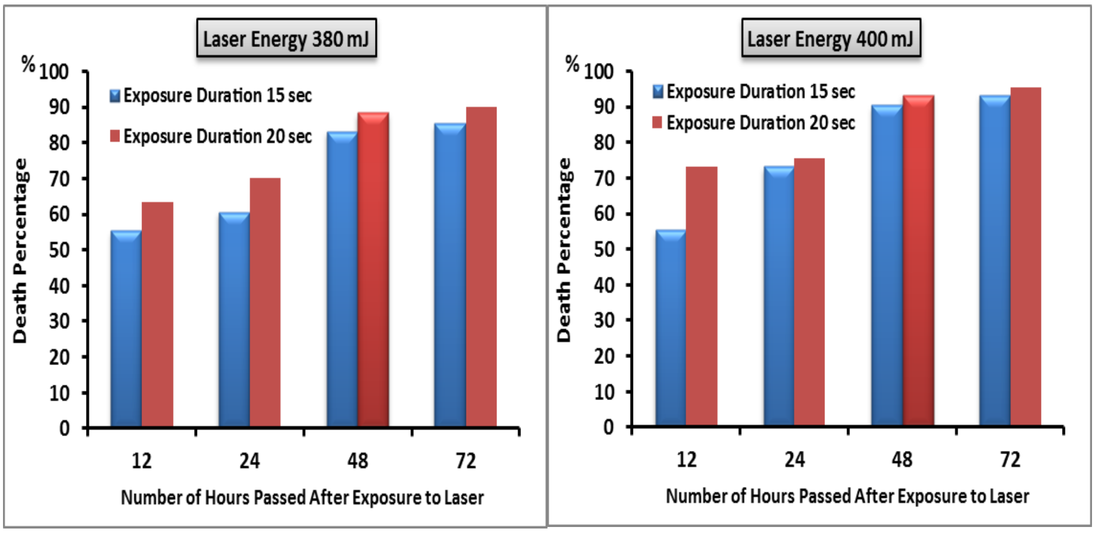
(b)



(b)



(d)



(e) (f)

Figure 10-Death percentage of ants based on the passage of the number of hours after the laser treatment: (a): 300 mJ, (b): 320 mJ, (c): 340 mJ, (d): 360 mJ, (e): 380 mJ, (f): 400 mJ

Conclusions

Nd:YAG laser made huge changes in the ant exterior in (shape, color, and deformities), as well as, causing death of the insect. Laser can be an alternative to toxic pesticides, because it is an economical, effective, non-toxic and a safe source that gives high heat without the need for high energy to work. In order for the laser beam to be effective, the distance between the laser source and the sample must be small so that the energy of laser is focused over a small spot of surface, thus the effect will be large.

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