

Irradiation Effect of Continuous Diode Laser on Locusts and Host Plants

Mingyin Yao¹, Muhua Liu¹, Jinhui Zhao¹, Qiang Zhou²

¹ College of Engineering, Jiangxi Agricultural University, Nanchang, Jiangxi Province, China

Email: mingyin800@126.com, suikelmh@shou.com, zjhxiaocao@sina.com

² College of Engineering, China Agricultural University, Beijing, China

Email: zq@cau.edu.cn

Abstract—To explore new physical means in controlling locusts, semiconductor continuous diode laser (wavelength 808nm, power 2W) was used to evaluate the effect of laser irradiation on locusts (*Locusta Migratoria Manilensis*) and host plants (fresh Gramineous Plant Green Bristle Grass). At different distances and time, the heads of I-III instar nymphs and VI-V instar nymphs were irradiated, and the death rate was observed two hours, two days and three days after treatment; the leaves and stems of host plants were irradiated, and the growth state was observed. The results indicated that the locusts were killed when power density nears the tissue's thermal damage threshold. Besides, the death rate was higher along with longer irradiation time, greater power density (nearer irradiation distance) and younger instar nymphs. At distance 3cm and time 2s, the death rate of I-III instar nymphs was 80% 3 days after irradiation, and the gross growth state of host plants kept well. So, locusts especially before III instar nymphs can be killed easily and host plants are not influenced if only suitable laser energy and wavelength are chosen. In this work, the results proved it's feasible to control locusts by laser.

Index Terms—laser irradiation; locust plague control; locusts; host plants

I. INTRODUCTION

Locust plague is one of the most overwhelming human disasters, and has ravaged many crops all over the world. Treatment by traditionally prevalent means is synthetic chemical insecticides; the pesticides have undesirable side effects on environment [1]. With the increase in environmental awareness, biological control has been examined over the last decades in countries such as Australia, China, America, and South Africa [2]. But biological pesticide has high cost, and has several days delay between spraying and killing locusts. To conserve energy and protect environment, in this way, we put forward physical means in controlling locusts by laser. Laser light has several unique characteristics that differentiate it from other light sources. These key properties (monochromaticity, coherence, collimation, and high power) are the basis for the peculiar applications of laser energy [3]. Laser irradiation can represent an excellent tool for use in medicine and biology since the

development of the ruby laser in 1960. For laser killing locusts, in 1980, a US physicist and his Soviet counterpart proposed that advanced military lasers might be used to help rid Africa and the Middle East of swarms of locust, and the fallen little corpses would be good fertilizer [4].

Whereas, it's better time to control locusts before third-instar nymphs. Locusts' wingbuds become distinct, and the ability of jump and feeding increases rapidly after third instar [5]. The nymphs feed on mostly fresh gramineous plants. When laser irradiation is chosen in controlling locusts, it's necessary to consider that locusts are killed and host plants aren't damaged. Furthermore, the fundamental of laser control locusts is based on laser-tissue interactions. Laser light can interact with tissue in four key ways: transmission, reflection, scattering, and absorption. Thereinto, laser light absorption by specific tissue targets is the fundamental goal. According to the Grothuss-Draper law, light must be absorbed by tissue to produce an effect in that tissue. The absorption of the photons of laser light is responsible for its effects on the tissue. The components of the tissue that absorb the photons preferentially depend on wavelength. These light-absorbing tissue components are known as chromophores. Absorption of energy by a chromophore results in conversion of that energy into thermal energy. Accordingly the significant thermal damage to tissue comes into being. For locusts and host plants, the difference of tissue's biology characteristics results in the difference of absorption to same light wavelength. Based on laser-tissue interaction, the efficiency of bringing heat is higher in near infrared wavelength. So the 808nm continuous wavelength semiconductor laser was chosen to compare the effect of irradiation on locusts and host plants. The study serves as basis for further investigation on the novel physical means by laser to control locusts.

II. MATERIALS AND METHODS

A. Locusts

Locusta Migratoria Manilensis of different instar nymphs were chosen to observe the activity and death rate after treatment. Locusts were maintained in the nylon cloth cubic framework under 28 °C -35 °C conditions throughout the study. Water and feed were provided.

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**Corresponding author: Qiang Zhou(1958-), Ph.D, Professor, China Agricultural University

B. Host Plants

Fresh Gramineous Plant Green Bristle Grass was used to observe the growth state after treatment. It was maintained at 28°C-35°C conditions in a plastic basin.

C. Laser Device

The laser used in this study is a high-power semiconductor diode laser with type 86807305. The power density and beam area were computed at different distances from output light pane. The laser’s computing parameters are shown in Table 1.

TABLE 1 COMPUTING PARAMETERS OF TYPE 86807305 DIODE LASER

Irradiation distance(cm)	0.5	1	1.5	2	2.5	3
Beam area (cm ²)	0.006	0.024	0.054	0.096	0.150	0.216
Power density(W/cm ²)	332.69	83.17	36.97	20.79	13.31	9.24

D. Statistical Analysis of the Death Rate of Locusts

The heads of *Locusta Migratoria Manilensis* I - III instars and IV - V instars nymphs were irradiated at different time and distances. Experiment individual was placed in the size 0.05m×0.04m×0.02m plastic box when irradiating (Fig.1). The irradiation and comparison groups were placed in nylon cloth cubic cage separately and fed on flesh *Green Bristlegrass Herb* in the same conditions, and the death rate was observed at the two hours, two days and three days after treatment .Thereinto, the number of locusts was 20 each group.

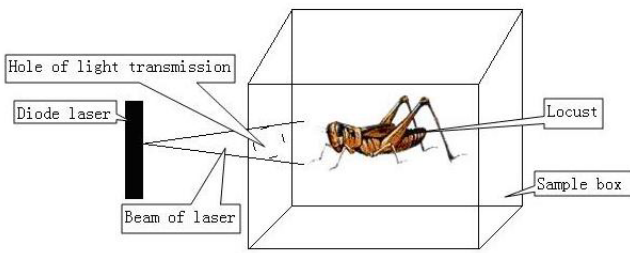


Fig.1 Sketch map of laser irradiating locust

E. Observation of the Green Bristle Grass’ Growth State

The leaves and stems of fresh Gramineous Plant Green Bristle Grass were irradiated. Hereinto, leaves were irradiated at 1cm distance from the output light pane and 30s irradiation time; the growth state was observed three days, seven days and 30 days after treatment. At 1cm, 2cm, 3cm and 4cm distance, leaves were irradiated 5s respectively; the growth state was observed seven days after irradiation. The stems were irradiated at 1cm distance and 30s time, the growth state was observed seven days after irradiation. The gross growth state was observed 30 days and 40 days after irradiation.

III. RESULTS

A. Death Rate of Locusts

Locusta Migratoria Manilensis nymphs were divided into I -III instars and IV - V instars. The heads were irradiated at different time and distances, and the death rate was observed at the two hours, two days and three days after treatment. The results of experiment were noted (Table 2).The statistics of death rate were shown (Fig.2), and effects of irradiation time and distance on death rate see Fig.3.

TABLE 2 THE DEATH RATE’S EXPERIMENTAL RESULTS OF LOCUSTA MIGRATORIA MANILENSIS

treatment	Irradiation Groups (s)	Irradiation Instars			Mortality after distance (cm) time	
		2 hours	2 days	3 days		
1	I -III	1	1	1	30%	50%
2	I -III	1	2	2	40%	60%
3	I -III	1	3	3	100%	100%
4	I -III	2	1	1	0%	50%
5	I -III	2	2	2	10%	60%
6	I -III	2	3	3	100%	100%
7	I -III	3	1	1	0%	20%
8	I -III	3	2	2	20%	50%
9	I -III	3	3	3	30%	60%
10	IV-VI	1	1	1	0%	20%
11	IV-VI	1	2	2	30%	40%
12	IV-VI	1	3	3	100%	100%
13	IV-VI	2	1	1	0%	0%
14	IV-VI	2	2	2	0%	10%
15	IV-VI	2	3	3	50%	100%
16	IV-VI	3	1	1	0%	0%
17	IV-VI	3	2	2	0%	0%
18	IV-VI	3	3	3	20%	30%
Comparison 1	I -III	no	no	no	0%	0%
Comparison 2	IV-VI	no	no	no	0%	0%

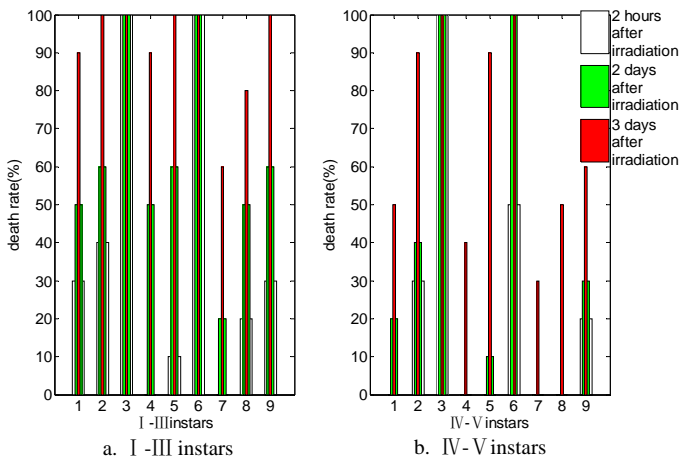


Fig.2 Stat. of death rate

The results indicate distinctly that power density nears the tissue’s thermal damage threshold, the locusts were killed. The death rate of locusts was higher along with longer irradiation time, greater power density (irradiation

distance) and longer time after irradiation, and I -III instars had higher death rate than IV -V instars at the same conditions (Table 2 and Fig.2). The death rate decreased with the increasing irradiation distance; the death rate increased with the increasing irradiation time (Fig.3).

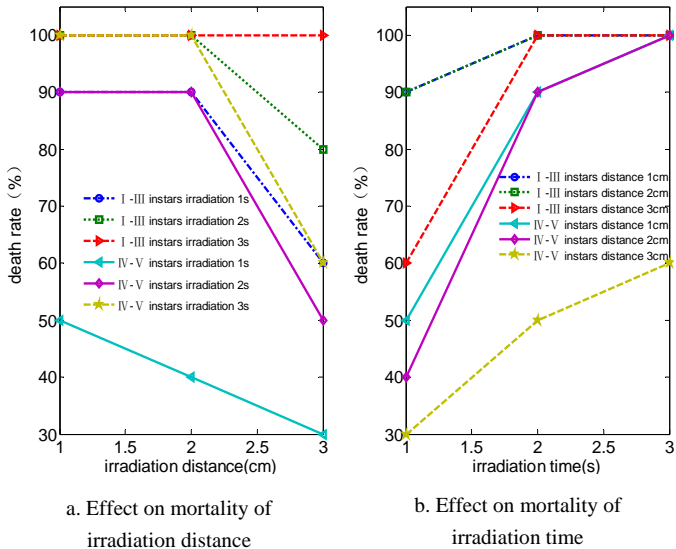


Fig. 3 Effect on death rate of irradiation time and distance

B. Growth State of Green Bristle Grass

The leaves of fresh Gramineous Plant Green Bristle Grass were treated at 1cm distance from the output light pane and 30s irradiation time; the growth state was observed three days (Fig.4(b)), seven days (Fig.4(c)) and 30 days (Fig.4(d)) after irradiation. At 1cm, 2cm, 3cm and 4cm distance, leaves were irradiated 5s respectively; the growth state was observed seven days (Fig.5) after irradiation. The stems were irradiated at 1cm distance and 30s time, the growth state was observed seven days (Fig.6) after irradiation. The gross growth state was observed 30days (Fig.7 (b)) and 40 days (Fig.7(c)) after irradiation.



Fig.4 Leaves were irradiated at 1cm and 30s



Fig.5 Leaves were irradiated at 1cm, 2cm, 3cm, 4cm and 5s separately

The above results show that the leaves and stems of



Fig .6 Stems were irradiated at 1cm and 30s



Fig .7 Gross growth state of host plants

fresh Gramineous Plant Green Bristle Grass were not influenced after irradiation. The plants neared maturity period 40 days after irradiation (Fig.7(c)), and the gross growth state kept well.

IV. DISCUSSIONS

The above experimental results indicate that the locusts were killed When power density nears the tissue's thermal damage threshold, and All treated locusts were killed 2 hours after irradiation at distance 1cm and time 3s (Table2). Whereas, at distance 1cm and time 5s, the growth state of treated leaves of fresh Gramineous Plant Green Bristle Grass were not damaged; and at distance 1cm and time 30s, the treated stems were not influenced.

For *Locusta Migratoria Manilensis* and Gramineous Plant Green Bristle Grass, the reflection spectrums are shown in Fig.8 and Fig.9 [6]. Absorption spectrum of plants to light sees Fig.10. Obviously, in 808nm wavelength, absorption of plants to light nears lowest level. In addition, locust's body has abundant melanin which belongs to high absorption media in near infrared range. And fresh plant has more 80% water which belongs to high scattering and low absorption media [7].

So, *Locusta Migratoria Manilensis* has higher absorptivity, vice versa, Gramineous Plant Green Bristle Grass has lower absorptivity in 808nm wavelength. Besides, the leaves of plant is thinner than locust's tissue, which ensures laser light transmits outside plant's surface but inside locust's tissue. And the reflection effect of laser in plants' stems is higher than in locust's tissue. Thereby, laser damages to locust and not to plant.

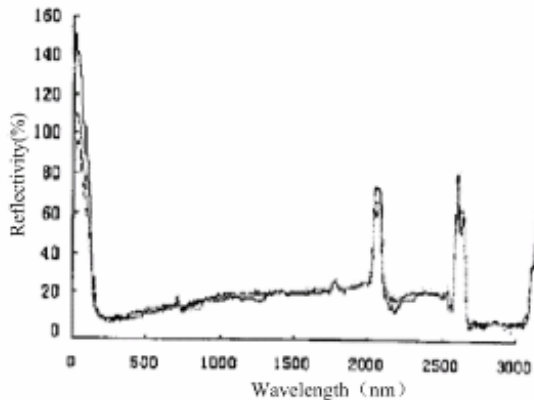


Fig.8 Reflectivity spectrums of locusts

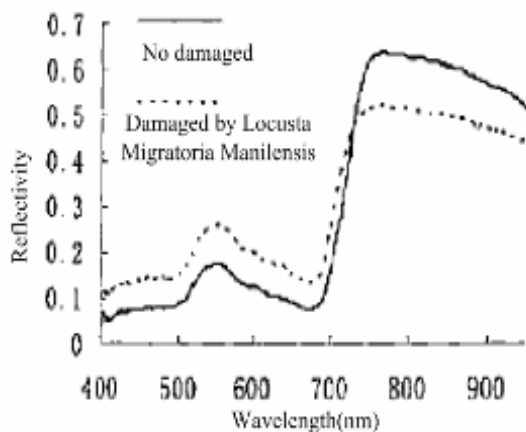


Fig.9 Reflectivity spectrums of Green Bristle Grass

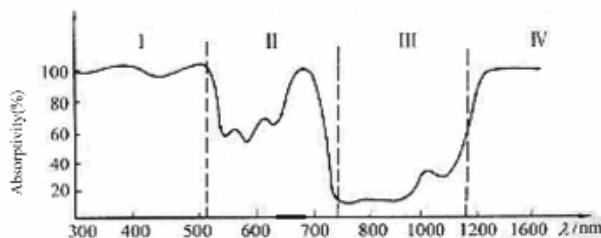


Fig.10 Absorption wavelength of plants to light

In this work we have observed the effect of 808nm laser irradiation on *Locusta Migratoria Manilensis* and fresh Gramineous Plant Green Bristle Grass. In table 2, 80% of treated I -III instars nymphs were killed within 3 days after irradiating heads at distance 3cm and time 2s. At the same condition, whether the leaves or stems were irradiated, the growth state of fresh Gramineous Plant Green Bristle Grass kept well.

Because laser's directional properties and selective characteristics are already well known, from the present study it is possible that 808nm laser control locusts and no damage to plants. It can be suggested that laser irradiation was efficient in novel physical means to control locust. The insights may be useful in the development of new strategies for the treatment of locust plague by using laser irradiation as a tool to be combined with vehicle mechanisms.

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