INFLUENCE OF GASEOUS LASER IN CONTINUOUS-WAVE AND PULSE REGIMES ON BIOMATERIAL CHARACTERISTICS

by

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Aromatic plants and laser beam wavelength in the red range of visible spectra (623.8 nm), most commonly used for treating plant species, were selected. As there is not much information in the references, it is necessary to set a scale with qualitative and partially quantitative evaluations of the results. Specimens of thyme seed (Thymus vulgaris) were selected as aromatic plants for studying the effect of low-power lasers on plant development, and continuous He-Ne laser, with irradiation times in the range of minutes.

Key words: laser, biomaterial, interaction

INTRODUCTION

The impact of laser on aromatic plants can be analyzed from multiple perspectives. Changing morphological characteristics raises many questions where multidisciplinary work with pharmacy and biology is required, but the first approach requires a precise metrological approach since the definition of dose of real beam intensities, exposure geometry, and photometric/radiometric conditions with bio-systems require precise parameters and approaches. For both rare plant species and widespread species, these studies can have significant economic consequences.

The change of properties of organic and inorganic materials, including biosystems, can be caused using elion techniques. The theoretical base for the change of various properties of a material is according to selected beam tied to certain scientific disciplines. Since a developed classic theory explaining interaction have existed, some beam techniques connected to nuclear technique, electronic optics, bioacoustics, and the interaction of electromagnetic radiation with material, belong to problems that have had their decades-long tradition [1-3]. The use of lasers for parameter modification is modeled differently according to the type of material (organic, inorganic, and biosystem), and given that it is a field of research that has spanned more than half a century, it has brought many unsolved tasks [4, 5]. For living systems, this is the terminology of biomodulation, biostimulation at the tissue or single-cell level. A range of possible results of certain exposure to laser beams in different modes of operation focused/unfocused for specific conditions: quantum generator and system – the material exposed to the laser beam, is very wide-ranging from destruction to the desired change in material properties or processes occurring at living organisms [6-12]. Modern research is looking for quantification as close as possible to real conditions so that more and more requirements are set for the metrological approach to the operating parameters that determine the desired/undesired results. A note should be made that from a basic point of view, the material needs to be seen through changes in electrical, magnetic, and dielectric properties, and that a defined impedance definition is required – *i. e*., with response functions, where specific electrical conductivity σ, magnetic permeability μ and dielectric permittivity ε. The definition and determination of impedance is a complex issue not only for biosystems but also for complex semiconductors,

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multilayer films, *etc*. and the question arises of how to approach the modeling of a particular solid-state form with complex composition.

The question of thresholds separating certain ranges of possible events/processes is one of the most important question that follow the issue of contact, coating to the threshold for an associated electric field that will lead to positive or negative results of exposure to a focused/unfocused coherent radiation/operating beam. Enrichment of experimental work always provides reliable conclusions, however, when evaluating results, one should always take into account the position of the treated systems on the globe and the time when irradiation takes place, even in well-controlled laboratory conditions. In addition, many of the references dealing with irradiation of major plant families: wheat, corn, beans, spinach, nettle, alfa-alfa, *etc*. need to be enriched with new plant families. The development of new quantum generators is also seeking information about dose responses up to the limit of damage to entities. Another major reason is to improve the efficiency of growing plant species of which aromatic plants are of particular interest [8, 13-15].

This paper deals with one type of aromatic plant Thymus vulgaris (thyme) and quantification of exposure to gaseous lasers in the selected mode of operation. Spectroscopic and morphological analyzes were chosen as quantitative indicators of changes in the sample properties and experiments with selected He-Ne laser types and CO_2, Ar^+:ion, since analysis of results, based on quantitative data acquired by spectroscopy and observation of morphological parameters is a good starting point.

The experiments performed were analyzed by several diagnostic methods. The paper provides guidelines for the selection of other methods that would complete a set of traits of interest for monitoring and suggest further design and conduct of more complex experiments.

MATERIAL AND METHODS

Thyme (*Thymus vulgaris*) is an aromatic perennial herb (half bush). Thyme is sown in early spring, with a sowing depth of 0.5 cm. The plant does not tolerate transplanting. It is harvested after flowering. Crop life is 3-5 years. The crops tolerate drought and frost. The plant is particularly sensitive in the initial stages of growth. Thyme tea is considered medicinal and helps with digestion and rheumatism. Only flowers and leaves are used.

Irradiation of thyme samples was performed using a He-Ne Felas medical LASER HN 12 laser, 12 mW, continuous-wave (CW). The beam was expanded by a collimator. Mirrors are avoided during irradiation, so as not to cause a change in the polarization of the incident beam, fig. 1 [4]. Most commercial laser beams have a Gaussian intensity profile, and the application of the collimator has partially balanced the central and peripheral sections of the beam. This allows the power density transmitted to the sample to be more uniform in all parts of the vessel, holding the grain samples. During the experiment, care was taken to minimize the effects of parasite absorption and reflection.

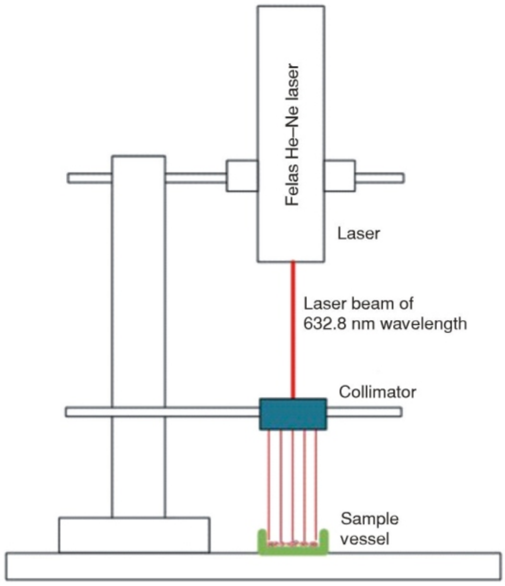

Figure 1. System geometry for irradiation of thyme grain samples

In this paper were presented only samples grouped into four sets with chosen parameters of irradiation and laser type. The first set is a set of control grains, which were not exposed to the laser beam. The second, third, and fourth sets were irradiated with exposure times of 1, 3, and 5 minutes.

RESULTS AND DISCUSSION

Due to the size of the irradiation vessel (grain holder), the number of grains in the irradiated grain groups is much smaller than the number of seeds in the control groups. The seeds were planted in pots of the same size with the same volume of soil and the same type of soil. Every two days, watering was done with 40 ml of water each. From day 16 of planting, 40 ml of water was used each day for watering. The average room temperature was kept at 20-25 °C. Plants were exposed to daylight during the day and artificial lighting during the night. For ease of labeling and referencing, groups will be referred to further in the paper as *e. g.* thyme 3 minutes (MD 3 minute), denoting the plants sprouted from thyme seeds, which were irradiated with a He-Ne laser for 3 minutes before planting. The grains were planted in the soil at a depth of 5 mm.

The seeds germinated after 3 days. The first height measurement starts from day 7. Plant growth data whose seeds were irradiated with a He-Ne laser is presented in tab. 1. On the 19^{th} day of planting, the appearance of a second pair of leaves was observed in samples, namely:

Table 1. Growth of plants whose seeds are irradiated with a He-Ne laser

Thyme		Thymus vulgaris			
		Control group	1 minute	3 minute	5 minute
h [mm]	7^{th} day	33	28	25	25
	11^{th} day	45	35	32	32
	19^{th} day	38*	45	42	44
	37^{th} day	28	31**	55	51

* On the 16^{th} day-most of the control stem plants have dried (from this day, the plants are watered daily with 40 ml per pot).
**On the 30^{th} day-most thyme plants 1 minute dried.

– MD control – no leaves,
– MD 1 minute – leaves (just in the budding),
– MD 3 minute – leaves (visible, clearly expressed) and
– MD 5 minute – leaves (visible, clearly expressed).

With the visual (subjective) observation of the MD samples, it is noted that the leaves of all plants look the same.

During the experiment, key phenomena in plant growth and development were monitored: sprouting, growing (height), and forming a second pair of leaves, fig. 2.

Figure 3. shows the comparative growth of all groups of plants.

The individual growth of plants by groups was fitted by one of the Boltzmann-type modified curves

$$y = \frac{a - b}{1 + \exp^{(x - c)/d}} + e \qquad (1)$$

where *a*, *b*, *c*, *d*, and *e* were parameters obtained through the process of fitting, and shown in figs. 4-6 (e not being an exponent).

This curve corresponds well to the dynamics of plant growth. The fitting graphs of the Boltzmann curve are shown with some fitting parameters in figs. 4-6. Control group of the thyme seed, group treated for 3 minutes and group treated for 5 minutes. The control group and group treated for 1 minute did not correspond ideally to the selected function due to the drying of part of the plants (already shown as reduction of group height), fig. 3.

In our previous work pulse lasers were also used as well as lasers in cw working regime. Generally, if the aim is to cause modulation processes CW laser (atomic

Figure 2. The layout of plants on day 21^{st} from planting sprouted from the thyme; (a) control group seed, (b) group of seed treated for 1 minute, (c) group of seed treated for 3 minutes, and (d) group of seed treated for 5 minutes

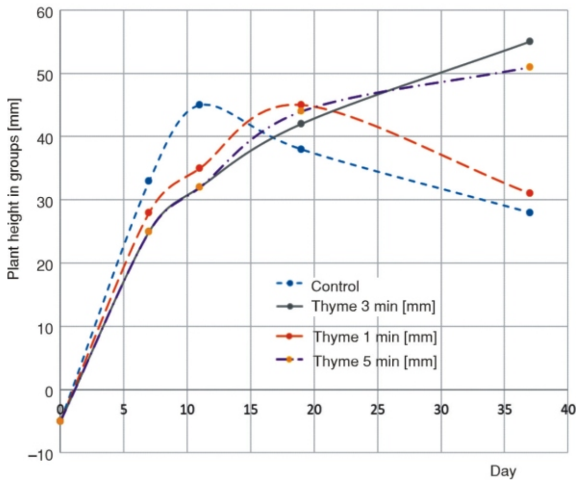

Figure 3. Plant height of thyme groups per day

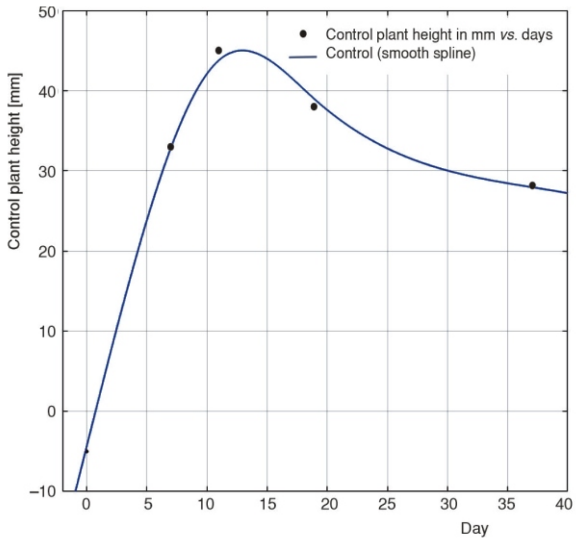

Figure 4. The growth curve of plants sprouted from the control thyme seed

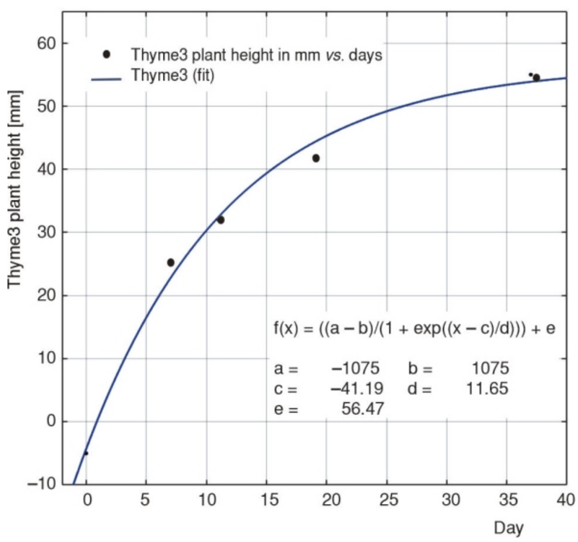

Figure 5. The growth curve of plants sprouted from thyme grains irradiated for 3 minutes with a He-Ne laser

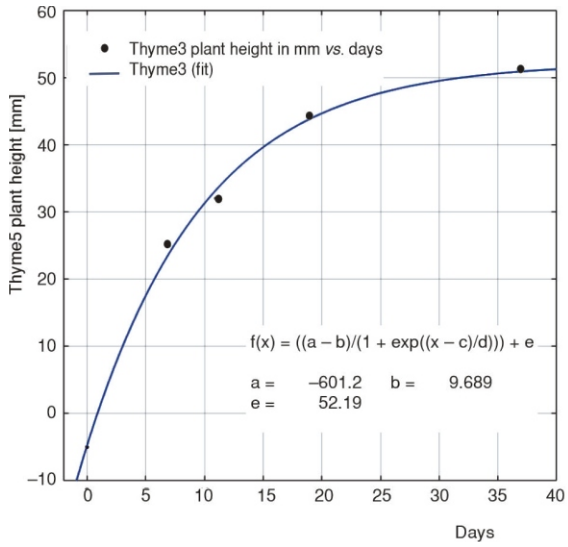

Figure 6. The growth curve of plants sprouted from thyme seeds irradiated for 5 minutes with a He-Ne laser

and molecular) and semiconductor laser were used in mW power range. Namely the range is 1-15 mW (approximately) and related to the size of the sample, the beam was expanded from laser spot size to needed area (10-20 cm^2). Pulse lasers were used to damage the biosamples (ruby laser – leaves). These types of laser would certainly damage the grain selected in this paper.

CONCLUSIONS

For thyme seeds irradiated with the He-Ne laser, plant growth was monitored and morphological parameters were measured. Growth curves were grouped by characteristic parameters. In thyme plants, emerged from control and He-Ne laser treated seed for 1 minute, drying of the groups of the individual plant was observed. This formally led to a decrease in height. The growth of plants sprouted from the control seed was the fastest in the beginning, followed by 1 minute treated seed. Growth of the seed treated for 3 minutes and 5 minutes, was the same, in the beginning. The significant difference between the groups was observed in plants sprouted from the seed of thyme treated with He-Ne. More detailed: plants that emerged from the control seed were the group with the highest height in the beginning (day 10), second was the plant group treated for 1 minute, third the plant group marked as 3 minutes, and finally 5 minutes. Note that the FTIR spectra of these samples of thyme (for all four subgroups – control, 1 minute, 3 minutes, and 5 minutes) have shown that maxima appeared in groups with small wave number shifts.

Despite the large number of theoretical and experimental approaches and data obtained, a large number of specific scenario measurements and studies are still required. Parallel techniques are expected to confirm the results or to point out the diversity of measurement methods of the same values across disciplines.

This only highlights the complexity of theory, calculus, measurement, and software packages (different software) that accompany this problem.

AUTHORS' CONTRIBUTIONS

The theoretical analysis, experiments, and original draft were carried out by S. D. Jevtić, M. Z. Srecković, and N. S. Mitrović. The biological aspects of the paper were done by K. M. Zarubica. Metrological and instrumentational aspects of the paper were the responsibility of V. S. Zarubica, A. J. Janicijević and Z. M. Stević. All authors analyzed and discussed the results.

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УТИЦАЈ ГАСНИХ ЛАСЕРА У КОНТИНУАЛНОМ И ИМПУЛСНОМ РЕЖИМУ НА КАРАКТЕРИСТИКЕ БИОМАТЕРИЈАЛА

У овом раду су изабране ароматичне биљке и снопови ласера таласних дужина (623.8 nm), којима су најчешће третиране биљне врсте. Пошто не постоји много података у референцама, потребно је да се резултати поставе у скалу са квалитативним и делимично квантитативним евалуацијама резултата. Као ароматичне биљке и проучавање утицаја ласера ниске снаге на њихов развој, изабрани су узорци семена мајчине душице (Thymus vulgaris) и континуални He-Ne ласер, са временима озрачавања реда минута.

Кључне речи: ласер, биоматеријал, интеракција