Int. Agrophys., 2011, 25, 403-405

INTERNATIONAL
Agrophysics
www.international-agrophysics.org

Note

Estimation of a laser biostimulation dose

B. Gładyszewska

Department of Physics, University of Life Sciences, Akademicka 13, 20-950 Lublin, Poland

Received December 30, 2010 accepted June 9, 2011

A b s t r a c t. The method for a quantitative determination of the laser irradiation dose supplied to the seed surface during the advance laser biostimulation of seeds prior to sowing is presented. Two, the most common laser irradiation geometries are discussed: the first, when seeds move with a constant speed, and the other where seeds freely fall down with acceleration characteristic for the gravity over illuminated area. Simple equations for calculating a laser irradiation dose are presented.

K e y w o r d s: biostimulation, seeds, laser irradiation dose

The advance laser biostimulation of agricultural seeds prior to sowing is a focal point of interest due to the reported acceleration of seed germination and the positive effect on plant yield (Aladjadjiyan, 2010; Dziwulska *et al*., 2009; Hernandez *et al.,* 2009, 2010; Podleśny 2007; Sujak *et al*., 2009). The laser biostimulation method uses the physical phenomenon consisting of the ability to absorb and store light energy by plant cells and tissues. Seeds have the same ability as they absorb light energy, transform it into chemical energy, store it and use it in growth, later. The supply of energy increases the potential power of seeds positively, influencing the intensity of the physiological processes which take place in seeds during germinating. The process gathered quite important interest and different seeds has been biostimulated and investigated up to now (Chen *et al.*, 2005; Ćwintal *et al*., 2010; Perveen *et al*., 2010; Podleśny and Podleśna, 2004; Rybiński and Garczyński, 2004).

Apart discussion how important is the influence of laser biostimulation, it seems to be essential in such studies to know what is an energy dose transferred to a statistical seed. Surprisingly, most of the works is based on, so called, the multiplication of a basic dose. Unfortunately, even if an experimental set-up, including a technical specification of a laser used is described in detail, the exact basic dose remains unknown. It is therefore crucial to find a method that allows to express real irradiation dose in more scientific way than the above mentioned 'multiplications'. As more as in other scientific areas such procedure is well known. A method for determining dosage (per a unit of surface area) is often applied in nuclear and solid state physics, characterizing, for example, the process of ion implantation by applying the dose as the number of ions per m^2.

The aim of the present work is to propose a method to determine the laser irradiation dose supplied to the seed surface during the advance laser biostimulation of seeds prior to sowing.

The most commonly used methods for a laser biostimulation of seeds are based on similar idea. Seeds move over an area illuminated by a divergent laser beam. In some set-ups seeds move with a constant speed, in others just freely fall down with acceleration characteristic for the gravity. Figure 1

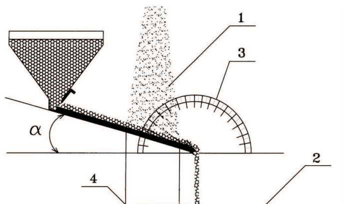

Fig. 1. Set-ups and geometries for a pre-sowing laser treatment of seeds: 1 – divergent laser beam geometry used when a constant seeds speed is chosen, 2 – divergent laser beam geometry used when seeds freely fall down with acceleration characteristic for the gravity, 3 – angle gauge, 4 – illuminated area where seeds are biostimulated with a laser beam, α – angle of inclination of the trough.

*Corresponding author's e-mail: bozena.gladyszewska@up.lublin.pl

© 2011 Institute of Agrophysics, Polish Academy of Sciences

shows schematically such two usually applied systems. In both geometries the movement of seeds is caused by a vibrating trough. As one can see on Fig. 1 a constant speed can be fixed by setting an angle of inclination of the trough. In the set-up a vibrating trough can be used also to dose a limited number of seeds being irradiated in a chosen time interval – however, the next stage of the process in this case is independent on set-up parameters as seeds just fall down over irradiated area. In both systems seeds move along the diameter of the irradiated area (to provide for all seeds as similar irradiation conditions as possible) and therefore the density of differential energy, dE, obtained by the seeds in time dt can be expressed by the following formula:

$$dE = P(x)dt\,, \qquad (1)$$

where $P(x)$ is the density distribution of the laser radiation power in irradiation area. Since the seed movement occurs with speed $v(x) = \frac{dx}{dt}$, Eq. (1) can be written in the following form:

$$dE = P(x)\frac{dx}{v(x)}\,, \qquad (2)$$

where: dx is an increment of route, and $v(x)$ is a speed of seed transfer across irradiation area.

The surface density of energy, E, supplied is expressed as follows:

$$E = \int_{x_0}^{x_k} P(x)\frac{dx}{v(x)}\ (\mathrm{J\ m^{-2}})\,, \qquad (3)$$

where: x_0 and x_k are coordinates representing the beginning and the end of the route of the moving seed through the area under laser irradiation.

Usually, when a divergent laser beam is used the light intensity can be described by a Gaussian distribution. Figure 2 shows an exemplary laser light intensity distribution for systems presented in Fig. 1. If the method of a constant velocity of seeds under irradiation is applied calculations of a dose becomes very simple. The surface density of energy, E, is expressed then as follows:

$$E = \int_{x_0}^{x_k} P(x)\frac{dx}{v} = \frac{1}{v}\int_{x_0}^{x_k} P(x)\,dx\,. \qquad (4)$$

As $P(x)$ is a Gaussian distribution we can write:

$$E = \frac{\sqrt{2\pi}}{v}\,\sigma\, P_{\max}\ (\mathrm{J\,m^{-2}})\,, \qquad (5)$$

where: $P_{\max}$ is the maximum value of power density, and σ is the standard deviation characteristic for a given distribution of power density.

When seeds cross the irradiated area freely falling down calculating a dose becomes more complicated. Taking into account that seeds move with a constant acceleration, g, and that $v = gt$ as well as that $t = \sqrt{\frac{2x}{g}}$, one can write:

$$E = \int_{x_0}^{x_k} P(x)\frac{dx}{v(x)} = \frac{1}{\sqrt{2g}}\int_{x_0}^{x_k} P(x)\,x^{-0.5}\,dx\,, \qquad (6)$$

Unfortunately the integral in this equation cannot be expressed as any elementary function. Therefore, the determination of a dose requires either some effort to calculate this integral (that is still possible) or an acceptance of some simplifications. In principle, we can base on the iteration method, and then:

$$\int_{x_0}^{x_k} P(x)\,x^{-0.5}\,dx \approx \sum_{i=1}^{n} P_i x_i^{-0.5}\,\Delta x = \Delta x \sum_{i=1}^{n} P_i x_i^{-0.5}\,, \qquad (7)$$

where: P_i and x_i correspond to momentary power density values and a position of a seed, respectively; Δx means the increment of a distance.

There is however a possibility to calculate a laser irradiation dose approximating the above integral by a simple combination of linear equations and a Gaussian distribution. The surface density of energy, E, can be then expressed as follows:

$$E = \sqrt{\frac{\pi}{g}}\,\sigma\, P_{\max}\,(a\,\sigma\, x_{\max} + b\, x_{\max} + c\,\sigma + d)^{-1}\ (\mathrm{J\ m^{-2}})\,, \qquad (8)$$

where: $a = -810.0\ \mathrm{m^{-2}}$, $b = 176.2\ \mathrm{m^{-1}}$, $c = 98.8\ \mathrm{m^{-1}}$, $d = 10.9$ and $x_{\max}$ corresponds to a distance of a maximum of the laser intensity from a chute. This approximation allows to calculate a dose of a laser irradiation with an error smaller than 5% for most reasonable set-up conditions: for the distance $x_{\max} \in \langle 0.2; 0.2 \rangle m$ and $x_{\max} \geq 2\sigma$, that in fact fully covers experimental requirements.

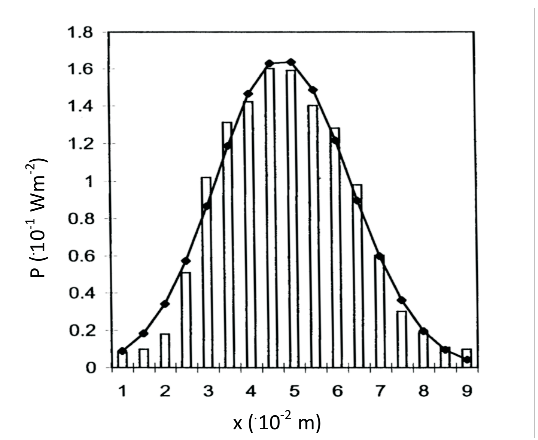

Fig. 2. Distribution of the surface power density of laser radiation fitted with a Gaussian function ($\sigma = 1.56\ 10^{-2}$ m, $x_{mean} = 4.77\ 10^{-2}$ m, $P_{max} = 16.5\ 10^{-2}\ \mathrm{W\ m^{-2}}$).

A laser biostimulation of seeds performed for a constant seed velocity allows a simple and a precise determination of the irradiation dose (Eq. (5)). When the other method is used it seems to be useful to base on Eq. (8). This later equation allows to determine a dose with accuracy better than 95%. A question arise, however, whether such accuracy could be considered as acceptable. First of all one should take into account that a surface of seeds differs considerably (even up to 100% for some spaces). When the energy dose is calculated to the unit of seed surface area, the influence of the statistical scatter of the seed surface area mentioned above is insignificant and such procedure is recommended in this work. However, biostimulated seeds are not uniform 'shields'. Seeds are individual organisms with a complicated and heterogeneous composition. Therefore, estimating dosage expressing it as units of energy per seed seems to be worth of consideration. In such a case 5% error of a dose estimation becomes also unimportant as the accuracy depends mainly on the seed surface distribution. The answer for the question in which way a dose should be defined depends on researchers dealing with the problem and is out of scope of this work. However, in both cases the presented calculations can be useful for a quantitative determination of an applied laser irradiation dose.

CONCLUSIONS

1. Determination of a laser irradiation dose as the multiplication of any basic dose that is quantitatively unknown should not be used when a presowing laser biostimulation is applied and studied.

2. When the constant seed speed geometry of a laser biostimulation is chosen the irradiation dose can be easily and quantitatively given by Eq. (5) in (J m^{-2}) units.

3. When seeds freely fall down with acceleration characteristic for the gravity, it is not possible to represent the exact irradiation dose as any elementary function. It remains however still possible to calculate a dose with accuracy better than 95% by the use of empirical Eq. (8) in (J m^{-2}) units.

4. It seems to be necessary to decide whether a laser dose should be expressed in (J $seed^{-1}$) units. In such case values obtained from Eqs (5) and (8) can be simply multiplied by the seed surface.

REFERENCES

Benavides M., Garnica S., Michtchenko A., Hernández C.A., Ramírez R., and Hernández D., 2003. Stress response and growth in seedling developed from seeds irradiated with low intensity laser. Agrofaz, 3, 269-272.

Chen Y.P., Liu Y.J., Wang X.L., Ren Z.Y., and Yue M., 2005. Effect of microwave and He-Ne laser on enzyme activity and biophoton emission of *Isatis indigotica*. Acta Botanica Sinica, 47, 849-855.

Hernandez A.C., Dominguez P.A., Cruz O.A., Ivanov R., Carballo C.A., and Zepeda B.R., 2010. Laser in agriculture. Int. Agrophys., 24, 407-422.

Osman Y.A.H., El-Tobgy K.M.K., and El-Sherbini E.S.A., 2009. Effect of laser radiation treatments on growth, yield and chemical constituents of fennel and coriander plants. J. Appl. Sci. Res., 5, 244-252.

Perveen R., Ali Q., Ashraf M., Al-Qurainy F., Jamil Y., and Ahmad M.R., 2010. Effects of different doses of low power continuous wave He-Ne laser radiation on some seed thermodynamic and germination parameters, and potential enzymes involved in seed germination of sunflower (*Helianthus annuus* L.). Photochem. Photobiol., 86, 1050-1055.

Pietruszewski S., Muszyński S., and Dziwulska A., 2007. Electromagnetic fields and electromagnetic radiation as non-invasive external stimulants for seeds (selected methods and responses). Int. Agrophysics, 21, 95-100.

Podleśny J., 2007. The effect of seed irradiation with laser and plant desiccation on yielding and quality features of white lupine seeds (in Polish). Acta Agrophysica, 148, 733-745.

Podleśny J. and Podleśna A., 2004. Morphological changes and yield of selected species of leguminous plants under the influence of seed treatment with laser light. Int. Agrophysics, 18, 253-260.

Rybiński W. and Garczyński S., 2004. Influence of laser light on leaf area and parameters of photosynthetic activity in DH lines of spring barley (*Hordeum vulgare* L.) Int. Agrophysics, 18, 261-267.

Sujak A., Dziwulska-Hunek A., and Kornarzyński K., 2009. Compositional and nutritional values of amaranth seeds after pre-sowing He-Ne laser light and alternating magnetic field treatment. Int. Agrophysics, 23, 81-86.

Wilczek M., Koper R., Ćwintal M., and Korniłłowicz-Kowalska T., 2005. Germination capacity and health status of hybrid alfalfa seeds after laser treatment. Int. Agrophysics, 19, 257-261.