1. Stepan KOVALYSHYN[1], 2. Vadym PTASHNYK[1], 3. Bogdan NESTER[1],
2. 4. Oleksiy SHVETS[1], 5. Paweł TYLEK[2], 6. Anna MIERNIK[2], 7. Paweł KIEŁBASA[2]

Lviv National Agrarian University, Lviv-Dubliany, Ukraine (1)
University of Agriculture in Krakow (2)

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Investigation of ultra-low photon emission of rapeseed seeds stimulated in an electric field

***Abstract**. This paper describes the response of rapeseed photon emission to their stimulation by an electric field. The stimulation time and the intensity of the electric field were the experimental factors. In the experiment, the electric field intensity was applied from 1 kV/cm to 3kV/cm in intervals of 0.5 kV/cm and for each of these values the stimulation time was from 5s to 30s in intervals of 5s. In the next stage of the project, field-stimulated seeds were parameterized using the Single Photon Couting (SPC) method. An R4220 photomultiplier was used to record photon radiation. It was found that the highest photon emission was characterised by the stimulation range from 1.8 kV/cm to 2.2 kV/cm, which expanded with increasing time of rapeseed stimulation. However, the amount of radiation increases monotonically depending on the duration of electrical stimulation. At the same time, the effect of changes in the intensity of the electric field is much smaller, which indicates the presence of structural features of the seed material and its selective susceptibility to electromagnetic interactions.*

***Streszczenie.** W pracy opisano odpowiedź emisji fotonów rzepaku na ich stymulację polem elektrycznym. Czynnikami eksperymentalnymi były czas stymulacji i natężenie pola elektrycznego. W doświadczeniu zastosowano natężenie pola elektrycznego od 1 kV/cm do 3kV/cm w odstępach co 0,5 kV/cm, a dla każdej z tych wartości czas stymulacji wynosił od 5s do 30s w odstępach co 5s. W kolejnym etapie projektu nasiona stymulowane polowo były parametryzowane metodą SPC (Single Photon Couting). Do rejestracji promieniowania fotonowego wykorzystano fotopowielacz R4220. Stwierdzono, że największą emisją fotonów charakteryzuje się zakres stymulacji od 1,8 kV/cm do 2,2 kV/cm, który rozszerzał się wraz ze wzrostem czasu stymulacji rzepaku. Natomiast ilość promieniowania wzrasta monotonicznie w zależności od czasu trwania stymulacji elektrycznej. Jednocześnie efekt zmian natężenia pola elektrycznego jest znacznie mniejszy, co wskazuje na obecność cech strukturalnych materiału siewnego i jego selektywną podatność na oddziaływania elektromagnetyczne. (**Badanie ultra niskiej emisji fotonów nasion rzepaku stymulowanych w polu elektrycznym**)*

Keywords: photon emission, electric field, rapeseed
Słowa kluczowe: emisja fotonów, pole elektryczne, rzepak

Introduction

Various methods of pre-sowing seed treatment and conditioning are used to increase the seed yield of many crops. The most effective and environmentally safe methods are those based on the use of physical agents [1]. Among them, pre-sowing seed electromagnetic field stimulation has become widespread. According to [2, 3], this method of pre-sowing seed treatment allows to increase the yield of many crops even by 10 - 30%. The results of many studies have confirmed that thanks to its application in some plant species, the dry matter content, leaf assimilation area and branching of the root system increase. It is also known that the application of high-frequency electromagnetic fields reduces the morbidity of seeds, killing pathogens on their surface, but not affecting the germination process. This treatment increases cellular efficiency and activates intracellular metabolic processes [4]. However, there is still a lack of convincing theoretical and experimental data that would indicate a cause-effect relationship between the modes of pre-sowing electrical stimulation of seeds and their sowing characteristics and yield. The phenomenon of photon emission, which has been discovered in many microscopic as well as macroscopic systems [5,6,7,8], can be used as a measure of the degree of stimulation of biological material. Changes within the photon emission in terms of surface luminescence distribution as well as other luminescence parameters such as kinetics of intensity changes, total intensity, spectral distribution and statistical distribution of the number of pulses changed in the selected time interval are related to biochemical and physiological characteristics, which results from changes in these values under the influence of stress, such as oxidative, radiation and temperature. Also Miernik et al. [9] presented the results of a study on the response of organic matter to electric field stimulation, where significant differences in the number of photons recorded were found between plant drought treated with a constant electric field and drought in which this interaction was not applied. Trzyniec et al. [10] in USL measurements, which they used to parameterize various food products e.g. apples, where the DL delayed luminescence method was used and the sample was illuminated with light of 300 lx and 555 nm wavelength for 600 seconds. In this publication, the delayed DL luminescence method was used, with an illumination time of 60 seconds. It should be noted that the authors of this publication are accredited by the Polish Accreditation Center with the number AB1698 for the procedure of measuring photon emission from biological materials. Moreover, they have a registered trademark Z.493517 allowing them to label products with a certain number of photons. Kielbasa et al [11] tested the feasibility of using ultra-weak luminescence emitted by organic matter and observed that this method provides a practical way to differentiate organic matter in terms of the degree of photon emission.

Material and methods

The purpose of this study was to determine the photon emission of winter rapeseed PR 44D06 by Corteva Agriscience (Fig. 1) that was exposed to an electric field of varying intensity, and using different exposure times of the seeds in question to this electric field.

Sampling was carried out according to a standardized method guaranteeing the representativeness of the study in terms of random variations of the controlled seed parameters. Prior to electrical stimulation, seeds were additionally dried for 24 hours in an oven at 40-45°C until reaching a moisture content of 10%. Stimulation was carried out at the station of direct electric field interaction up to 3 kV. The constant electric field station is equipped with a system of electrodes with adjustable distance from 1 cm to 10 cm [12,13]. It is powered from a single-phase transformer through a voltage multiplier and allows to achieve field strengths from 0 kV/cm to 3 kV/cm (Figure 2). After electrical stimulation, seeds were stored for 24 h in a dark room at 18-22°C. In the next stage of the project, seeds stimulated with electromagnetic field were parameterized by Single Photon Couting (Figure 3). A HAMAMATSU R4220 photomultiplier [5,7] was used to record the photon radiation.

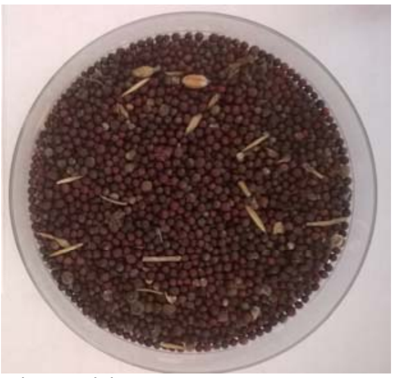

Fig. 1. Research material

Fig. 2. Test stand for electric field stimulation

Fig. 3. Test stand for single photon counting

The light-emitting sample is placed in a measuring chamber. The chamber is thermally stabilized depending on the type of test performed. The light-emitting sample was placed in a light-proof measuring chamber. The light-proof chamber is equipped with a system of targets for periodic obscuration of photons, which results in measuring noise and emission alternately. This is especially important when the intensity of emitted radiation is residual and the recorded signal does not differ much from the measurement noise. The measurement result of ultra-weak photon emission is the absolute difference between the number of photons recorded by the photomultiplier in the light-proof chamber with the material and the number of photons recorded by the photomultiplier in this chamber without the material, according to the relation:

L=A-B [photon],

where: L - the number of photons emitted by the test sample, A - the number of photons emitted by the sample placed ; in the light-proof chamber, B - the number of indications (photons) generated by the empty light-proof chamber.

The duration of recording of photon emission was 30 minutes for each sample. The experiment involved the application of an electric field with an intensity of 1 kV/cm, 1.5 kV/cm, 2 kV/cm, 2.5 kV/cm, and 3 kV/cm, which was applied to rapeseed at time intervals of 5s, 10s, 15s, 20s, 25s, 30s, for each of the aforementioned electric field intensities.

Results

Analyzing the photon emission structure, it was observed that in the case of exposure to an electric field of 1 kV/cm (Figure 4), the highest photon emission was observed for a stimulation time of 15 seconds. Longer stimulation time i.e. exceeding 15s translates into lower photon emission. It should be noted that the photon emission structure at 300 second intervals is similar for all stimulation times. It should be noted that in the structure of the total photon emission from rapeseed was recorded after the shortest time of exposure to the electric field, because it was only 5s. It was noted that extending the time of exposure of rapeseed to an electric field of 1 kV/cm above 20 seconds is not justified from the point of view of photon emission, because it does not bring an increase in this emission.

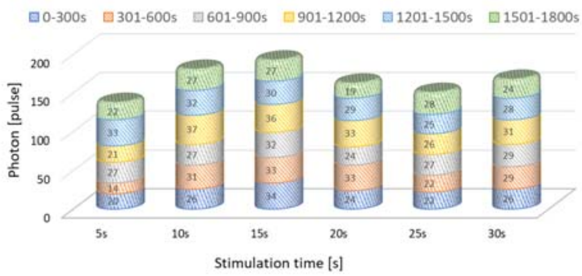

Fig. 4. Photon emission structure in rapeseed after stimulation with 1 kV/cm electric field

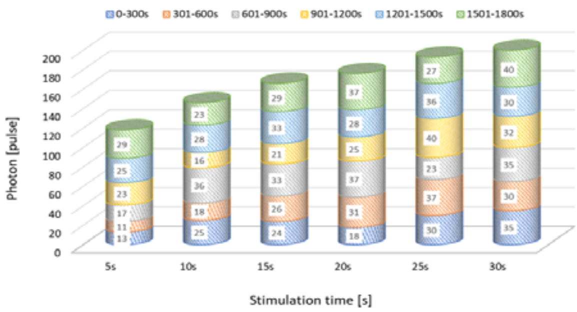

Fig. 5. Photon emission structure in rapeseed after stimulation with 1.5 kV/cm electric field.

In the case of exposure to an electric field of 1.5 kV/cm (Fig. 5), an almost linear relationship was observed between exposure time and the number of photons emitted by rapeseed. Thus, as the exposure time of rapeseed to the electric field increased, the number of photons emitted by rapeseed increased. The highest value was recorded for the time of exposure of the electric field to rapeseed of 30s, while the lowest value of photon emission was found at the shortest time of exposure of seeds to the electric field, which was 5s. In this case, increasing the time of seed exposure to the electric field is justified from the point of view of maximizing photon emission. It should also be noted that the structure of photon emission during the measurements was very even and such a relationship was observed regardless of the length of the time interval for counting individual photons.

Very similar photon emission characteristics to those when rapeseed was exposed to an electric field at 1 kV/cm were recorded when an eclectic field intensity of 2 kV/cm was applied (Fig. 6)

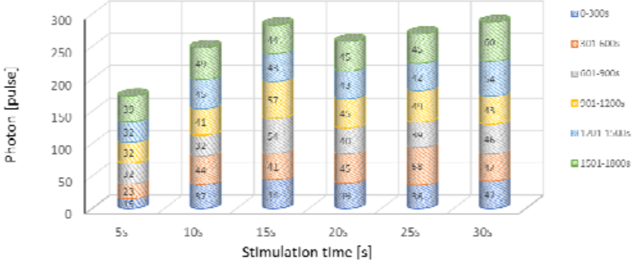

Fig. 6. Photon emission structure of oilseed rape seeds after stimulation with 2 kV/cm electric field

The most effective stimulation time from the pointof view of the number of emitted photons was the interval of 15 seconds, where the highest total number of photons was recorded. The photon emission structure was similar for all stimulation intervals except for the shortest stimulation time of 5s, where the highest photon emission intensity was found between 1501-1800s exposure of the material in the lightproof chamber. Slightly different photon emission characteristics within the analyzed combinations of stimulation time and electric field strength were observed when stimulated with an electric field of 2.5 kV/cm (Figure 7). In this case, it was observed that stimulation times of 10 s and 15 s resulted in the highest and very similar photon emission in this variant of the experiment.

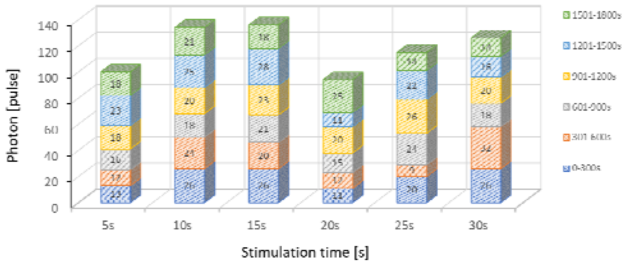

Fig. 7.Photon emission structure of oilseed rape seeds after stimulation with an electric field of 2.5 kV/cm

The lowest photon emission was observed in rapeseed that was stimulated for 20 seconds. Slightly different photon emission characteristics were found at an electric field strength of 3 kV/cm (Figure 8), where the highest photon emission was characterized by rapeseed that was stimulated for 25s and 30s.

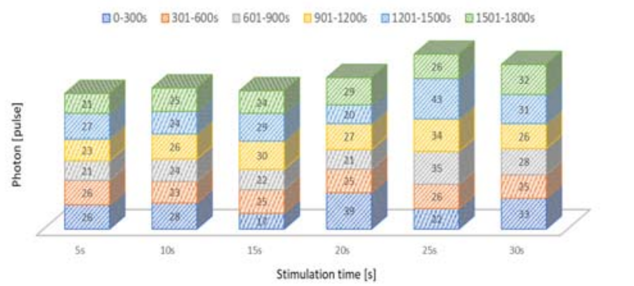

Fig. 8. Photon emission structure in rapeseed after stimulation with 3 kV/cm electric field

In the analyzed case it was clearly observed that longer time of stimulation with eclectic field results in higher value of photon emission. The emission structure at 300 second intervals does not differ significantly from the previously discussed cases. Taking into account the whole combination of the experiment,

Figure 9 shows the photon emission from rapeseed that was stimulated with an electric field of different intensity and different stimulation time was applied.

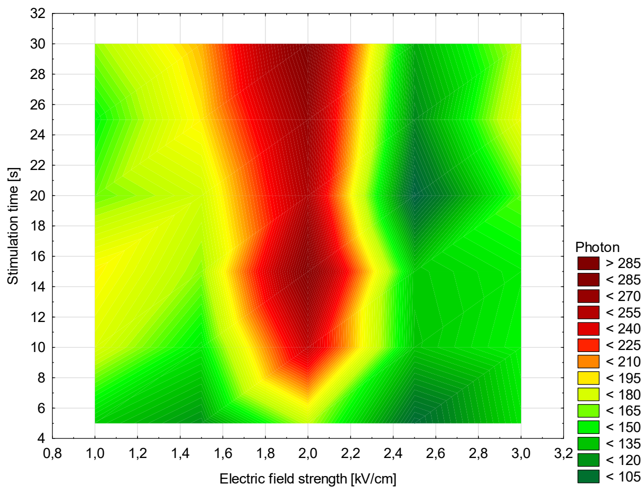

Fig. 9. Photon emission structure as a function of electric field strength and stimulation time

The red color indicates the highest photon emission values, while the dark green color indicates the lowest photon emission values. It was found that electric field strength in the range from 1.8 kV/cm to 2.2 kV/cm generates the highest photon emission of rapeseed. This relationship is present in the entire time combination range except for the shortest stimulation time of 5s. The highest photon emission values are concentrated within two combinations of stimulation parameters and duration, namely an eclectic field strength of 2 kV/cm and a stimulation time of about 16s, and again an electric field strength of 2 kV/cm but with a stimulation time of 28-30s. All other combinations of the experiment give a smaller effect of photon emissivity of stimulated rapeseed. This means that there is a certain optimum of electric field effects on rapeseed causing an increase in photon emission from the seeds. In addition, it can be observed that the exposure time of rapeseed is of secondary importance from the point of view of photon emission. Changing the exposure time of the electric field on the seed only slightly changes the photon emission structure of the seed, i.e. slightly increasing the space of high photon emission.

Conclusion

Photon emission was found to be directly dependent on the duration of electrical stimulation of rapeseed. It was noted that the effect of electric field strength is much smaller on the degree of photon emission, which indicates the presence of structural features of the seed material and its selective susceptibility to electrical interactions. Moreover, the uniform distribution of photon radiation throughout the measurement interval indicates that the positive effect is maintained in the seeds for at least 24 hours. The highest photon emission was found to be in the stimulation range from 1.8 kV/cm to 2.2 kV/cm, which increased with increasing stimulation time of rapeseed. In order to establish an unambiguous relationship between the amount of stored energy and its effect on biological processes in the cell, a number of additional experiments should be carried out with the sprouts of the stimulated material.

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***Authors**: Stepan Kovalyshyn Professor, Lviv National Agrarian University, Vol. Velykogo str., 1, 80381 Dubliany, Ukraine E-mail: stkovalyshyn@gmail.com; Vadym Ptashnyk PhD, Lviv National Agrarian University, Vol. Velykogo str., 1, 80381 Dubliany, Ukraine E-mail:ptashnykproject@gmail.com; Bogdan Nester Lviv National Agrarian University, Vol. Velykogo str., 1, 80381 Dubliany, Ukraine; Oleksiy Shvets Lviv National Agrarian University, Vol. Velykogo str., 1, 80381 Dubliany, Ukraine; Paweł Tylek Associate Professor,, University of Agriculture in Krakow, Faculty of Forestry, Al. 29-listopada 46, 31-425 Kraków, E-mail: pawel.tylek@urk.edu.pl; Anna Miernik MSc Eng, University of Agriculture in Krakow, Faculty of Production and Power Engineering, Balicka Av. 116B, 30-149 Krakow, E-mail: anna.miernik@urk.edu.pl; Paweł Kiełbasa Associate Professor, University of Agriculture in Krakow, Faculty of Production and Power Engineering, Balicka Av. 116B, 30-149 Krakow, E-mail:pawel.kielbasa@urk.edu.pl;*

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