

# ELECTRON PARAMAGNETIC RESONANCE STUDY OF THE EFFICIENCY OF RF ELECTROMAGNETIC FIELD AND RF PLASMA SEED PRETREATMENTS FOR GERMINATION STIMULATION OF CARROT SEEDS

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## 1. Introduction

In the recent years, low temperature plasma and electromagnetic fields pre-sowing seeds treatments are considered as ecologically safe, cheap and effective methods for the improvement of seeds physiological quality, their germination and resistance to stress and diseases. It has been shown in a number of previous studies that plasma and electromagnetic field pre-treatments of seeds improve their germination and sprouting process, lead to suppression of fungal and bacterial pathogens /1–3/. At the same time there is a lack of researches which are going to explain the plasma and radio-wave stimulation mechanism. It is supposed that exposure to magnetic fields activates seed enzyme complexes, which control the major stages of seed germination and ensures faster growth of the germ /4/. Low temperature plasma treatment provides the seed surface irradiation with UV radiation, bombardment with charged particles and radicals formed in plasma, and the formation of functional groups on treated surface /5/.

Last years electron paramagnetic resonance (EPR) is a leading technique in the investigations of biological objects such as plant seeds and foodstuffs. This technique is based on the presence of a substantial amount of free radicals in the investigated species. EPR was used for recognition of  $\gamma$  irradiated seeds, identification of physiological role of enzymes and revealing of radical production in magnetoprimed seeds /6, 7/.

In this paper, we have studied the EPR spectra of carrot seeds, widely used in food industry vegetable, after RF air plasma and RF electromagnetic field pre-treatments of seeds.

## 2. Experimental

Tested species were processed with 5.28 MHz air plasma at a pressure of 40 Pa. A capacitively coupled discharge was operated between two plane-

parallel water-cooled copper electrodes with a diameter of 120 mm placed in a stainless steel vacuum chamber with the inner volume of 53.2 m<sup>3</sup>. The experimental set-up is described in detail in /3/. A Petri dish with seeds to be treated by the plasma was put on the grounded electrode before the vacuum chamber pumping. The exposure duration was 5, 10, and 15 min. Under the experimental conditions the gas temperature did not increase beyond 310°C.

The experimental conditions for electromagnetic field treatment were as follows: the alternator frequency was 5.28 MHz, the root-mean-square value of magnetic  $H$  and electric  $E$  components of the electromagnetic field strength was 590 A/m ( $B \approx 1$  mT) and 12.7 kV/m respectively, the amplitude values  $H^* = H\sqrt{2}$  and  $E^* = E\sqrt{2}$  reached 835 A/m ( $B \approx 1.4$  mT) and 17.96 kV/m respectively. The duration of seeds exposure to electromagnetic field was 10, 15 and 20 min.

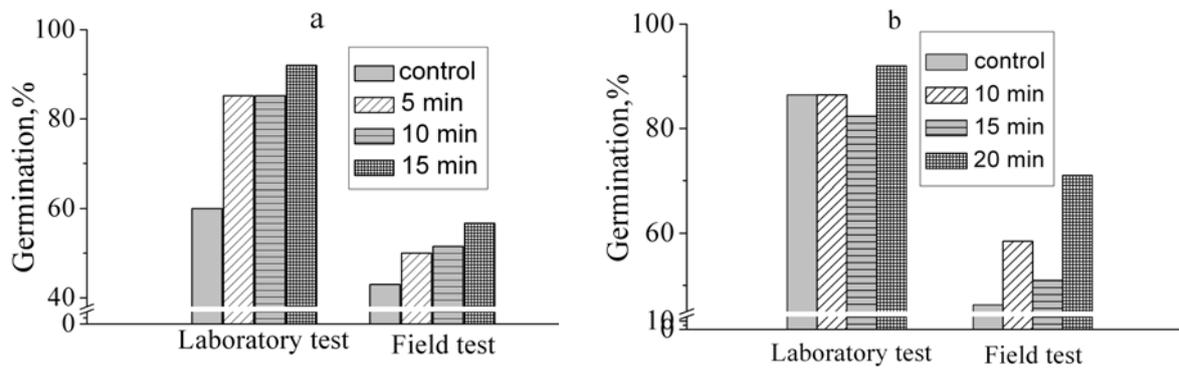
All treatments for all experimental conditions and seed species were replicated three times.

The effectiveness of pre-sowing plasma and radio-wave seed treatments was examined by means of evaluation of seed germination in the laboratory and field tests. In the laboratory tests the untreated (control) seeds and the samples exposed to plasma and RF electromagnetic field were grown on a moist filter paper in Petri dishes that were kept in a thermostat at 25 °C for 5–7 days. Seed germination was evaluated on the 12th day after the seed sowing term. Seed vitality test was fulfilled on the 9th day, after the first sprout has been appeared. A plot with the area of 50 sq. m. was used for the field test.

The EPR spectra were recorded with EPR spectrometer “RadioPAN” SE/X-2543 with  $H_{102}$ -cavity at a frequency of 9.32 GHz. The polarizing magnetic field was modulated with a frequency of 100 kHz. Modulation amplitude was 0.1 mT. Microwave power was 55 mW. An in-phase ESR signal (when the reference-voltage phase and EPR signal phase at the synchronous detector input coincide,  $\varphi = 0^\circ$ ) was measured. Coal was used for measurements of a standard of EPR signal intensity and g-factor value. For each measurement, 42 seeds were placed in the EPR cavity. The EPR spectra of the samples were recorded at room temperature using the standard procedure of EPR measurements presented in /8, 9/.

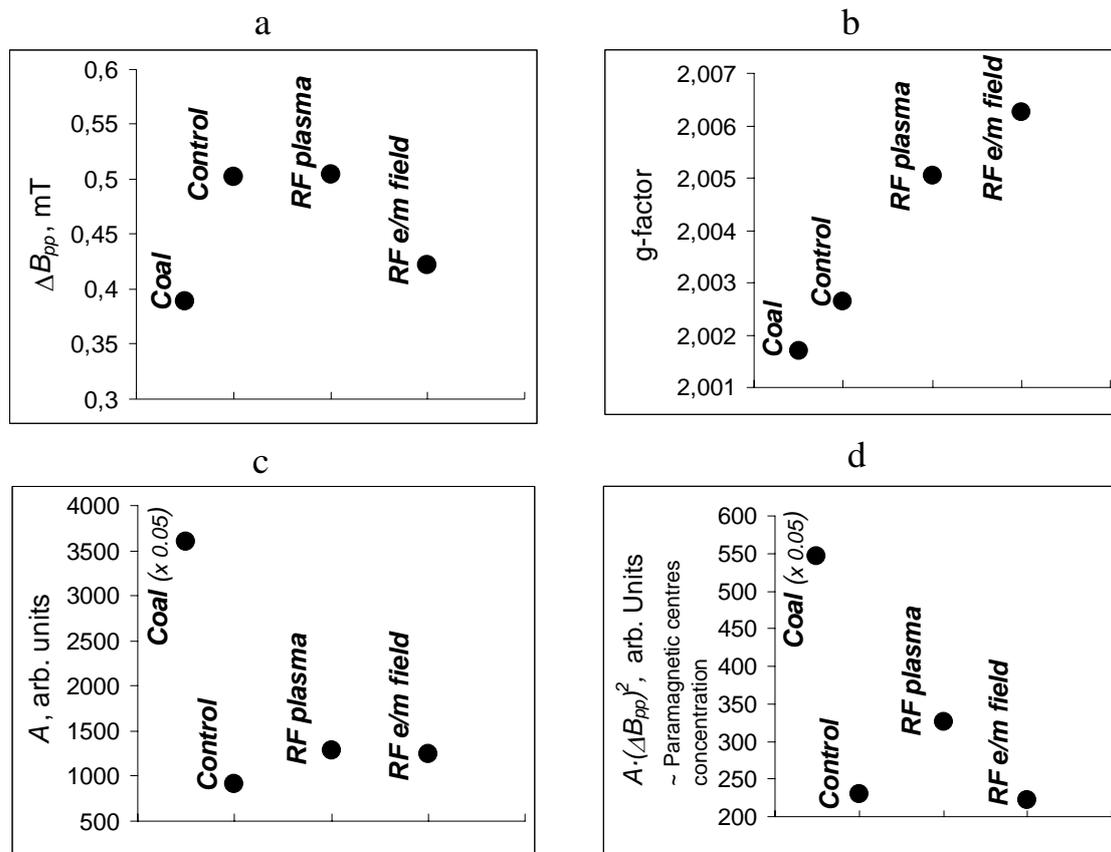
### 3. Results and discussion

The germination of the treated samples is presented in fig. 1 in dependence on the exposure time. The influence of seeds pre-treatments during 10 – 15 min resulted in the significant germination enhancement that increased in the laboratory conditions by 53% and 6% for plasma and radio-wave treatment respectively. Good correlations were found between the results of laboratory and field tests.



**Figure 1.** Germination of carrot seeds in the control and after the RF plasma (a) and radio-wave (b) treatments in dependence on treatment duration

The results of EPR spectra analysis of seeds before and after the treatments are presented in fig. 2. The estimated values of  $g$ -factor for plasma and radio-wave treated seeds were 2.0051 and 2.0062 respectively. At the same time the value of  $g$ -factor in the untreated seeds was a lot lower (2.0026). It should be supposed that molecular structure of free radicals in seed changes as a result of the treatments.



**Figure 2.** Results of EPR spectra analysis: a – width  $\Delta B_{pp}$  of the EPR signal peaks, b –  $g$ -factor  $A$ , c – EPR signal amplitude, d –  $A \cdot (\Delta B_{pp})^2$

A significant increase of paramagnetic centres concentration was observed in the seeds which were treated with RF plasma in comparison with the untreated ones. This fact can be an evidence of free radical level increase in seeds after the treatment that plays an important role in seed metabolism acceleration and stimulation of biochemical and physiological processes in seeds as a result of plasma and radio-wave treatments.

#### 4. Conclusions

This study demonstrated that low-pressure RF air plasma and RF electromagnetic field pre-treatments of carrot seeds improved their sowing quality due to the seed germination enhancement and seed vitality increase. It has been revealed from the EPR spectra of seeds that the RF plasma and RF electromagnetic field treatments increased the concentration of free radicals in seed that can help to explain the plasma and radio-wave stimulation mechanism of seed germination.

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