THE EFFECT OF PLASMA TREATMENT OF SEEDS OF SOME GRAIN AND LEGUMES ON THEIR SOWING QUALITY AND PRODUCTIVITY

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The effect of 5.28 MHz plasma and radio-wave treatments on seed sowing quality has been investigated. It has been shown that pre-sowing plasma and electromagnetic treatments during 10–15 min lead to enhancement of laboratory and field germination of seeds, survival and crop capacity.

Key words: rf plasma, rf electromagnetic field, seed treatment, germination, fungicidal effect.

1. INTRODUCTION

Plasma and radio-wave technologies have been successfully applied for various natural materials treatment. In agriculture these methods can be an effective substitute for the traditional pre-sowing seed treatment with chemical agents which are either expensive or harmful to environment and human health. It has been shown in a number of previous studies that plasma and electromagnetic field pre-treatments of seeds stimulate their germination and lead to suppression of fungal and bacterial plant pathogens [1–6]. A considerable part of such investigations deals with 13.56 MHz plasma. The effect of electromagnetic fields on biological objects was examined mainly in the microwave (300 MHz–300 GHz) or in the low frequency (50–100 Hz) region. In this paper, an influence has been studied of low temperature 5.28 MHz plasma as well as rf electromagnetic field on seed sowing qualities and yield of some grains and legumes.


2. EXPERIMENTAL CONDITIONS

Tested seeds of legumes and grain-crops (Lupinus angustifolius - blue lupine, Galega virginiana - catgut, Melilotus albus - honey clover and soy) were treated with radio frequency (5.28 MHz) plasma and exposed to a high frequency electromagnetic field.

A capacitively coupled rf discharge was operated between two parallel round copper electrodes with diameter 120 mm in air at pressures 0.3–0.7 Torr [7]. The investigated samples were placed on the lower (grounded) electrode. The supplied full specific rf power was $W \approx 0.6 \text{ W/cm}^3$. The experimental conditions for rf 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 were 590 A/m and 12700 V/m accordingly. The diamagnetic dish with seeds was placed in an axial zone of the inductive coil (length – 90 mm and internal diameter – 80 mm). Treatment were performed in air at atmospheric pressure. The duration of plasma and radio-wave exposure was 5, 10, 15 and 20 min.

The effectiveness of pre-sowing seed treatment was examined by means of evaluation of the laboratory/field germination ability, seed vitality and a level of fungi infection on sprouting seeds for processed and untreated (control) samples. In a laboratory experiment each treated set of seeds contained 100 seeds. The processed and control samples were grown on a moist filter paper in Petri dishes that were kept for 5-7 days (before the first sprout occurrence) in a thermostat at 20–21°C. A plot with the area of 25 sq. m. was used for the field test. The estimation of seed germination was performed on the third, the seventh and the tenth day of the cultivation. The vitality test was performed in the field investigations. The vitality was evaluated as a ratio of number plants in the ripeness stage to the germinated ones.

3. RESULTS AND DISCUSSIONS

It is shown that plasma and radio-wave treatments result in the increase of the laboratory and field germination of seeds as well as their vitality, in the reduction of seed contamination level with fungal infections (Figs. 1, 2). The optimal duration of plasma and electromagnetic treatments was 10–15 min for almost all tested species. Laboratory and field germination of steadfast seeds (soy, honey clover and catgut) increased by 10–20 % as a result of seed coat scarification during the plasma treatment (see Fig. 1). The same results were observed for the electromagnetic field treatment that can be considered as a mediator of seeds’ cellular receptors triggering intracellular mechanisms leaded to the improvement of seed sowing qualities (Fig. 2). Non-steadfast seeds (blue lupine) germinate more
evenly and the plasma treatment effect is not so strongly pronounced as for steadfast seeds. The plasma and radio-wave treatment during $t > 15$ min leaded to seed germination suppression practically for all tested species.

![Fig. 1 – Field germination capacity (a) and seed vitality (b) for control and plasma treated seeds in dependence on exposure durations.](image1)

![Fig. 2 – Field germination capacity of control and treated seeds (a) and a level of fungal infection of blue lupine (b) after electromagnetic field treatment for different exposure durations.](image2)

Plasma processing had a significant fungicidal effect on seeds: a level of fungal infection (*Fusarium, Ascochyta*, etc.) of treated crops was lower by 3–15 % compared with untreated ones (see Fig. 2b). At the same time it was not observed any effect of the treatment on the level of seed infection with *Anthracnose*.

The difference was observed between optical emission spectra generated by plasma without seeds and during their treatment. The species identified in the spectra are neutral molecular nitrogen $N_2$ (bands of the first and the second positive systems), ionized molecular nitrogen $N_2^+$ (bands of the first negative system) (Fig. 3). Appearance of CO molecules (bands of the Angstrom, the Herzberg and
the third positive systems) and ionized O$_2^+$ molecules (the second negative (2-) system) in spectra during seeds treatment confirmed that the plasma chemical etching of seed surface plays an important role in stimulation of biochemical processes that influence on seed germination [4].

We consider atomic oxygen and OH radicals generated in plasma to be the most probable sterilizing agents, while the nitrogen presented in air plasma plays an important role in the intensification of the biological processes in seeds.

Thus, the radio-frequency electromagnetic field and rf cold plasma processing of seeds of grains and legumes promoted increase in their germination energy as well as in laboratory and field germinating capacity due to both the change of transport properties of the cellular plasmatic membranes accompanying with an enhancement of humidity permeability of seed surface and the reduction of seed contamination with pathogenic fungi. Pre-sowing radio-wave treatment increased of grain and green mass productivity of legumes by 14–24 % [8].

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![Fig. 3 – Emission spectrum of rf air plasma in the ranges of 280–400 nm (a) and 400–900 nm (b) under conditions of seeds irradiation.](image)
REFERENCES