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Review articles

USE OF BIOPHYSICAL METHODS TO IMPROVE YIELDS AND QUALITY OF AGRICULTURAL PRODUCTS

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Abstract: Until as recently as a century ago, the exposure of biological systems to radiation was limited only to the natural sources. Today, however, a broad range of radiation types and doses have found a wide variety of uses and applications, so much so that it would be difficult to make a list of all the areas of human activity in which radiation is used for one purpose or another. The study of radiation effects on individuals and populations as a whole has become important only with the development of methods and sources of man-made radiation. Given that what is present in this case are physical effects on biological systems (living organisms), all these methods can be placed under the heading of *biophysical influences*.

In the last 50 years, the effects of extremely low-frequency electromagnetic fields (ELF-EMF) have been studied with great diligence. These fields are the ones most commonly found in the human environment and they have been used in our studies in this field. The present paper provides a brief review of the literature data and our findings on the effects of ELF-EMF on various crop species using the RIES (Resonant Impulse Electromagnetic Stimulation) method, developed at the Faculty of Agriculture of the University of Novi Sad.

Key words: Electromagnetic field, extremely low frequencies, RIES, biophysical stimulation.

Results and Discussion

Twentieth century agriculture was marked by intensive use of chemical products, which has resulted in a significant increase of yields but has at the same

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time led to the endangerment of agroecosystems. Although the potentials of conventional crop growing technologies have not been fully exhausted yet, new approaches have started to appear in agricultural production. The 21st century in agriculture will be marked by new technologies, and these will without a doubt include biophysical methods.

Until as recently as 15 years ago, which was when we began our work on the application of extremely low-frequency (ELF) electromagnetic fields (EMF) in agriculture, many physicists insisted that such low frequencies were incapable of producing any significant effect in plants. Nowadays, however, a critical number of findings have been obtained that clearly identify changes occurring in plants as a result of biophysical influences Most scientists agree that the cell membrane is the primary location at which these interactions occur, with the processes continuing in the cell afterwards. Piacentini et al. (2001) indicate that ELF-EMF may have a stimulatory or inhibitory effect on plant tissue growth depending on the plant species involved. According to Marinković et al. (2002, 2003), the nature of the effect also depends on the hybrid, seasonal biological rhythms, field frequencies, period of exposure, and geomagnetism of the microsite. Kalinin et al. (2001) indicate ELF-EMF may have: **I** energetic effects, **II** biophysical and biochemical effects, **III** informational effects.

The great amount of attention given to the effects of the electromagnetic field in agriculture has been due to the possibility of being able to exert influence on plant growth and thus produce significant economic effects.

Types of electromagnetic radiation (based on photon wavelength and energy):

I Ionizing radiation, **II** UV radiation (that incorporates several bands, with the C one being of high importance from the standpoint of biology), **III** Visible light, **IV** IR radiation, **V** Radio frequency radiation, **VI** Extremely low-frequency electromagnetic field (ELF-EMF).

Biophysical methods used in agriculture:

1. Treatments of living organisms with: UV rays, gamma rays, ultrasound, ionizing radiation, etc. **2**. Laser treatments, **3**. Dielectric separation and stimulation of seeds, **4.** Magnetic stimulation, **5**. Electromagnetic stimulation, **6.** Use of ELF-EMF, **7**. The golden section principle, the EMF principle of the Great Pyramid of Giza, **8.** Weed control using high electromagnetic frequencies, **9.** Cold electron plasma (e^-).

This paper will discuss in greater or lesser detail some of the above effects as they pertain to plant growing and will describe the various findings obtained in the field domestically and internationally.

A study conducted in Urbino, Italy by Piacentini et al. (2001) showed that there is an interaction between ELF-EMF and biological systems. The interaction starts at the cell membrane level and proceeds further from there. The study was performed on cells undergoing mitosis and the growth and development of the whole plant was found to be affected. It was determined that ELF-EMF affects the phosphoinositide signal that triggers transduction, activating phosphoinositide-dependent phospholipase C, which reduces the concentration of phosphatidylinositol-4,5-biphosphate. The plants were exposed to a 50 Hz ELF for a period of 10 minutes. The study's results support the proposition that the cell membrane is the primary site of ELF-EMF action.

Use of ELF-EMF has produced the following results:

Marinković et al. (2002, 2003, 2004, 2006) obtained significant results using ELF-EMF on wheat and barley. The above-ground weight of the seedlings increased by an average of 23.5% (1.2 mg/plant), while root weight increased by 46% (3.1 mg/plant). The yields in small-plot trials and commercial growing conditions increased by 310-1,620 kgha^{-1}, while the protein content grew by 0.09-0.56%. Grzegorz and Leszek (2006) reported statistically significant increases of 3.0 and 4.1% in naked barley and oats, respectively. The protein percentage increased by 1.5-5.3%. In Bhatnagar et al. (1978), nitrate reductase activity was higher in seeds treated with the EMF, and the roots and stems developed at a higher rate as well. Similar findings were reported by Chauhan and Agarwal (1977), while Aksynov et al. (2001) found that ELF-EMF affected wheat germinability and caused changes in germination, viscosity, pH value, and esterase activity. In a study on wheat conducted by Phirke et al. (1996), the best results were obtained by rotating a magnetic disc at 800 rpm for 21-22 minutes with a magnertic field strength of 0.10 T.

Studies of ELF-EMF in maize carried out by Marinković et al. (2002, 2003) showed that ELF-EMF increased seedling root weight by 37% (28 mg/plant) and above-ground weight by 31% (22.0 mg/plant). In commercial growing conditions, grain yields were increased by 980-1,616 kgha^{-1} (8.4-18.7% on average across six localities).

Crnobarac et al. (2002) reported increases of sunflower yield ranging from 222 to 390 kgha^{-1} and an increase of seedling weight of 21-38%. Kalinin et al. (2001) achieved similar results with a 3 KVT generator and 245 MHz frequency. Crnobarac et al. (2002) reported that soybean yields increased by 306-658 kgha^{-1} and that the increases in trials were 110-1,440 kgha^{-1}. Similar results were reported in a paper by Vakharia et al. (1991) that studied magnetic field effects in peanut. In the study, pod yield grew from 8.3 to 9.3 and 10.2 g/plant, and plant luxuriance, root length, and oil content increased as well.

In a study of sugar beet carried out by Marinković et al. (2002), taproot yield grew by 4.3 to 20.6 tha^{-1} and sugar content increased by 0.56-1.81%. The yield of sugar increased by 950 kgha^{-1}on average.

Marinković et al. (2002) cited potato yield increases of 2.5-6.6 tha^{-1}, Gvozdenović (2002) reported a pepper yield increase of 15 tha^{-1} on average, and Takač et al. (2002) obtained an average yield increase of 3.1 tha^{-1} in tomato. Studying the effects of the micro EMF on strawberry, Kopecek (1972) found that the plants reached the fruit-bearing stage 20 days earlier and had better vigor. Piacentini et al. (2001) obtained similar results with cucumber. Namba et al. (1998) studied the influence of 1-100 Hz 500 μT ELF-EMF in buckwheat, green shiso, radish, and Welsh onion and determined that each of the species had its own ideal ELF-EMF range (in radish, for example, the 1 Hz increased germinability by 30%). Spilde (1989) observed that ELF-EMF may have not only a stimulatory but also an inhibitory effect on germinability. Bondarenko et al. (1996) and Spinu et al. (1998) achieved positive effects watering vegetables with magnetically treated water, with the yield increases being in the 10-20% range. In a study on tomato by Ward (1996), treatment with an electric current of 12 V and 2.5 x 10^{-4}A resulted in plant weigh reduction, and the treated plants had an increased concentration of potassium as well.

Kuljančić et al. (2002) managed to increase vine yields by 550-1,360 $kgha^{-1}$ depending on variety and locality. The increases translated into financial gains of 275-680 per hectare.

According to Vasilevski (2003), laser treatments of carrot increased the yields of this crop by 0.78-2.55 kgm^{-2}. The same author kept wheat seeds under pyramids made out of different materials during germination and found that this increased root length by 63.7- 144.6%.

Taro et al. (2004) define electrons with an energy of less than 300 keV as low-energy electrons, or so-called soft electrons. Such electrons have been shown to have a number of advantages over gamma rays when used in the process of grain disinfection. The specific amount of energy used will vary depending on seed morphology. Thus, 60 keV are used for brown rice, 75 keV for wheat, 100 keV for white pepper, coriander, and basil, and 210 keV for black pepper. The use of electrons with such energies has been found to have no significant effect on seed quality. The first applicable treatments in this field have been developed by the Schmidt Seeger AG company and the Fraunhofer Institute for Electron Beam and Plasma Technology, as reported by Cutrubinis Mihalis et al. (2005). Setsuko et al. (2000) obtained similar results using a voltage of 170-190 kV for seed disinfection. Voltages of 200 kV and above inhibit germination. Similar results were obtained by Takashi et al. (2004). The importance of microwave fields in seed disinfection is convincingly demonstrated by the findings of Kalinin et al. (2001) as well.

Conclusion

- Our understanding of how ELF-EMF works is becoming increasingly clear in recent years.
- More and more scientists agree that the cell membrane is the primary receptor of ELF-EMF signals, which are later transmitted further on into the cell.
- The information effects of ELF-EMF in the cell have been receiving increasing attention in addition to the biochemical and biophysical ones.
- The use of fast electrons (e-disinfection) has become a reality.
- This method is environmentally friendly and has many other advantages over chemical disinfection.
- The use of ELF-EMF produces significant yield increases.
- The above methods are inexpensive and environmentally safe.

- We hope that the day is not far when we will see massive use of these technologies in agricultural production.
- The use of these technologies will mark the beginning of a new era in world agriculture.

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UPOTREBA BIOFIZIČKIH METODA RADI POBOLJŠANJA PRINOSA I KVALITETA POLJOPRIVREDNIH PROIZVODA

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R e z i m e

Izloženost bioloških sistema u prirodi različitim vrstama zračenja, do pre samo jednog veka bila je ograničena isključivo na prirodne izvore. Danas, međutim, oblast primene najrazličitijih vrsta i doza zračenja je veoma raznovrsna, i teško je navesti sve oblike ljudske delatnosti u kojima se ona koristi. Proučavanje njihovih efekata na jedinke ili populacije u celini, dobilo je na značaju tek razvojem metoda i izvora zračenja koje je čovek stvorio. Obzirom da se radi o fizičkim dejstvima na biološke sisteme, tj. žive organizme, sve ove metode mogu se svrstati u domen *biofizičkih delovanja*.

U poslednjih pedesetak godina se sa posebnom pažnjom ispituje uticaj *EMF*-a (Electromagnetic Field) ekstremno niskih frekvencija (*ELF* – Extemely Low Frequency), koja se najčešće nalaze u čovekovom okruženju, a koja se primenjuju i u našim ispitivanjima.

U radu će biti dat kratak pregled dosadašnjih rezultata istraživanja autora i literaturnih podataka o dejstvu elektromagnetnog polja niskih frekvencija na gajene biljne vrste, primenom metode *Rezonantno-Impulsne Elektromagnetne Stimulacije (RIES)*, razrađene na Poljoprivrednom fakultetu u Novom Sadu.

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