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Research article

Pulsed magnetic field: A contemporary approach offers to enhance plant growth and yield of soybean

Ramalingam Radhakrishnan*, Bollipo Diana Ranjitha Kumari

Stress Physiology and Plant Biotechnology Unit, Department of Plant Science, School of Life Science, Bharathidasan University, Tiruchirappalli 620024, Tamil Nadu, India

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ABSTRACT

The possible involvement of pulsed magnetic field (PMF) pretreatment in development and yield of soybean was investigated. Seeds were subjected to 20 days with 1500 nT at 10.0 Hz of PMF for 5 h per day. PMF pretreatment increased the plant height, fresh and dry weight, and protein content with the changes of protein profile in 8 days old seedlings. In addition, activity of enzymes such as β-amylase, acid phosphatase, polyphenol oxidase and catalase was enhanced while α-amylase, alkaline phosphatase, protease and nitrate reductase activities declined due to PMF exposure. However, a considerable increment of Fe, Cu, Mn, Zn, Mg, K and Na contents with reduced level of Ca was found in PMF treated seedlings. The number of leaves, pods, seeds and length of pods, and weight of seeds were also remarkably higher in PMF treatment in contrast to controls. The results suggest that pretreatment of PMF plays important roles in improvement of crop productivity of soybean through the enhancement of protein, mineral accumulation and enzyme activities which leads to increase the growth and yield.

1. Introduction

Agricultural productivity is minimized by the number of factors such as soil salinity, droughts, soil erosion and wide spread of disease. Soybean is one of the important commercial crops in many countries. It is rich in nutrient content such as 40% of protein, 18–22% of oil, 35% of carbohydrates, minerals and isoflavonoids such as genistein and daidzein are useful to prevent heart disease, cancer, diabetes and hypertension. The yield of soybean is affected by both biotic and abiotic factors. In recent years, the farmers expect alternative fertilizers against chemical fertilizers, due to the increase of cost and harmful effects of chemical fertilizers. Usage of MF to improve the crop productivity is a recent method and it gives better plant growth and yield than chemical fertilizers. In addition, it is ecologically friendly and nonpolluting to the soil base, specifically the consumption of electric power levels is very low which can be no hazard to environment. This PMF technology when it becomes fully developed for commercial use, it should offer the attraction of being affordable to farmers [1]. Pre-sowing seed treatment of MF can be used in practical agriculture to improve the plant growth and yield [2,3].

Since, MF is one of the natural components in the earth. Plants and other living things are interacted with magnetic field in day to day life. Generally, earth acts as magnet with their south and north poles and the natural effects of magnetic field have been changing the plant growth and yield in the globe. Specifically, the electromagnetic spectrum of sunlight stimulate the growth of plants by the process of photosynthesis. The possible mechanism would be a change in the electrostatic balance of the plant system at the cell membrane level, as it is the primary site for action of any inhibition or enhancement of plant growth. Certain mechanisms for action of extremely low frequency electromagnetic fields on biological systems have been reported in earlier [4]. Galland and Pazur [5] described the effects of magnetic field by radical pair mechanism and ion cyclotron resonance mechanisms.

In addition, geomagnetic field strength could affect variety of enzymes in biological organisms. The Ca^{2+}/calmodulin dependent cyclic nucleotide phosphodiesterase [6] and cytochrome C oxidase [7] changed due to the effect of MF. Electric or magnetic treatments enhanced seed vigour by influencing the biochemical processes, which stimulate the activity of proteins and enzymes [2,8] and then some studies reported that MF had a positive effect on the number of flowers and yield [9], nutrient [10,11] and water uptake [12].

Some reports are available that higher intensity of magnetic field is useful to increase the seed germination and plant growth [2,3]. Our present research work in magnetic field induced soybean plant development differed from previous research work of Shine et al. [3] by the application of pulsed magnetic field with low intensity (1500 nT) and frequency (10.0 H) for 5 h per day upto 20

* Corresponding author.
E-mail address: ramradhakrish@gmail.com (R. Radhakrishnan).

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days. However, very limited studies have been conducted in biology to describe the role of low frequency and intensity of magnetic field. Therefore, there is a need to elucidate the effect of PMF on changes of seed germination, seedling growth and yield in crop plant. To date, very few reports have explored the interaction of MF with protein, enzyme activity and uptake of minerals in plants. The aim of the present investigation is an attempt to evaluate the ability of PMF on soybean seed germination, plant growth and yield, and the positive effects of PMF are confirmed by the analysis of protein, activities of enzymes and uptake of minerals.

2. Materials and methods

2.1. Seed pretreatment with PMF

Seeds of soybean (*Glycine max* (L.)) cv. CO-3 were obtained from Tamil Nadu Agricultural University, Coimbatore, India. The healthy uniform dry seeds (8.6% of moisture content) were selected and each 100 g seeds kept at the geometric centre of coil assemblies were subjected to 10.0 Hz at 1500 nT as per the method of Leelapriya et al. [1]. Control seeds were kept under similar condition (local geomagnetic field only) but in the absence of pulsed magnetic field. Exposure was 20 days for 5 h per day and control seeds were kept under the similar condition in the absence of the PMF. The magnetic treatment of seeds was applied using an electromagnet highly improved version of the classical Helmholtz coil. This consisted of four-coil system that are made up of two larger (inner) coil frames and two smaller (outer) coil frames, where instead of the classical two identical coils there are now two pairs of coils, each pair having a different diameter (Fig. 1). The four coils have the same number of turns and connected in series-aiding configuration. The four coils are mounted co-planar and co-axial. The ratios between the radii of inner and outer coil frames and the spacing between them are pre-determined according to the parametrical equations of Fanselau [13] and Brauenbeck [14].

The coil assemblies designed and fabricated at Madras Institute of Magnetobiology (Chennai, Tamil Nadu, India) have been carefully calibrated using high precision magnetometers (the size of the magnetometer is approximately 3.0 cm) and current measuring devices in the Magnetic Standardization Lab of the Institute. The high precision measurements involved calibration of the coils for arriving at the coil constant expressed in nano teslas (nT) per milli ampere (mA) and the generated magnetic field (a few hundred nano teslas) determined correct to the order of 1–2 nT. The magnetometer used for these measurements is a magnetic observatory field standard called the Zero-Balance Magnetometer manufactured by the Danish Meteorological Institute, Copenhagen, Denmark. The magnetometer has provision for determining the correction for temperature variation so that the final field measurements are free of any contribution arising from any temperature changes.

Pulsed electric current from a signal generator (Fig. 2) energizes the coil system such that the strength, frequency and waveform of the output current can be controlled to any set of desired values, thus offering along the axis of the coil system a magnetic field of any desired frequency, intensity and waveform.

2.2. Seed germination and seedling development

PMF pretreated and control seeds were surface sterilized with 0.1% mercuric chloride solution for 5 min, washed thoroughly 5 times with distilled water and then propagated in clay pots containing air dried clay and sand mixture (3:1). The pots were maintained under natural photoperiod with 35% (w/w) soil moisture content. Seed germination and viability was observed at 4 month intervals upto 2 years, and germinated seedlings were uprooted and measured the length, fresh and dry weight of 8 days old both control and treated seedlings.

2.3. Protein contents and SDS PAGE

Seedlings were homogenized with 50 mM Tris–HCl buffer pH 7.2, 5% sucrose and 14 mM mercaptoethanol, and then centrifuged at 10,000 rpm for 15 min at 4 °C. The protein concentration of the supernatant was determined by a standard method of Bradford [15]. The samples were denatured for 1 min in a boiling water bath with sodium dodecylsulfate (SDS), sample buffer and equal

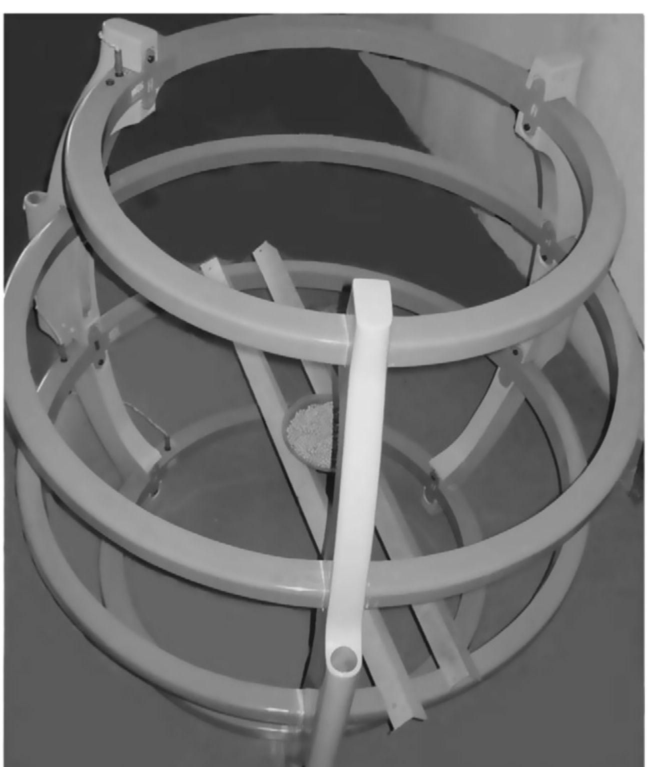

Fig. 1. Magnetic field enclosure.

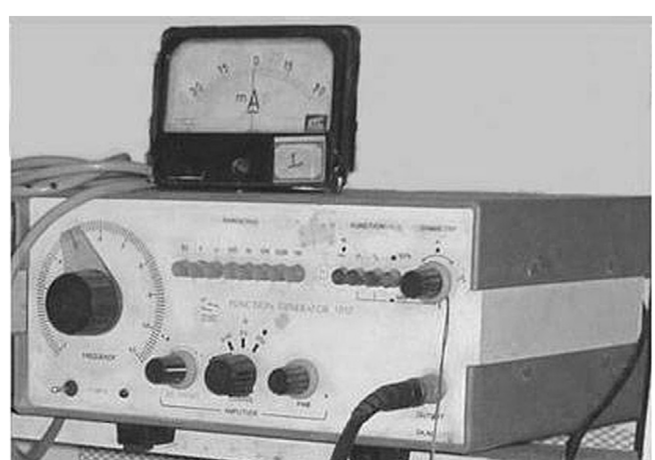

Fig. 2. Function generator.