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Improvement of the seed germination, growth and yield of onion plants by extremely low frequency non-uniform magnetic fields

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ABSTRACT

The effects of pre-sowing magnetic treatments on germination under laboratory conditions and emergence, growth and yield of onion (cv Red Creole) plants under field conditions were investigated. Onion seeds were exposed to 60 Hz full-wave rectified sinusoidal non-uniform magnetic fields (MFs) induced by an electromagnet at 160 mT for 15 and 20 min. Non-treated seeds were considered as controls. Plants were grown in experimental plots (2.4 m^2) and were cultivated according to standard agricultural practices. During vegetative stage and bulb forming, samples were collected at regular intervals for growth rate analyses. At physiological maturity, the plants were harvested from each plot and the yield and yield parameters determined. Under laboratory conditions, the magnetically treated seeds showed a higher germination percentage than the control seeds. Significant differences were found between both treatments and the best finding was found for 160 mT for 15 min. In field experiments, the treatments led to a significant increase in seedling emergence, root length, seedling height, seedling dry weight and leaf area per plant. Also, at the vegetative stage, the leaf and root relative growth rates of plants derived from magnetically treated seeds were greater than those of the control plants. At the bulb forming stage, bulb relative growth rates from magnetically exposed seeds were greater than those of controls. At the bulb maturity stage, all magnetic treatments significantly increased mean bulb weight, bulb yield per area, number of tunics per bulb, bulb diameter and dry bulb weight in comparison to the controls. The results suggest that pre-sowing extremely low-frequency non-uniform MF treatment has the potential to improve crop productivity of onion through the enhancement of germination, seedling emergence, plant growth, bulb formation and yield.

1. Introduction

Investigations on the influence of magnetic fields on seeds and plants over many years suggest that they lead to better plant growth and yield than chemical fertilizers and contributed to the improvement of the crop productivity and protection. In addition, there have been developed magnetic technologies in several countries that are ecologically friendly and non-polluting to the soil and are potentially attractive as being affordable to farmers (Liboff et al., 1992; Katsen et al., 2003).

Magnetic field (MF) treatment of seeds is potentially a safe and affordable physical method that has been reported to greatly speed up the release of seeds from the dormant state (García-Reina et al., 2001), to improve seed germination and vigor (Alexander and Doijode, 1995; Moon and Chung, 2000; Vincze et al., 2003), plant growth and vigor (Gubbels, 1982; Masafumi et al., 1998; Celestino et al., 2000) and plant yield (Matsuda et al., 1993; Pietruszewski, 1993; Wójcik, 1995). Also, MF induces an increase in seed water uptake (García-Reina et al., 2001), enzymatic activity of seeds (Bhatnagar and Deb, 1977), essential nutrient uptake into leaves (Esitken and Turan, 2004), chlorophyll pigment content (Novitsky et al., 2001), protection against heat stress (Ruzic and Jerman, 2002) and pathogens (Sadauskas et al., 1987; Pál, 2005; De Souza et al., 2006) without adversely affecting the environment.

Abbreviations: MF, magnetic field; ELF, extremely low frequency; rms, root mean square; RGR, relative growth rate; ASE, average standard error of mean; CV, coefficient of variation.

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Likewise extremely low frequency (ELF) MF exposure significantly changes activity of several enzymes (α-amylase, β-amylase, acid phosphatase, alkaline phosphatase, protease, polyphenol oxidase, catalase, and nitrate reductase) and accelerates the synthesis of total protein in soybean seedlings (Radhakrishnan and Kumari, 2012). Consequently, magnetic treatment of seeds contributes to the enhancement of post-germination plant development and crop stand. However, problems with poorly defined exposure setups, insufficient description of magnetic field conditions and the lack of detailed dosimetric data are present in many bioelectromagnetic studies with seeds and plants (Miclaus and Racuciu, 2007; Markov, 2014). Also, a biophysical mechanism behind the influence of MF on physiological processes is still not resolved.

According to FAO data (FAO, 2013), onion (*Allium cepa* L.) is now the third most important vegetable produced in the world. In Cuba, the crop is grown in an area of 10,713 hectares with a total production of 133,949 tons per hectare (FAO, 2013). Compared with many other crops, the onion has a fairly complex life cycle involving several distinct development phases. The onion seed is one of the shortest-lived seeds of the common vegetable crops, rapidly losing viability after harvest unless special precautions are taken for its storage. For this reason, it is generally recommended that only fresh onion seed be used for crop production (Riekels et al., 1976), and only seed of high germination percentage should be sold. Onion seeds are expensive due their fast loss of germination capacity (Black et al., 2006) and it exposes seed companies all over the world to huge losses (George, 1985). Therefore, there has been great interest to find simple and inexpensive methods to improve seed germination, growth and yield of onion plants.

Some studies have been carried out to enhance the onion seed germination under laboratory conditions (Alexander and Doijode, 1995; García et al., 2002; Kubisz et al., 2012); however, very little research has been conducted to describe the role of MF treatment on seedling emergence, growth and yield of onion plants under field conditions. Thus the objective of this paper was to determine the possible effect of pre-sowing 60 Hz non-uniform MF treatments on the germination of onion seeds under laboratory conditions, on seedling emergence, plant growth, bulb formation and also on plant yield under intensive orchard conditions.

2. Materials and methods

2.1. Plant material

Certified onion seeds (*Allium cepa* L.cv. Red Creole) were genetically uniform (stated on the package by the supplier) and were provided by the Seed Laboratory of the Ministry of Agriculture in Granma Province, Cuba. Seeds without visible defects, insect damage or malformation were selected and stored in desiccators over 70% (v/v) glycerine. Seed moisture content was10–12% on a fresh weight basis before the MF treatments, and final germination percentage was 85%.

2.2. Magnetic exposure conditions

Pre-sowing magnetic treatments were applied using an electromagnet (De Souza et al., 2006). In the occupied region by the sample the applied MFs was pronouncedly inhomogeneous, being the minimum, the mean, the maximum and the standard deviation 52.8 mT, 102.1 mT, 131.5 mT and 29.7 mT, respectively.

Dry onion seeds were piled in the center of a Petri dish (9 cm diameter) without any medium or support, which was placed on the pole of the electromagnet. The following magnetic treatments were applied: T1; a full-wave rectified sinusoidal non-uniform MF of 160 mT (rms, the effective (root-mean-square) value) for 15 min; T2; a full-wave rectified sinusoidal non-uniform MF of 160 mT (rms) for 20 min; Control: the local geomagnetic field only. No MF other than that of the local geomagnetic field was detected within the electromagnet when switched off. The above magnetic treatments were chosen as a result of previous screenings conducted under laboratory and greenhouse conditions (De Souza, 2002).

The MFs generated were adjusted by varying voltage applied to the coils until the required working strength was achieved. For the applied voltage, the MF generated were measured in the region occupied by the seeds (pole face) using a Lakeshore Model 410 magnetometer with the probe mechanically coupled to a micrometric positioning system. The magnetic field $B(r, t)$ produced by our magnetic conditioning device in the region occupied by the sample varies with the time approximately as a full-wave rectified sinusoidal voltage with a frequency of 60 Hz and an amplitude $B_m(r)$.

2.3. Laboratory experiments

Seed germination was determined according to ISTA rules (1999). After magnetic treatment, four replicates of 25 seeds for each treatment, including control, were labeled and placed in 12 cm × 12 cm plastic germination boxes, containing two layers of absorbent paper (Anchor Paper Co., St. Paul, MN) moistened to saturation with distilled water. The germination boxes were arranged in a completely randomized experimental design and placed in a germination chamber in the dark at 23 ± 2 °C for 14 days.

Seed germination was recorded at 7 and 14 days after sowing (October, 2009). Germinated seeds were grouped as normal, abnormal; there were also ungerminated seeds. Emergence of 1 cm radicle through the seed coat and the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether it is able to develop further into a satisfactory plant under favorable conditions were considered as germination criteria (ISTA, 2004). Therefore, germination percentage was only calculated based on the number of normal seedlings. The experiment was repeated in September 2010.

2.4. Intensive orchard experiments

The seeds (exposed/controls) were labeled and sown in different raised nursery beds before being transplanted into intensive orchard (field) conditions. The nursery beds (15 cm high) were 1.5 m long and comprised of 6 rows 20 cm apart. The seeds were sown 5 cm apart and 0.6 cm deep in rows at a density of 0.35 g seeds m^{-2}, according to standard agricultural practices. Daily irrigation was applied during the morning. Growth conditions were characterized by average maximum, minimum and mean temperatures of 33.8, 21.3 and 26.8 °C, as well as photoperiod of 12 h and relative humidity of 83%.

Normal emerged seedlings on any day with at least 1 cm hypocotyl length were counted and the emergence index in soil and percentage were calculated for each nursery bed according to Mock and Skrdla (1978):

$$\text{emergence index} = \sum \frac{(\text{seedling emerged on a day})(\text{days after planting})}{\text{total seedlings emerged}} \quad (1)$$

From each nursery bed, 45-day-oldseedlings were removed from the soil to determine root length (from the root neck to the tip), seedling height and seedling dry weight (after drying in ventilated oven at 80 °C for 72 h) and leaf area per plant (Delta-T Devices Area Meter, Cambridge, UK) including petioles and leaves by random sampling of five seedlings for each treatment. Seedlings were