Colegio de Postgraduados

Effect of the elicitation with magnetic field of corn seeds on the development and nutrition of sprouts

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ABSTRACT

Objective: To evaluate the effect of exposing corn seeds to a 100 mT magnetic field (MF) on their sprout development.

Design/methodology/approach: A completely randomized design was used, with five treatments (0, 10, 15, 30, and 60 minutes of MF exposure) with three repetitions (72 experimental units). From the germination process, the gibberellic acid concentration (GA_3) and α-amylase activity were determined, morphometric and biochemical parameters of the foliar tissue from the sprouts were measured, such as total phenols, flavonoids, and catalase (CAT), peroxidase (POX) and phenylalanium ammonium lyase (PAL) activities. Finally, some nutritional quality parameters of the sprouts were quantified, such as protein and ash content.

Results: The results showed that the treatment of corn seeds with a MF had a favorable effect on the germination process increasing the GA_3 concentration. Also, improvement in the development and quality of the sprouts, by increasing the growth of the shoot, root length, concentration of phenolic compounds and ash content in corn sprouts was found.

Limitations on study/implications: escalate elicitation to the field level.

Findings/conclusions: The elicitation of corn seeds with a magnetic field generates positive changes that transcend the corn sprouts.

Keywords: physical biostimulation of seeds, corn sprouts, *Zea mays*.

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INTRODUCTION

The nutritional quality of plants is a crucial factor to ensure their optimal growth and ability to respond to different environmental conditions. In this sense, applying innovative techniques that promote the improvement of the nutritional quality of plants, from their initial developmental stages, such as germination, has been the subject of growing interest in agricultural research (Bai *et al.*, 2019). Corn (*Zea mays* L.) is one of the most important crops worldwide, due to its extensive utilization in human and animal nutrition (Pingali, 2012). However, the nutritional content of corn seeds is affected by various factors, such as their growing conditions and nutrient availability in the soil. In this sense, researchers

explore new strategies that improve the nutritional quality of corn plants from their initial phase. Magnetic field (MF) exposure on seeds has been shown to have positive effects on different aspects of plant development, including germination, growth, and response to biotic and abiotic stress (Davies and Abeles, 1991). In this context, this research aims to investigate the MF effects on the germination process and changes in the development and nutritional quality of corn sprouts.

MATERIALS AND METHODS

Each treatment was done, in triplicate, with 72 C.V. napalú corn seeds as an experimental unit, exposed to a MF of 100 mT for 10, 15, 30, and 60 minutes. The research was divided into two stages, on the germination process at 72 hours and 7-day sprouts.

Within the germination process, the gibberellic acid (GA_3) concentration was quantified following the Holbrook *et al.* method (1981), and the α-amylases activity following the Miller *et al.* method (1959).

In the sprouts, shoot height and root length were measured. The assessed biochemical and nutritional parameters of sprout foliar tissue were total phenols (Folin-Ciocalteu), flavonoids (aluminum trichloride method), phenylalanine ammonium lyase (PAL) activity, by Beaudoin-Eagan (1985); catalases (CAT) and peroxidases (POX) activity described by Hanna *et al.* (2011). Finally, the protein and ash content were determined following the Bradford method and by Colombato (2000) respectively. A statistical analysis (simple ANOVA) was performed on the results obtained from each experiment, using the Statgraphics Centurion XVIII statistical software, using the Tukey's mean comparison test ($P<0.05$).

RESULTS AND DISCUSSION

The results indicated that the MF treatment on corn seeds had a favorable effect on the germination process, increasing the GA_3 concentration (Table 1).

The elicitation of corn seeds to MF generated a significant increase in the GA_3 concentration, from 15 minutes of exposure. This phytohormone plays an important role in seed germination and stem elongation (Salisbury and Ross, 1992). Similar results were reported by Podleśny *et al.* (2021), where pea seeds exposure to a MF caused a GA_3 increased content. This may be because MF not only affects the chemical properties

Table 1. Effect of corn seeds elicitation with a MF on the gibberellic acid concentration and the enzymatic activity of α-amylases involved in the germination process.

Treatments	GA_3 ($\mu g\ g^{-1}$ fresh weight)	α-amylases ($U\ mg^{-1}$ protein)
Control	1329.89±68.42 c	0.083±0.00 a
CM-10	1356.56±68.42 c	0.123±0.01 a
CM-15	1889.89±93.65 a	0.110±0.02 a
CM-30	1707.67±66.66 ab	0.086±0.00 a
CM-60	1627.67±46.18 b	0.085±0.02 a
DMS ($P<0.05$)	127.897	0.032

of plants but also generates various physical changes in the properties of solutes within the plant cell (Galland *et al.*, 2005). This research demonstrated that there were no changes in the α-amylases activity during the germination of maize seeds previously exposed to MF.

The elicitation of corn seeds through MF not only changes the germination process but also induces changes in the development and growth of corn sprouts (Table 2).

Elicitation of seeds with CM for 60 minutes caused a significant increase of 30% in shoot height and a 21% increase in root length concerning the control. The improvement in root length is a positive result since it would allow the seedling to extract moisture and absorb more nutrients from the soil and, as a consequence, achieve greater growth in the seedlings (Saktheeswari and Subrahmanyam, 1989). The secondary metabolism of sprouts due to exposure of corn seeds to CM increased (Table 3).

The seed's exposure to MF significantly increased the total phenols and flavonoids concentration in the foliar tissue of the sprouts, the 15-minute treatment being the one that had the greatest increase; this concentration relates to the PAL activity (Wei *et al.*, 2015). The results of the antioxidant enzyme activity are depicted in Table 4. The 30-minute exposure of corn seeds significantly increased the CAT activity compared to the control. POX activity had no significant differences. Cheng and Zhang (2016) report contrary results, where the exposure of corn seeds to 200 mT MF in a 3 h exposure period increased CAT activity by 34% so the intensity and exposure time are important factors to consider.

Table 2. Measurement of morphometric parameters of corn sprouts obtained from magnetic field seed elicitation.

Treatments	Shoot height (mm)	Root length (mm)
Control	62.45±17.53 b	20.01±6.31 b
CM-10	51.79±18.90 c	16.70±6.94 c
CM-15	63.59±19.20 b	22.01±6.50 b
CM-30	71.01±16.20 b	22.89±5.55 ab
CM-60	81.87±20.15 a	24.56±8.42 a
DMS ($P<0.05$)	6.15	2.23

Table 3. Total phenols, flavonoids, and enzymatic activity of PAL in leaf tissue of sprouts obtained from the elicitation of corn seeds by magnetic field.

Treatments	Total phenols (mg g^{-1} dry weight)	Flavonoids (μg g^{-1} dry weight)	PAL activity (U mg^{-1} of protein)
Control	1.05±0.02 c	7.20±0.43 c	0.039±0.007 b
CM-10	1.37±0.14 b	10.70±0.33 b	0.047±0.004 b
CM-15	1.68±0.03 a	12.53±0.47 a	0.076±0.016 a
CM-30	1.39±0.14 b	10.79±0.74 b	0.049±0.011 ab
CM-60	1.55±0.01 ab	10.56±0.41 b	0.057±0.009 ab
DMS ($P<0.05$)	0.17	0.90	0.019

Within the assessed nutritional parameters (Table 5), we can highlight that the 15-minute exposure of corn seeds to MF doubled the ash content compared to the control. While for the protein content, there were no significant differences compared to the control, this is not a negative result since the protein content is maintained and not affected by the interaction of the magnetic field with the corn seeds.

There is no scientific evidence that describes the effect of MF on the ash content increase during plant germination. However, some studies suggest that MF can improve nutrient absorption and mineral accumulation in plants, which could have an indirect effect on the ash percentage in the sprouts. For example, Zhang *et al.* (2014) found a Fe accumulation in the roots of white corn plants. Guo and collaborators (2016) observed a Ca, Mg, and Fe accumulation in the roots of tomato plants. Also, Jafari, Ahmadi & Fathi (2018) found greater nitrogen (N), phosphorus (P), and potassium (K) uptake in wheat plants through nutrient uptake by plant roots.

Various hypotheses have been proposed about how magnetic fields improve nutrient absorption and mineral accumulation in plants. One of them is that the magnetic fields affect the plant root cell membrane structure, which in turn improves membrane permeability and nutrient absorption (Dhiman & Sastry, 2014).

Table 4. Effect of corn seeds elicitation with a magnetic field on the antioxidant enzymes activity of sprout foliar tissue.

Treatments	**CAT activity ($U\ mg^{-1}$ of protein)**	**POX activity ($U\ mg^{-1}$ of protein)**
Control	122827.66±4788.2 b	1.760±0.32 a
CM-10	103444±2660.94 d	1.402±0.38 a
CM-15	114859±298.264 c	1.389±0.47 a
CM-30	167339±1578.67 a	1.160±0.53 a
CM-60	78788.7±1662.61 e	0.951±0.17 a
DMS ($P<0.05$)	4837.55	0.728

Table 5. Protein and ash content of corn sprouts obtained from seeds elicitated with a magnetic field.

Treatments	**Protein ($mg\ g^{-1}$ fresh weight)**	**Ashes (%)**
Control	0.015±0.0004 a	2.0±0 b
CM-10	0.015±0.0003 a	3.0±1 ab
CM-15	0.016±0.0003 a	4.0±0 a
CM-30	0.015±0.0001 a	3.0±0 ab
CM-60	0.016±0.0002 a	2.6±0.5 ab
DMS ($P<0.05$)	0.001	0.939

CONCLUSIONS

The elicitation of corn seeds with a magnetic field is an alternative to improve the development and quality of sprouts, by increasing the growth, phenolic compounds, and ash content in corn sprouts.

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