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Magnetic field effect on breaking tuber dormancy, early sprouting, seedling growth, and tuber formation in potato (*Solanum tuberosum* L.)

Anzel Bahadir[a], **Nilufer Kocak Sahin**[b], **Ramazan Beyaz**[c], **Mustafa Yildiz**[b,*]

[a] Department of Biophysics, Faculty of Medicine, Duzce University, Konuralp, Duzce 81620 Turkey
[b] Department of Field Crops, Faculty of Agriculture, Ankara University, Ankara 06110 Turkey
[c] Department of Soil and Plant Nutrition, Faculty of Agriculture, Kırşehir Ahi Evran University, Kırşehir 40200 Turkey

*Corresponding author, e-mail: myildiz@ankara.edu.tr

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ABSTRACT: Magnetic field (MF) treatment improves the germination of seeds and enhances the performance of various crops. In this study, the effects of different MF strengths (0-control, 75, 150, and 300 mT) and exposure time periods (0-control, 24, 48, and 72 h) on sprouting of dormant seed potato tubers, vegetative growth (emergence time and plant height), tuber formation (tuber number per plant and mean tuber weight), and total chlorophyll content in 2 potato (*Solanum tuberosum* L.) cultivars ('Necta' and 'Banba') were investigated in all parameters examined in both cultivars, the worst results were recorded in control treatment where no MF strength was used. Emergence times of sprouts were reduced significantly when seed potato tubers were exposed to 150 mT MF strength for 72 h in both cultivars. The fastest emergence times were recorded as 14.0 days in cv. 'Nectar' and 17.0 days in cv. 'Banba' when seed tubers were exposed to 150 mT MF strength for 72 h. In control treatment, emergence time of sprouts was noted as 31.8 days in cv. 'Nectar' and 39.5 days in cv. 'Banba'. The best results in other parameters (plant height, total chlorophyll content, tuber number per plant and mean tuber weight) were again obtained from seed tubers treated with 150 mT MF strength for 72 h whereas the worst results were noted in control treatment in both cultivars. Thus, MF pre-treatment can compensate for the negative effects of dormancy in seed potato tubers.

KEYWORDS: dormancy, magnetic field strength, potato

INTRODUCTION

The effects of magnetic fields (MFs) on living organisms are being examined. The MF treatment is one of the physical treatments that have been reported to enhance the performance of various crops. The physical treatments influence the physiological and biochemical processes in seeds and thereby contribute to a greater vegetative growth and improve crop yield and quality [1]. The MF treatments are being used in agriculture as a new environmentally friendly technique to improve the germination of seeds and increase yield by affecting the physiological and biochemical processes in seed material [1–3]. It has been reported that exposing seeds to MFs may accelerate or stimulate growth, seed vigor, and yield in various plant crops [2, 4]. Moreover, MF treatments affect photosynthetic pigment content [5] and mineral uptake [3, 6] by altering biochemical processes related to free radicals and stimulating the activity of enzymes [6].

Potato (*Solanum tuberosum* L.), a very important plant, is the fourth-largest food crop produced in the world (following maize, wheat, and rice) with approximately 390 million tonnes of production [7]. This product is a staple in many diets throughout the world, and the underground swollen tubers of the plant are rich source of proteins, carbohydrates, minerals, and vitamins [8]. Dormancy is affected from pre-harvest and post-harvest conditions [9]. Dormancy in the potato is explained as the physiological stage of the tuber in which sprouting will not occur although there are favorable conditions such as temperature (15–20 °C) and humidity (90%) [10]. Dormancy in potato is the period from haulm killing to the time 80% of the tubers show at least one sprout longer than 2 mm [11, 12]. The onset of dormancy is associated with the cessation of meristematic activity at the stolon tip during tuber initiation. Tuber dormancy deepens further

following the death/destruction of the canopy. Dormancy gradually develops in potato tubers from the moment cell division in the stolon tip ceases and the tuber starts to expand. During dormancy, biochemical reactions and physiological processes continue to occur within the tuber, but they do not manifest as morphological changes. Thus, potato dormancy is controlled by complex interactions between genotypic and environmental factors during tuber development and storage, but the underlying mechanisms are still poorly understood [13]. Although there were some reports on the effect of MF in potato, none of them mentioned about dormancy breaking effect of MF strength in tubers and effects towards crop production such as tuber number per plant and mean tuber weight except the current study. From this aspect, the present study aimed to examine the effects of different MF strengths (0-control, 75, 150, and 300 mT) and exposure times (24, 48, and 72 h) on breaking dormancy in seed potato (*Solanum tuberosum* L.) tubers, vegetative growth, total chlorophyll content, tuber number per plant, and mean tuber weight in 2 cultivars ('Nectar' and 'Banba').

MATERIALS AND METHODS

Plant material

Seed tubers from 2 potato cultivars ('Nectar' and 'Banba') weighing 40–60 g and commonly grown in Turkey were used as plant material in this study. 'Nectar' produces high numbers of tubers with very smooth skin and very suitable for pre-packing. It has good resistance to tuber blight, gangrene and common scab while also kept well in storage. 'Banba' produces a high percentage of wide long-oval tubers. It is resistant to foliage blight, common scab, drought and mechanical damage. Both cultivars are in the "early main crop" group. Seed tubers showing dormancy were used to reveal the effects of MF strength on dormancy breaking.

Magnetic field generation

A MF system consists of 2 Helmholtz coils forming an electromagnet mounted on a wooden frame. The number of turns of copper wire per coil was 3000. The mean MF in the center of the coils ranged from 50 to 500 mT. Coils which were placed horizontal were connected to a power supply (0–12 A, ref. 13506-93, PHYWE, Gottingen, Germany). Moreover, intensity through the coils was measured by an ampermeter. GD anode was placed between coils. The accuracy and uniformity of MF strengths were detected by a digital teslameter (ref. 13610-93, PHYWE, Gottingen, Germany).

Magnetic field treatment

Seed tubers of 2 potato cultivars ('Nectar' and 'Banba') placed in the middle of the gap between the coils were exposed to different MF strengths (0-control, 75, 150, and 300 mT) for 0-control, 24, 48, and 72 h. The MF strengths used in the study (75, 150, and 300 mT) were determined according to the protocols described by Aycan et al [14]. All treatments were carried out in laboratory condition where all parameters such as temperature and humidity were controlled.

Growth conditions

MF-treated and untreated (control) tubers from 2 potato cultivars ('Nectar' and 'Banba') were planted in pots with a peat/soil mix. Throughout the study, the plants were regularly irrigated, and soil moisture was measured using the Soil Moisture Meter (Bioterm 812, PL). All the required agronomic practices including fungicides, herbicides, insecticides, and fertilizers were applied to obtain better yield output.

Measured yield parameters

Emergence time of sprouts was recorded within 40 days after study initiation while total chlorophyll content (mg chlorophyll/g fresh tissue) in the leaves of the plants was calculated in leaves of 90-day-old plants when photosynthetic activity was the highest in the yield formation period. Other parameters (plant height (cm), tuber number per plant, and mean tuber weight (g)) were determined when tubers were harvested 120 days after study initiation. After recording emergence time values, plants were transferred to bigger pots in which there was the same volume of soil allocated for a plant as in field condition and incubated in a greenhouse at 25 ± 1 °C under cool white fluorescent light (1000 μmol $m^{-2}s^{-1}$) with a 16 h light/8 h dark photoperiod. Plant heights were measured by laser meter (DeWalt DW03050) with a precision of 1 mm.

Total chlorophyll content was calculated and expressed as mg/g fresh tissue. Twenty leaves from 20 separate plants out of 100 were used. Fresh leaf tissue (50 mg) was put in 3 ml methanol and kept in total darkness at 23 ± 1 °C for 2 h. The chlorophyll in the tissue passed into the methanol. After 2 h, absorbance values were determined at 665 and 650 nm in UV Spectrophotometer [15].

Days 40, 90, and 120 were selected for the end of the emergence period, for the middle of the yield formation period and for maturity period, respectively.

Statistical analysis

The experiment was conducted according to the "Completely Randomized Block Design" concept. For each MF strength (0-control, 75, 150, and 300 mT) and exposure time (0-control, 24, 48, and 72 h), 10 replicates were tested. Each replicate contained 10 pots with 1 tuber in each. That means 100 tubers were sown for each treatment in both cultivars at the beginning of the study. All statistical analysis was performed using the SPSS Statistics 22 (IBM Corp, Chicago, IL, USA) computer program. Two-way analysis of variance (ANOVA) was used to test the effects of the main factors (MF strength and exposure time) and their interactions. As control, values obtained from 0 mT MF strength for 0 h exposure time were recorded for each parameter. The values in 75, 150, and 300 mT MF strength for 0 h exposure time, and the ones recorded in 24, 48, and 72 h exposure time at 0 mT MF strength are the same as the values obtained in control treatment. Means were compared using Duncan's multiple range test at the 1% level of probability in the experiment. Data presented in percentages were subjected to arcsine ($\sqrt{X}$) before statistical analysis [16].

RESULTS

The effects of different MF strengths and exposure times are shown in Table 1 and Table 2 for cvs. 'Nectar' and 'Banba'. Correlations between MF strengths and exposure times for both cultivars in all parameters were statistically significant ($p < 0.01$).

The results showed that the emergence time of sprouts was shortened by increasing exposure time in each MF strength and by increasing MF strength in each exposure time period for both cultivars. The shortest emergence times were recorded as 14.0 and 17.0 in cvs. 'Nectar' and 'Banba', respectively when seed tubers were treated with 150 mT MF strength for 72 h. In 72 h exposure time period, at MF strengths below and over 150 mT, emergence times of sprouts were longer in both cultivars. Sprouts were emerged 31.8 and 39.5 days after study initiation in control treatment where no MF strength was used while they were emerged 14.0 and 17.00 days after study initiation at 150 mT MF strength for 72 h in cvs. 'Nectar' and 'Banba', respectively. This meant that emergence times were shortened more than half in both cultivars (Table 1 and Table 2).

It was observed that plant height was increased by increasing exposure time and MF strength except 300 mT. Plant height increased from 25.5 and 25.6 cm in control treatment (no magnetic field strength was used) to 82.5 and 90.8 cm at 150 mT MF treatment for 72 h in cvs. 'Nectar' and 'Banba', respectively (Table 1 and Table 2).

The highest values with respect to total chlorophyll content were recorded as 2050.5 and 2150.3 μg/g fresh tissue at 150 mT MF strength for 72 h in cvs. 'Nectar' and 'Banba', respectively. On the other hand, the lowest total chlorophyll contents were recorded in control treatment where no MF stregth was applied, as 1064.3 and 1127.5 μg/g fresh tissue in cvs. 'Nectar' and 'Banba', respectively (Table 1 and Table 2).

At the end of the study (120 days after study initiation), the highest results in tuber number per plant and mean tuber weight were recorded as 8.0 and 78.2 g in cv. 'Nectar', and 10.0 and 59.1 g in cv. 'Banba', respectively, at 150 mT MF strength for 72 h exposure time period. The lowest results were again noted in control treatment as 3.0 and 39.0 g in cv. 'Nectar', and 6.0 and 36.7 g in cv. 'Banba' (Table 1 and Table 2).

The best values were observed in 150 mT MF strength in all parameters for both cultivars (Table 1 and Table 2). When exposure times were examined, the best results were obtained in long exposure times. Thus, the best results were noted in the 72 h exposure time whereas the worst ones were recorded in the control treatment where no exposure time was applied in both cultivars. In other words, dormancy breaking effect of magnetic field was most efficient at 150 mT strength for an exposure time of 72 h.

DISCUSSION

All plants are continuously exposed to weak MFs and low-frequency electromagnetic fields (EMFs) at the Earth's surface because the earth's geomagnetic field ranges between 25 μT at the equator to 75 μT at the poles [17]. However, the effect of weak MFs on biological organisms including plants is not understood sufficiently [18]. It is difficult to reveal the effects of magnetic fields (MFs) on living organisms because biological systems are nonhomogenous and complex structures. Although the mechanisms of MF are not well understood, there are many studies reporting that MF can induce biological changes. MFs can be classified as weak (<1 mT), moder-

Table 1 Effects of different MF strengths and exposure times on emergence time of sprouts (within 40 days), total chlorophyll content (in day 90), plant height, tuber number per plant, and mean tuber weight (in day 120) in cv. 'Nectar'.

MF	Emergence time (day)				Plant height (cm)			
strength	0 h	24 h	48 h	72 h	0 h	24 h	48 h	72 h
0-control	31.8 ± 0.80^{f}	31.8 ± 0.80^{f}	31.8 ± 0.80^{f}	31.8 ± 0.80^{f}	25.5 ± 0.96^{g}	25.5 ± 0.96^{g}	25.5 ± 0.96^{g}	25.5 ± 0.96^{g}
75 mT	31.8 ± 0.80^{f}	31.5 ± 0.95^{f}	26.3 ± 0.95^{e}	19.5 ± 0.96^{c}	25.5 ± 0.96^{g}	38.8 ± 0.95^{f}	39.8 ± 0.98^{f}	42.3 ± 0.90^{e}
150 mT	31.8 ± 0.80^{f}	31.0 ± 1.00^{f}	25.8 ± 0.97^{e}	14.0 ± 1.00^{a}	25.5 ± 0.96^{g}	77.8 ± 0.98^{b}	80.8 ± 0.97^{a}	82.5 ± 0.97^{a}
300 mT	31.8 ± 0.80^{f}	26.0 ± 1.00^{e}	21.3 ± 0.99^{d}	17.8 ± 0.96^{b}	25.5 ± 0.96^{g}	63.5 ± 0.94^{d}	63.8 ± 0.96^{d}	67.5 ± 0.98^{c}
	Tuber number per plant				Mean tuber weight (g)			
	0 h	24 h	48 h	72 h	0 h	24 h	48 h	72 h
0-control	3.0 ± 1.00^{f}	3.0 ± 1.00^{f}	3.0 ± 1.00^{f}	3.0 ± 1.00^{f}	39.0 ± 0.94^{d}	39.0 ± 0.94^{d}	39.0 ± 0.94^{d}	39.0 ± 0.94^{d}
75 mT	3.0 ± 1.00^{f}	3.5 ± 0.98^{ef}	5.3 ± 0.92^{cde}	7.5 ± 0.95^{ab}	39.0 ± 0.94^{d}	33.0 ± 0.97^{e}	39.3 ± 0.96^{d}	41.0 ± 0.89^{c}
150 mT	3.0 ± 1.00^{f}	3.8 ± 0.95^{def}	5.5 ± 1.00^{cd}	8.0 ± 1.00^{a}	39.0 ± 0.94^{d}	38.2 ± 1.02^{d}	65.9 ± 0.99^{b}	78.2 ± 0.96^{a}
300 mT	3.0 ± 1.00^{f}	6.0 ± 1.00^{bc}	4.0 ± 1.00^{def}	3.0 ± 1.00^{f}	39.0 ± 0.94^{d}	30.7 ± 0.95^{f}	28.0 ± 1.00^{g}	25.0 ± 1.00^{h}
	Total chlorophyll content (μg/g fresh tissue)							
	0 h	24 h	48 h	72 h				
0-control	1064.3 ± 0.96^{j}	1064.3 ± 0.96^{j}	1064.3 ± 0.96^{j}	1064.3 ± 0.96^{j}				
75 mT	1064.3 ± 0.96^{j}	1145.8 ± 1.07^{i}	1256.3 ± 0.96^{h}	1288.2 ± 0.88^{g}				
150 mT	1064.3 ± 0.96^{j}	1855.4 ± 0.94^{c}	1916.9 ± 1.01^{b}	2050.5 ± 0.94^{a}				
300 mT	1064.3 ± 0.96^{j}	1416.9 ± 0.92^{e}	1444.3 ± 0.98^{d}	1395.7 ± 0.98^{f}				

Values represent mean ± standard error of the mean. Values followed by different letters for each parameter are significantly different at the 0.01 level.

Table 2 Effects of different MF strengths and exposure times on emergence time of sprouts (within 40 days), total chlorophyll content (in day 90), plant height, tuber number per plant, and mean tuber weight (in day 120) in cv. 'Banba'.

MF	Emergence time (day)				Plant height (cm)			
strength	0 h	24 h	48 h	72 h	0 h	24 h	48 h	72 h
0-control	39.5 ± 1.04^{f}	39.5 ± 1.04^{f}	39.5 ± 1.04^{f}	39.5 ± 1.04^{f}	25.6 ± 1.01^{h}	25.6 ± 1.01^{h}	25.6 ± 1.01^{h}	25.6 ± 1.01^{h}
75 mT	39.5 ± 1.04^{f}	31.3 ± 0.99^{e}	30.8 ± 0.97^{de}	29.3 ± 1.03^{d}	25.6 ± 1.01^{h}	39.0 ± 1.00^{g}	40.3 ± 1.04^{g}	42.5 ± 1.02^{f}
150 mT	39.5 ± 1.04^{f}	26.0 ± 1.00^{c}	21.3 ± 0.99^{b}	17.0 ± 1.00^{a}	25.6 ± 1.01^{h}	80.4 ± 1.03^{c}	88.3 ± 0.96^{b}	90.8 ± 0.93^{a}
300 mT	39.5 ± 1.04^{f}	31.0 ± 1.00^{de}	26.3 ± 0.97^{c}	20.5 ± 0.95^{b}	25.6 ± 1.01^{h}	75.7 ± 0.93^{e}	77.3 ± 1.02^{de}	78.0 ± 1.00^{d}
	Tuber number per plant				Mean tuber weight (g)			
	0 h	24 h	48 h	72 h	0 h	24 h	48 h	72 h
0-control	6.0 ± 1.00^{def}	6.0 ± 1.00^{def}	6.0 ± 1.00^{def}	6.0 ± 1.00^{def}	36.7 ± 0.97^{e}	36.7 ± 0.97^{e}	36.7 ± 0.97^{e}	36.7 ± 0.97^{e}
75 mT	6.0 ± 1.00^{def}	5.0 ± 1.00^{ef}	6.0 ± 1.00^{def}	8.0 ± 1.00^{bc}	36.7 ± 0.97^{e}	33.3 ± 0.98^{f}	38.5 ± 1.04^{d}	44.9 ± 0.93^{c}
150 mT	6.0 ± 1.00^{def}	7.3 ± 0.96^{bcd}	8.8 ± 0.95^{ab}	10.0 ± 1.00^{a}	36.7 ± 0.97^{e}	34.6 ± 0.91^{f}	50.4 ± 1.02^{b}	59.1 ± 0.97^{a}
300 mT	6.0 ± 1.00^{def}	6.3 ± 1.04^{cde}	4.8 ± 0.93^{ef}	4.0 ± 1.00^{f}	36.7 ± 0.97^{e}	29.7 ± 0.95^{g}	45.0 ± 1.00^{c}	38.3 ± 1.01^{de}
	Total chlorophyll content (μg/g fresh tissue)							
	0 h	24 h	48 h	72 h				
0-control	1127.5 ± 0.99^{j}	1127.5 ± 0.99^{j}	1127.5 ± 0.99^{j}	1127.5 ± 0.99^{j}				
75	1127.5 ± 0.99^{j}	1214.6 ± 1.05^{i}	1327.7 ± 0.99^{g}	1321.1 ± 0.92^{h}				
150	1127.5 ± 0.99^{j}	1927.4 ± 0.99^{c}	1985.7 ± 1.00^{b}	2150.3 ± 0.99^{a}				
300	1127.5 ± 0.99^{j}	1500.5 ± 0.96^{f}	1558.3 ± 1.06^{e}	1789.5 ± 0.97^{d}				

Values represent mean ± standard error of the mean. Values followed by different letters for each parameter are significantly different at the 0.01 level.

ate (1 mT–1 T), strong (1–5 T), and ultra-strong (>5 T) [19]. MFs can easily penetrate biological tissues, and they cannot be shielded [20]. Field intensity and gradient are important parameters having a role on the biological effects of MFs [21, 22]. MFs can directly affect charges (ions, proteins, etc.) and magnetic materials found in tissues [23]. Four parameters of MF interact with biological systems: target tissue(s), magnet characteristics, magnet support device, and dose applied [24]. On the other hand, it is assumed that 3 physical properties of MF have important roles on the interaction with biological systems: electro-dynamic induction with ionic conduction currents, magneto-mechanical in-

teraction, and electro-spin interaction [25, 26]. In addition, biochemical changes such as radical pair mechanism, ion cyclotron resonance mechanism, ferrimagnetism, and enzyme activity have been explained by several theories [27]. The MF's effect observed with radical pair recombination is a well-known mechanism by which MFs interact with biological systems. MF exposure can affect the conversion between singlet and triplet states of radicals and change the radical pair recombination rate [25]. Thus, concentration and activity of paramagnetic free radicals, which might cause oxidative stress, genetic mutations, and/or apoptosis [19], can be increased by the exposure of MF. However, there is not a satisfactory explanation about how MFs affect biological systems [28].

There is a direct connection between the biological effects of MF and the type, degree, and exposure duration of the field. Many scientists have researched the positive and negative biological effects of MFs on living organisms. MFs cause changes in the biological activities of organisms. MF exposure to the various plant species may cause different biological effects at the cellular, tissue, and organ levels [1, 3]. MF pre-treatment techniques under appropriate conditions are a promising technique for improving seed germination, vegetative growth, and fruit yield of vegetable crops. Exposure of seeds to magnetic field strength increases seed germination and plant development by increasing water assimilation and photosynthesis [29–31]. MF pre-treatment increases germination performance or growth in various plants such as sunflower [32], tomato [4], soybean [5], cotton [3], potato [33], lentil [33], flax [14], grass pea [33], and *Lathyrus chrysanthus* Boiss [34] with different strengths, frequencies, and exposure times. For this reason, we investigated interactive effects of different MF strengths and exposure times for increasing sprouting by breaking dormancy, vegetative growth, tuber characteristics, and total chlorophyll content parameters in 2 potato (*Solanum tuberosum* L.) cultivars ('Nectar' and 'Banba').

Pittman [35] published the first report about MF treatment of potato. The author used a permanent 115 mT MF to stimulate fresh potato tubers and found the mass of leaves and stems as well as the number, mass, and yield of tubers increased by 20%. A variable MF with an induction of 0.9, 1.8, 3.6, and 5.5 T has a positive effect on the storage life of potato tubers measured in losses and wastage because of natural diseases [36].

Rakosy-Tican et al [37] have reported that the effect of MF treatment could be changed according to species, genotype, explant type, treatment period and culture medium.

Marks and Szecówka [38] examined the influence of 3 different MF strengths (20, 40, and 80 mT) applied to potato tubers for 1 h on the growth of above ground parts. Their results showed that there were statistically significant differences between MF treatment and control applications with respect to the length and number of stems, mass of leaves and stems, and index of potato germination. All parameters increased compared to the control treatment, which demonstrates that magnetic stimulation of potato tubers has a favorable effect on the course of vegetation of above ground parts of plants.

El-Gizawy [1] studied the effects of extremely low MF intensities on germination of true potato seeds, vegetative growth, and tuber parameters of the cv. 'Spunta'. They used 3 MF strengths: 20, 30, and 40 mT for 3 short periods: 5, 10, and 15 min compared to untreated true potato seeds (control). Their results indicated that MF treatments significantly increased the sprouting percentage of true potato seeds and parameters of vegetative growth. In their study, true potato seeds exposed to 30 mT MF for 10 min produced the highest significant values of germination percentage, plant height, number of leaves per plant, and fruit yield parameters (number of tubers, fresh weight of tubers per plant, and potato tuber diameter).

Yildiz et al [33] reported that treating seeds/tubers from lentil (cv. 'Çiftçi'), grass pea (cv. 'Gürbüz'), and potato (cv. 'Marabel') with MF strength had positive effects on breaking dormancy. Their results showed that there were statistically significant effects on breaking tuber dormancy in potato (*Solanum tuberosum* L. cv. 'Marabel') by applying pre-treatment with various levels of MF strength and exposure time. They found that 150 mT MF strength for 72 h exposure time showed the best results to break seed tuber dormancy, whereas the control group showed the worst. Thus, they suggested that the differences in the effects of MF strengths and exposure times were related to plant species and cultivars.

In our study, in cv. 'Nectar', results obtained in 300 mT MF strength for 72 h exposure time in tuber number per plant and for 24, 48, and 72 h exposure times in mean tuber weight were lower than control treatment. Similarly, in cv. 'Banba', values recorded in 300 mT MF strength for 48 and 72 h exposure times in tuber number per plant and for 24 h exposure time in mean tuber weight were

lower than control treatment. In both cultivars, the data recorded in 300 mT MF strength for all exposure times for other parameters (emergence time, plant height and total chlorophyll content) were higher than control treatment. Our findings were parallel to the ones of Beyaz et al [39]. In the study examining the effect of gamma radiation on seed germination and seedling growth, the researchers reported that seed germination increased at 150 Gy gamma dose over control treatment where no gamma radiation was applied while some developmental parameters such as seedling height and seedling fresh weight at the same dose (150 Gy) were lower than control treatment. This could be attributed to the negative effects of higher MF strength occurring in the further stages in development.

In the current study, the effects of different MF strengths and exposure times on emergence time of sprouts, plant height, total chlorophyll content, tuber number per plant, and mean tuber weight were examined. In accordance with our results, the pre-treatment of tubers with different MF strengths had a statistically significant positive effect on the emergence time, plant height, total chlorophyll content, tuber number per plant, and mean tuber weight. The best values were obtained from tubers treated with a MF strength of 150 mT for 72 h exposure time whereas the worst results were noted in control treatment in both cultivars ('Nectar' and 'Banba').

CONCLUSION

Consequently, these results showed that MF pre-treatment compensated for the negative effects of dormancy in potato tubers. This pre-treatment eliminates the necessity of special reservoirs and/or storages to break tuber dormancy. Moreover, MF treatment can contribute to reduce production costs by improving the efficiency of the tuber production system. However, further research is needed to determine the positive biological effects of MFs according to type, strength, and the exposure time in plants, especially in agriculturally important crops, to reduce yield losses, increase crop performance, and provide breeders with temporary and quick solutions.

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