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Impact of variable magnetic field stimulation on growth of aboveground parts of potato plants**

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A b s t r a c t. The paper presents the results of investigations on of the influence of variable magnetic field applied for stimulation of potato tubers on the growth of aboveground parts of potato plants. Parameters adopted for rating of the growth included the average height of the stems, measured from ridge top to the end of sprout, the average number of potato plant stems, the average mass of stems and leaves, the average index of stimulation rate of emergence, the ratio of the number of stems grown from a tuber to the number of eyes. The tests were carried out 50 on tubers in 3 replications. The stimulation was performed using a solenoid with induction levels of 20, 40, and 80 mT. The time of stimulation was 1 h, and the exposure doses were 1 145.9, 4 583.6, and 18 334.6 kJ m^{-3} s, respectively. Field experiments were carried out in three replications. The results clearly indicated a statistically significant favourable influence of magnetic induction and exposure dose on the length and number of stems, the mass of leaves and stems, and on the index of the potato germination, causing an increase of those parameters in relation to the control treatment, which demonstrates that magnetic stimulation of potato tubers has a favourable effect on the course of vegetation of above-ground parts of potato plants.

K e y w o r d s: solenoid, magnetic field, magnetic induction, exposure dose, potato

INTRODUCTION

The characteristic feature of a variable magnetic field is caused by the change of the position of magnetic poles in a unit of time. The change of pole positions may result from the use of rotating magnets (Yano *et al*., 2001) or, in the case of the use of electromagnets, by changing the frequency of current flow (Halliday, 2003). Depending on the level of applied magnetic induction and frequency of polarity shift, different effects on various plant organisms can be obtained. Pietruszewski (1999, 1999a), using pre-stimulation of seeds of wheat with varying magnetic field (induction of 30 mT, 50 Hz), obtained improved seed germination and increased yield levels. Podleśny and others (2004, 2007), stimulating horse bean seeds and pea seed with magnetic field with induction of 30 and 85 mT at a frequency of 50 Hz, also obtained accelerated plant growth and increased yield. Sabehat *et al*. (1998), stimulating sowing seeds with magnetic field with induction of 100 mT at 50 Hz, found that plant growth was stimulated better with an increase of temperature, and Gutzeit (2001) confirmed this observation. Fischer *et al*. (2004), stimulating the seeds of sunflower with magnetic field with induction of 20 μT and 16 Hz frequency, obtained an increase of the mass and height of the plants. Aksenov *et al*. (2001), stimulating wheat seed with magnetic field of the induction of 30 mT and the frequency of 50Hz, received a boost to the growth of roots and shoots. Strange *et al*. (2002), using magnetic field with induction of 10 and 100 μT, 50 Hz, observed increased ion penetration in the root system of bean. Positive impact of variable magnetic field was also claimed by Davis (1996) in the case of radishes, Ruzic *et al*. (1992) for edible chestnuts, Kobayashi and others (2004) in the case of Japanese Cryptotaenia-Hornwort, and Takimoto *et al*. (2001) in relation to reddish common bean. The first scientific report about magnetic stimulation of potato was published by Pittman (1972). Using permanent magnetic field with induction of 115 mT to stimulate fresh potato tubers, he obtained an increase in the mass of leaves and stems, in the number and mass of tubers, and yield of commercial

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tubers increased by 20%. It was also found that a variable magnetic field with induction of 0.9, 1.8, 3.6 and 5.5 T had a favourable effect on the storage life of potato tubers measured in losses and wastage due to natural diseases (Marks, 2005). The lack of information in the available literature on the impact of variable magnetic field on the growth and development of potato, and the promising results reported by the authors quoted, obtained in relation to other plant species and cultivars, were the basis for undertaking this research on the effects of fluctuating magnetic fields on the course of potato growth.

The purpose of this paper is to demonstrate the effect of stimulation of seed-potatoes with alternating magnetic field on the growth and development of the aboveground parts of potato plants as described by the length and number of stems, sprouts and leaves, and by the mass and germination rate of tubers in relation to the control sample (non-stimulated).

MATERIALS

The field studies were carried out on an early variety of potato (var. Vineta) during 2 years. Both the laboratory and the field tests were performed at facilities of the Department of Agricultural and Food Technology, Agricultural University in Cracow. The following features (50 measurements) were determined during this experiment: height of stems measured from the ridge apex to the top of the sprout, the number of stems per one plant, the mass of stems and leaves, to the nearest 0.001 g, the index of stimulation (%), and the ratio of the number of stems grown from a single tuber to the number of eyes on the seed-potato tuber. The measurements were performed in three periods: 35, 45, and 60 days after planting.

METHODS

Stimulation of seed-potatoes with variable magnetic field was carried out using a solenoid as a device which meets the basic research assumption that the magnetic induction should be uniform over the entire surface of seed-potato. A schematic of the solenoid, an original device developed and constructed by the authors, is presented in Fig. 1, the electrical configuration of the device in Fig. 2, and visualization of the distribution of the generated magnetic field (Fig. 3). Visualization of results was compared with the actual values recorded by Smart Magnetic Sensor type SMS 102. The actual characteristics of magnetic induction generated by the solenoid were drawn on this basis, as illustrated (Fig. 4). The solenoid made it possible to obtain magnetic field with induction of 80 mT, so the studies used induction values of 20, 40, and 80 mT. Based on preliminary research carried out, the exposure time of 1 h was adopted. The value of magnetic induction and the exposure time allowed us to determine 3 doses of exposure, namely: 1145.9, 4583.6, and 18334.6 kJ m^{-3} s as dependent variables.

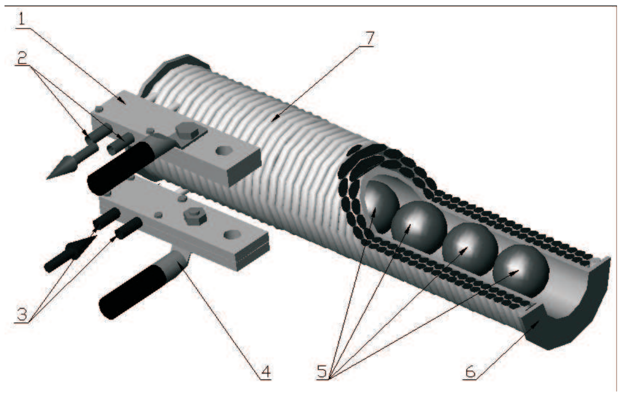

Fig. 1. Schematic of the solenoid for magnetic stimulation of seed potatoes: 1 – power supply, 2 – cooling liquid outlet, 3 – coolant inlet, 4 – power cords, 5 – potato tubers; 6 – housing, 7 – winding (Szecówka, 2008).

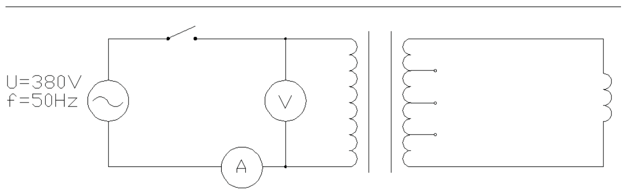

Fig. 2. Schematic diagram of electrical system of the solenoid (Szecówka, 2008).

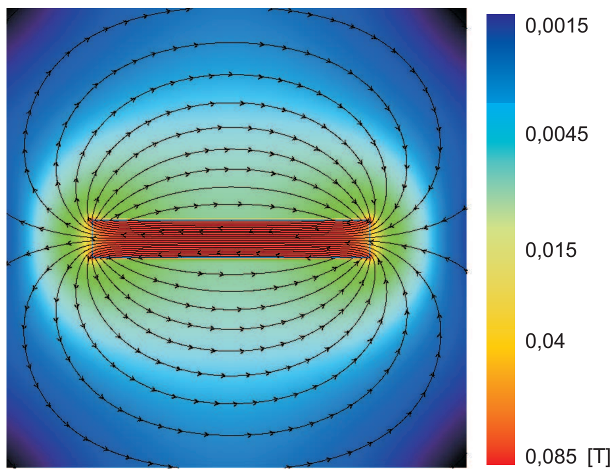

Fig. 3. Visualization of the distribution of magnetic field inside of the solenoid, constructed with the help of Vizmag 3.15 (Szecówka, 2008).

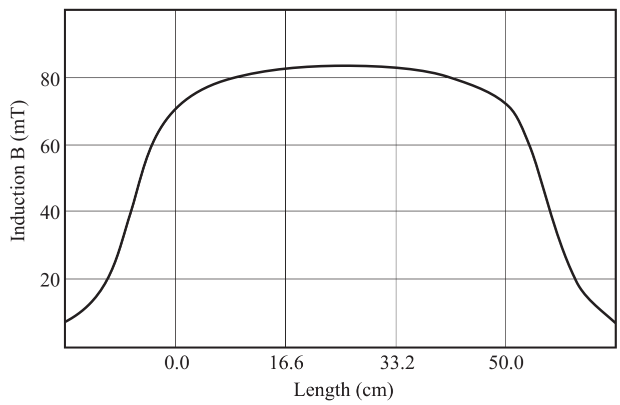

Fig. 4. Characteristics of solenoid magnetic induction (Szecówka, 2008).

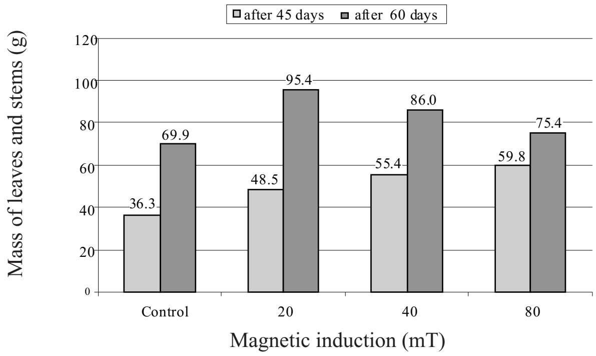

Fig. 5. Effect of magnetic induction on the mean mass of leaves and stems of potato plants.

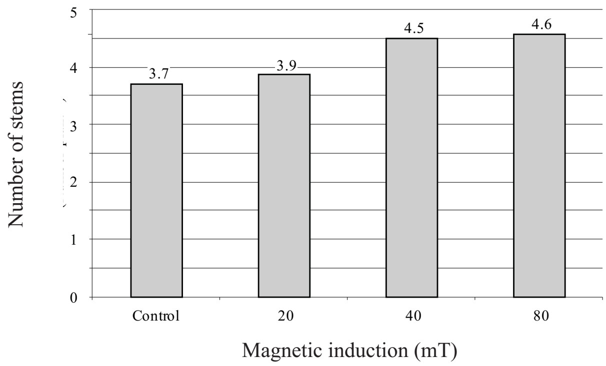

Fig. 6. Effect of magnetic induction on the number of stems of potato plants.

RESULTS

The effect of magnetic induction (Fig. 5) on the mass of aboveground parts of potato plants after 45 days of vegetation caused an increase in the value of the mass of stems and leaves, compared with the control sample. The largest increases were observed in plants stimulated by induction of 80 mT, where the mass was up 65% compared to the control sample. Other levels of induction also gave a positive effect, at 33% for the induction of 20 mT and 52% for the induction of 40 mT, respectively. However, after 60 days the rate of increase of the mass of leaves and stems showed a clear decrease with increasing magnetic induction. The highest increase in comparison with the control sample was observed for the induction of 20 mT, lower for 40 mT, and the lowest the induction of 80 mT. Increase of mass amounted to 36% for 20 mT, 23% for 40 mT and 8% for 80 mT, respectively. The average mass of stems and leaves of plants stimulated with magnetic field was 22% higher than that of plants that were not stimulated. The evolution of these indicators confirms the observation made when determining the number of stems, namely, that with the end of the growing season the rate of increase declined, although the absolute mass was higher than that of the control sample. The coefficient of the mass is equal to 1.9 for the control sample, 2.0 for 20 mT, 1.5 for 40 mT, and 1.2 for 80 mT. The coefficient of the rate of the mass increment is equal to 1.9 for the control sample, 2.0 for 20 mT, 1.5 for 40 mT, and 1.2 for 80 mT.

The other levels doses of induction also showed a positive effect.. Statistical analysis showed significant variation between the value of the control sample and inductions of 40 and 80 mT. Thus, this factor and the impact of magnetic induction have proved to be positive (Fig. 6). Effect of dose on the height of exposition potato stems (Fig. 7) showed that increasing the dose rate of growth also continued to expand, and in all measurement dates in two years of the study. The highest dose showed the highest growth rates is 18334.6 kJ m^{-3} s, an intermediate dose of 4583.6 kJ m^{-3} s, and the lowest 1145.9 kJ m^{-3} s.

The differences for the measurement period (45 or 60 days) are statistically relevant. The influence of the induction on the number of the stems growing from one bulb also showed a positive effect (Fig. 6). The average amount of the stems of the potato grew with the increasing induction reaching its maximum for the induction of 80 mT. Comparing this to the control sample, the increase is as big as 23%. The remaining levels of the induction have proved to be positive as well. The statistical analysis showed significant variation between the value of the control sample and inductions of 40 and 80 mT. Thus, the influence of the magnetic induction confirmed again to be positive for this factor. The affect of the exposure doses on the height of the potatoes' stems (Fig. 7) showed, that the rate of growth increased with the exposure dose in all measurement dates in both years of the study. The doses of 18 334.6, 4 583.6, and 1145.9 kJ m^{-3} s determined respectively the highest, intermediate and the lowest growth rates.

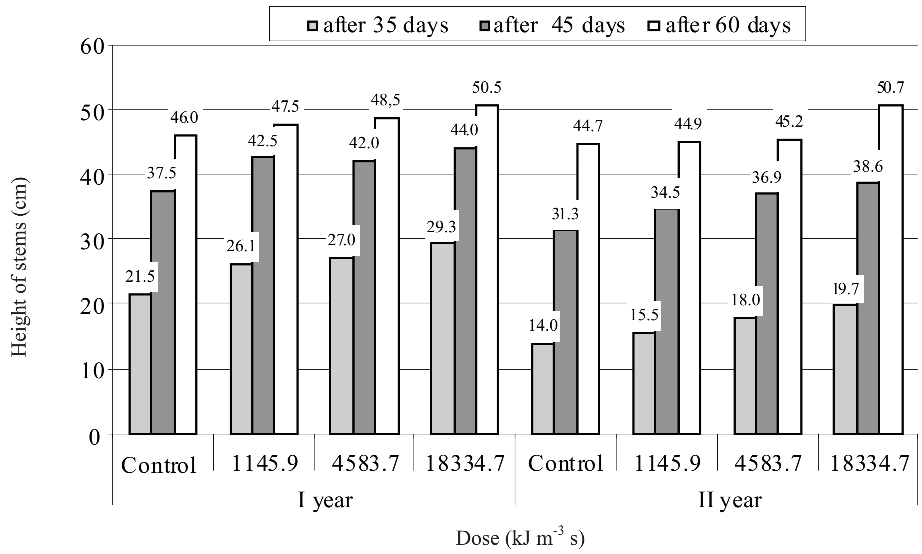

Fig. 7. Effect of exposure dose on the height of stems of potato plants.

The effect of induction on the height of the stems of potato (Fig. 7) proved to be statistically significant. The largest increases were obtained for the induction of 80 mT, where after 35 days the stems were 33% higher, after 45 days 19% higher, and 60 days 9% higher compared with the control sample. The average height of the stems was 20% greater than in the non-stimulated plants. The other values of induction also gave a positive result. It should be noted, however, declining at the time of the dynamic growth of stems grown from stimulated seed compared to the attempt to control, respectively, 33, 19, and 9% for the induction of 80 mT. The pace of growth set out the ratio of height after 60 days to stems of a height of the stems after 35 days was 3.2 for vegetation control sample, 2.8 for the induction of 20 mT and 2.6 for the induction of 40 and 80 mT, which means that speeds up the rate of magnetic induction growth of stems at the beginning of vegetation in relation to the stems of plants that were not stimulated and reduced growth rate with the increase of induction. Thereafter, the rate of increase declined, although the stimulated stems were higher than the stems grown from non-stimulated seed-potatoes. Acceleration of the growth rate in the early years of growing potatoes is positive, because vegetation accelerates and improves the health of plants.

The effect of dose on the number of single stems of potato plants (Fig. 8) also proved to be significant. With increasing of the dose also the number of stems of potato plants increased, although in different years the reaction was varied. The first year of studies showed that the highest number of stems was obtained for the highest dose of exposure; the number of stems was 29% higher in comparison with the control sample. For the intermediate dose the number of stems was 19% higher, and for the lowest dose 8% higher than for the control sample. This relationship developed in a similar manner in the second year of studies. For the highest dose, the number of stems was 20% higher, for the intermediate dose – 15%, and for the lowest dose 13% higher as compared to the control sample. The average number of stems per a single potato plant in the first year was 4.4, and in the second year of the study – 5.8, which, compared to the control sample, means that the number of stems increased by 19 and 15%. The difference between the years was 32% and it was statistically significant.

The relationship between the dose and the mass of leaves and stems, that is the mass of the aboveground part of potato (Fig. 9), is similar to those for the above two factors. That is, with increasing exposure doses the mass of leaves and stems of potato plants grew, on all measurement dates. For the highest dose, the mass increase in relation to the

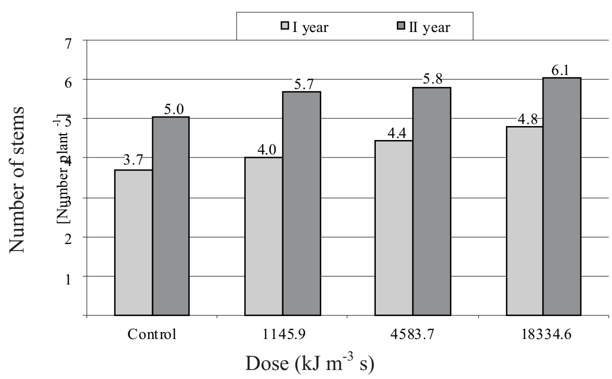

Fig. 8. Effect of exposure dose on the number of stems of potato plants.

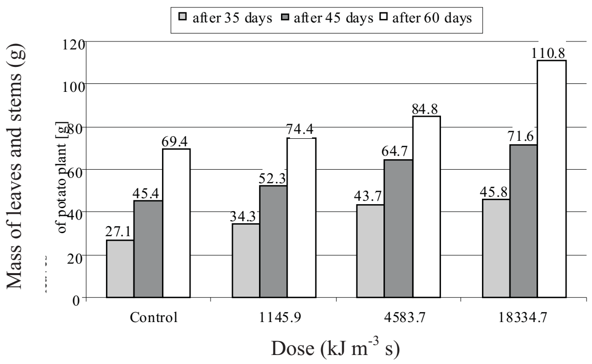

Fig. 9. Effect of exposure dose on the mean mass of stems and leaves of potato plants.

control sample was 69% for the first measurement date (35 days), 58% for the second (45 days), and 59% for the third (60 days). For the intermediate exposure dose, the values of the percentage increase of the mass were 60, 2, and 22%, and for the lowest dose – 26, 15, and 7%. On average, the annual increase of the mass of stems and leaves of stimulated plants in relation to that of the non-stimulated plants was 61% for the highest dose of exposure, 36% for the intermediate dose, and 13% for the lowest dose. Differentiation of the impact of the exposure dose on the mass of aboveground parts of the plants proved to be statistically significant. The coefficient of mass growth was 2.5 for the control sample, 2.1 for the lowest dose, 1.9 for the intermediate dose, and 2.4 for the highest dose of exposure. The values of the coefficients of increase of the mass of stems and leaves show that magnetic stimulation of seeds accelerates the growth of aboveground parts of plants at the beginning of vegetation. The coefficients of mass growth of stimulated plants, calculated as the ratio of the average mass for the three doses of exposure to the mass of stems and leaves produced by the control sample, indicates that on the measurement date 35 days after planting the ratio was 1.4, on the second date – 45 days of planting – 1.3, and on the third – 60 days of planting – 1.2.

A confirmation of the positive effect of magnetic stimulation on the growth of the over-ground part of potato is the indicator of the sprouting rate of the tubers (Table 1). The number of stems grown from a non-stimulated tuber was 62% compared to the number of eyelets on the tuber, that is the potential number of stems, 71% for tubers stimulated with the lowest and intermediate exposure doses, and 75% for tubers stimulated by the highest dose. The increase in the number of stems growing from stimulated tubers in relation to the control sample is 14% for the lowest and intermediate doses of exposure, and 21% for the highest dose.

T a b l e 1. Effect of exposure dose on number of stems and indicator of grown rate

Dose (kJ m^{-3} s)	Number of stems (number $tuber^{-1}$)	Number of stems (number $plant^{-1}$)	Indicator of growth rate (%)
Control	8.0	5.0	62.3
1 145.9	7.9	5.7	71.7
4 583.7	8.1	5.8	71.6
1 8334.7	8.0	6.0	75.4

The obtained results clearly show the positive impact of variable magnetic field on germination, growth and development of the aboveground parts of potato plant, namely the size of the assimilative surface has a direct effect on the plant yield.

CONCLUSIONS

1. The stimulation of seed-potatoes with variable magnetic field was found to have a statistically significant positive effect on the germination, stem length and number and mass of stems and leaves of potato plants.

2. Statistically significant effects, directly proportional to the magnetic induction and to the exposure doses, were shown for stimulating the germination, stem length and the number and mass of stems and leaves of potato plants.

3. All adopted levels of magnetic induction and exposure doses showed positive, albeit diverse, effects on the germination, stem length, the number and mass of stems and leaves of potato plants.

4. The results obtained for the dependent variables (germination, length and number of stems, and mass of leaves and stems) differed significantly between both values of applied magnetic induction, doses of exposure, and for the control sample (non-stimulated tubers).

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