EFFECT OF MAGNETIC FIELD ON GROWTH AND PROTEIN CONCENTRATION IN ABOVEGROUND HERBAGE OF FIELD PEA (*PISUM SATIVUM* L.) CULTIVARS

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Received Januar 10, 2024

Abstract. Research of the exposure of youg pea (*Pisum sativum* L.) plants of two cultivars (Gold and Uran) to magnetic field (MF) of different flux densities (250 and 350 mT) was conducted in controled conditions during 20 days. Pea plants were countinously exposed to magnetic field of neodymium magnets. Upon the statistical analysis there were revealed significant effects of MF treatments ($P<0.01$) on root freshweight, aboveground herbage freshweight and total plant freshweight. Cultivars differed in root ($P<0.05$), stem ($P<0.01$) and total plant length ($P<0.05$). There was also revealed significant Treatment × Cultivar interaction for all the tested traits.

Key words: Field pea, Magnetic field, Plant length, Plant mass, Protein concentration

1. INTRODUCTION

Field pea (*Pisum sativum* L.) is an arable crop used for livestock feeding as a concentrate feed (grain) and forage (herbage mass, either ensiled or fresh). Pea grain is important source of plant protein and its concentration varies in broad range from 12 to 33 % in dry matter [1,2] with high content of essential aminoacids [3]. Pea yield and quality vary with cultivar and agroecological conditions [4-7]. Various agrotechnical measures are employed to increase yield and quality of arable crops, among which are primarly soil fertilization and crop protection. Because of it, agriculture is among the main causes of environment pollution, besides the industrial waste and urban activites [8] which affect the climate change and lower the yield and quality of field crops.

Use of magnetic field (MF) in agricultural production has shown positive effects to plant biomass production. According to [9], MF interacts with seeds and plants and accelerates metabolism, which leads to an improved germination. The same author in his review has given the explanation that the primary and secondary plant metabolites, enzyme activities, uptake of nutrient and water are reprogrammed to stimulate the plant growth and yield under favorable conditions. Also, during adverse conditions of abiotic stress such as drought, salt, heavy metal contamination in soil, MF mitigates the stress effects by increasing antioxidants and reducing oxidative stress in plants. Application of MF has also shown the possibility of improving the resistance to plant diseases, tolerance to stress conditions and uptake of nutrients and water from soil [10]. According to [11], there is relvealed thet many aspects of plants growth, seed germination, yield, quality and water can be affected by magnetic fields but the research outcomes were sometimes incosistent and contradictory, what indicates that effects of MF on plants may depend on species and MF characteristics like intensity and exposure time.

Effects of various MF treatments were recorded in various crops like pea [12,13], maize [14], wheat [15,16], soybeans [17], radish [18], cotton [19], strawberries [20,21].

Effect of MF on germination, growth and productivity of plants was tested in various researches. Research of [17] has revealed that MF improves crops' productivity due to increased proteins activity, and minerals and enzyme accumulation. According to [16] revealed that increase of pretreated wheat seed germination was linked to increased α-amilase values. Research of [22] has shown improved elongation of epycotyle of pea seedling incubated under low MF flux density.

Aim of this research was to investigate the effect of permannet MF of various flux density at constant exposure of pea cultivars during their growth on some morphological traits and protein concentration in aboveground plant parts.

2. MATERIALS AND METHODS

The research is conducted in controlled conditions with two pea cultivars (Uran and Gold, spring dry pea varieties of the Agricultural Institute Osijek, Croatia). Seeds were sowed in polystyrene containers with 50 cm^3 of volume for each sowing place. Containers were filled with commercial substrate „Klasman Potgrond P". Tested of permanent MF effects tratments were: 1^{st} zero control; 2^{nd} MF flux density of 250 mT (M1) and 3^{rd} MF flux density 350 mT (M2). In the M1 and M2 treatments the neodymium magnetswere placed into the center of soeing place. Control and treatments were conducted in four replications and each replication consisted of 12 pea plants. Treatments lasted 20 days in controlled conditions of fytotron in the light regime of 12 h day and 12 h night. Day temperature was 22°C and night was 18°C, whilst the relaitve air humidity was constatly held at 80 %.

After 20 days of treatment, plants were carefully picked and washed from the substrate. There were measured the following traits: number of developped plants, root length, stem height, root freshweight and stem freshweight. Total plant length and freshweight were calculated by adding the lenght and root lenght and freshweight.

Nitrogen concetration in aboveground plant part was measured according to the Dumas method on C/N analyzer. Nitrogen concentration was calculated into pea grain protein by multiplying with 5.36 [23].

Analysis of variance and LSD testing ($P<0.05$ and $P<0.01$) was done by SAS 9.4 software (SAS Institute Inc.).

2. RESULTS AND DISCUSSIONS

Root lengths differed significantly between cultivars ($P<0.05$) (Table 1.). Cultivar Gold has developped longer root than Uran. Reaction to MF treatments differed between cultivars (the interaction was significant at $P<0.01$ level). MF treatment significantly affected the root length of Uran cultivar only, and the highest value was after M2 treatment and the lowest after M1. Other researchers also found cultivar-specific reaction to the MF tratment [24,25].

Similarly to our findings in Uran variety pea, [26] have observed increased root length of rice 3, 7 and 10 days after sowing due to the countinous exposure to MF of 125 and 250 mT, whilst [27] found no effect of cuntinous MF of 130 mT to lupins (*Lupinus angustifolius* L.) after 14 days of exposure.

In the [28] research, five-minute pretreatment of pea seeds with MF of 180 mT gave the longest seedlings' roots.

Considering the pea stem length, Uran pea variety generaly developed longer plant stem than Gold. In previous researches there was well established that pea stem hieght is cultivar-determined trait [29,30] what was confirmed in the control variant of this trial. Although the MF treatments didn't significatlny affect the stem length when averaged over cultivars, interaction MF × Cultivar was significant ($P<0.01$). When looked at each cultivar values, both MF treatments were associated with shorter stem when compared to the control (Table 1.), and Gold had the least value at M2, whilst Uran at M1.

Oppositely to our findings, [12] have found the greatest pea plant heights after the 14-day exposure to stationary MF (125 and 250 mT) in controlled conditions. [13] found the highest pea seedling stem length after 10-days treatment of continuous MF of 250 mT. Authors [28] got the greatest pea seedlings stems after five-minutes seed pretreatment with MF of 180 mT.

Countinous exposure to MF resulted in positive effects in other plant species also. After 14 days of lupine growth in controlled conditions under permanent MF of 130 mT, plant stems were greater than under control [27]. In the [31] research have found in 10-days old maize plants the greatest stem lengths when they grew under countinous MF (125 and 250 mT).

Considering the total plant length, cultvar Gold has shown greater average value than Uran ($P<0.05$) (Table 1.). Cultivar × Treatment interaction has shown highly significant effects ($P<0.01$). The two tested cultivars reacted differently to the tested two levels of MF flux densities. Gold had similar values in control and M1, and signficantly lower in M2, whilst Uran had similar values in control and M2, whilst the least at M1.

Our results differed from findigs of [13] and [12] who found similar positive reaction of pea plants to both tested levels of MF flux densities (125 and 250 mT), and of [31] in maize as well.

Table 1.

Effects of MF treatments to pea plant root length, stem height, and total plant length (cm)

Treatment (A)	Cultivar (B)		Average (A)
	Gold	Uran	
Root length (cm)			
Control	6.47	6.10	6.28
M1	6.81	5.85	6.33
M2	6.18	6.47	6.32
Average (B)	6.49	6.14	6,31
LSD $_{0.05}$ (A) = n.s. LSD $_{0.01}$ (A) = n.s.	LSD $_{0.05}$ (B) = 0.2542 LSD $_{0.01}$ (B) = n.s.		LSD $_{0.05}$ (AB) = 0.2267 LSD $_{0.01}$ (AB) = 0.3106
Stem height (cm)			
Control	7.74	8.96	8.35
M1	7.50	7.72	7.61
M2	6.96	8.76	7.86
Average (B)	7.40	8.48	7.94
LSD $_{0.05}$ (A) = n.s.	LSD $_{0.05}$ (B) = 0.4054		LSD $_{0.05}$ (AB) = 0.17

LSD $_{0.01}$ (A) = n.s.	LSD $_{0.01}$ (B) =0.5511		LSD $_{0.01}$ (AB) = 0.2329
Total plant length (cm)			
Control	14.21	15.06	14.64
M1	14.32	13.57	13.94
M2	13.14	15.22	14.18
Average (B)	13.89	14.62	14.25
LSD $_{0,05}$ (A) = n.s. LSD $_{0,01}$ (A) = n.s.	LSD $_{0,05}$ (B) = 0,5909 LSD $_{0,01}$ (B) = n.s.		LSD $_{0,05}$ (AB) = 0,3001 LSD $_{0,01}$ (AB) = 0,4111

Research has revealed significant effect of MF treatments and treatments × cultivar interactions ($p<0.01$) on roots freshweight (Table 2.). When averaged over cultivars, the greatest root mass was observed on control, and least after M2 treatment. Gold cultivar followed the same trend. Regarding the Uran variety, control gave the greatest root mass also, but between MF varinats there was no difference. However, in the pea seed pretreatment research of [28] with MF of different flux density and exposition duration, the greatest values of pea seedling roots' freshweight and dryweight were found after pretreatment with MF of 180 mT during 10 minutes exposition. Under the countinuous exposure of lupine plants to MF of 130 mT in controlled conditions root mass didn't differ from control treatment [27]. Regarding the abovegrand herbage mass, when averaged for the all treatments, cultivars didn't differ from each other (Table 2.), but significant differences were revealed between treatment averages, and the interaction Treatment × Cultivar was also significant ($P<0.01$). When averagd over cultivars, both of MF treatments were associated with significantly lower vales than in the control. However, cultivars differed in their reaction to treatments. Cultivar Uran had greatest value at control, whilst Gold at M1. Findigs in this research were opposite to [12] who found greatest pea stem mass after the countinous exposure of plants to MF (of 125 and 250 mT). In the [28] research, pea seed pretreatment in MF of 180 mT during 10 minutes exposure gave the highest values of stem of pea seedlings. In the [27] research have found in lupins after 14 days of countinous MF treatment (130 mT) in controlled conditions greater shoot mass than in control. Also, [31] in their exposure of maize seeds to stationary MF (125 or 250 mT) found the greatest values for aboveground herbage mass of seedlings when 10-days old plants growth occured in countinous MF of both tested densities of magnetic flux. Significant differences ($P<0.01$) were revealed for total plant mass as affected by the tested treatments as well as for reactions of Treatments × Cultivars (Table 2.). When averaged over cultivars, highest values were at control, significatly lesser at M1, and the least at M2. The sam trebd was observed for the Gold cultivar, whilst Uran variety had the least value at M1 treatment. Opposite to the results from this research, [12] have revealed the greatest total plant mass of pea plants upon the countinous exposure to MF treatments (125 and 250 mT) during 14 days. Also, [31] observed the greatest maize seedling mass when the seedlings grew under countinous MF (both 125 and 250 mT) in their trial with seeds and seedlings exposure to stationary MF.

Table 2.

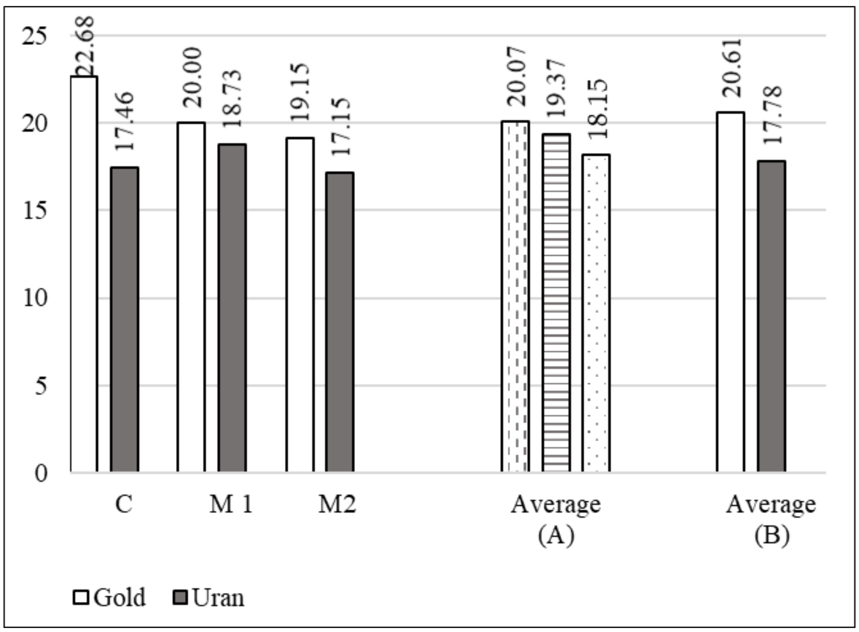
Effect of MF treatments on root, aboveground and total plant mass of pea seedlings (g/plant)

Treatment (A)	Cultivar (B)		Average (A)
	Gold	Uran	
Root freshweight (g/plant)			
Control	1.21	1.39	1.30
M1	0.94	0.74	0.84
M2	0.45	0.74	0.59
Average (B)	0.87	0.95	0.91
$LSD_{0.05}$ (A) = 0.1285 $LSD_{0.01}$ (A) = 0.175	$LSD_{0.05}$ (B) = n.s. $LSD_{0.01}$ (B) = n.s.		$LSD_{0.05}$ (AB) = 0.038 $LSD_{0.01}$ (AB) = 0.0523
Stem freshweight (g/plant)			
Control	1.08	1.17	1.13
M1	1.15	1.00	1.08
M2	0.91	1.10	1.01
Average (B)	1.05	1.09	1.07
$LSD_{0.05}$ (A) = 0.0921 $LSD_{0.01}$ (A) = n.s.	$LSD_{0.05}$ (B) = n.s. $LSD_{0.01}$ (B) = n.s.		$LSD_{0.05}$ (AB) = 0.0547 $LSD_{0.01}$ (AB) = 0.075
Total plant mass (g/plant)			
Control	2.28	2.56	2.42
M1	2.10	1.73	1.92
M2	1.92	1.84	1.61
Average (B)	1.92	2.04	1.98
$LSD_{0,05}$ (A) = 0.2151 $LSD_{0,01}$ (A) = 0.2928	$LSD_{0,05}$ (B) = n.s. $LSD_{0,01}$ (B) = n.s.		$LSD_{0,05}$ (AB) = 0.0659 $LSD_{0,01}$ (AB) = 0.0903

Considering the protein concentration, there were observed significant differences between cultivars (Figure 1.) as well as interaction of Cultivar × Treatment (P<0.01). Cultivar Gold had 2.83 % greater protein concentration than Uran.

Protein concentration in pea grain or pea herbage varies in a broad range fro 13 to 27 %, and greatly depends on growth conditions and cultivar [32,33,1]. Therefore the observed values and differences are in harmony with previous researches.

Culitvars reacted differentialy to MF treatments with regard to protein concentration. Gold had the highest value at control, significantly lesser at M1, and the least at M2. Uran had the highest value at M1, significantly lesser at control, and the least at M2 treatment.



LSD	A	B	AxB
0.05	ns	1.057	0.435
0.01	ns	1.437	0.597

Fig. 1 – Effects of MF treatments on protein concentration in aboveground plant parts of pea (%)

3. CONCLUSION

Authors [34] state the factors that affect the MF effects: genotype, frequency of alternating fields, density of magnetic flux, duration of seed exposure, absolute dose of exposure and polarity. Accodring to [35], duration of exposure is more important than the strength of MF. Therefore can be hypothesized that negative effects of the coundected MF treatments to the pea root, aboveground, and total plant mass, and protein concentration might be the consequence of too long exposure of pea plants (20 days) to the MF treatments.

Although there are being are used high levels of MF fluy density, in the range from 500 μT do 15 T [36] in research of MF effects to plants, it is possible that the investigated levels in this research were too high for the countinous exposure. Therefore further research is required on the topic of this article.

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