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European Journal of Experimental Biology, 2013, 3(3):126-134

ISSN: 2248 –9215
CODEN (USA): EJEBAU

Effect of electric field intensity and exposing time on some physiological properties of maize seed

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ABSTRACT

In this research, some physiological properties of maize were investigated as a function of electric field intensity and exposing duration. Maize seeds with initial 28%germination percentage were selected and exposed to electric fields under different time durations. The experiments were conducted with four levels of electric fields (namely, 2, 4, 9 and 14 kv) and four levels of time durations (including 15, 45, 80 and 150 s) in the form of complete randomized block design. After exposing the seeds to electric field, the physiological properties of seeds and seedlings at the first stage of growth were evaluated in terms of seedling dry and wet weight, length of seedling, length of leaf, length of stem, length of root, coefficient of uniformity, germination rate, mean germination time, and germination percentage. At each test, three replications were accomplished and the mean values were calculated. The results revealed that the effects of electric field and exposing time duration on all of the physiological properties of maize were statistically significant.

Keywords: Electric field, Maize, Germination, Exposing time

INTRODUCTION

Maize with the scientific name of Zeais among the oldest cultivated crops which ranks as one of the most widely grown food grain crop, serving as staple food for many people in the world. It has been of importance in the life of people since 4500 years ago [1]. World maize production has increased from 615 million tones in 2001 to 840 million tones in 2010. In Iran, maize is widely cultivated on an area of about 9 million hectare with an annual production of about 22 million tones[2].In the modern agriculture of the 21th century, increasing attention has been paid to the productive growth of cultivated plants which are also environmentally safe. Studies carried out show that the application of high quality, specially prepared seed is an important, yet still underestimated, yield-forming factor in the cultivation of many species of agricultural plants. Genetic modification (GM) of seeds has been performed to produce special kinds of chemical compositions in the products. By doing the GM process, the desired traits will be changed and increased in the seeds and finally new genes and varieties are created. In the treatment of seeds prior consist mainly in treating the seed with various chemicals. These methods are recognized as harmful for the environment because they are not selective in respect of wildlife although the agro-chemicals introduced are often very efficient. Nowadays, with the proposal of the rational use of agricultural land, greater importance is attributed to some physical methods of the pre-sowing treatment of seeds which are commonly regarded as being friendlier to the environment [3-5]. These physical factors often only modify the course of some physiological processes in the seeds, which increases their vigor and contributes to the improved development of the plant [6]. Exposure of seeds to electromagnetic (electric and magnetic) fields is one of the safe and affordable potential physical pre-sowing treatments to enhance post-germination plant development and crop stand [7]. Special attention should be paid to the electromagnetic fields which can stimulate some processes occurring in the seeds and plants [8-10].In recent years, several studies have been accomplished by researchers to evaluate the effects of electric and magnetic fields on the viability of plants and biological commodities [9, 11-17]. Enhancement of seed vigor and germination of different species by treating seeds with magnetic or electromagnetic fields has been confirmed by many scientists [11-13, 18-19]. Takac et al. showed that utilization of electromagnetic fields increased the pepper yield to 64.9%. Marinkovic reported a 144.8% increase in potato yield as a result of electric fields treatment [14-15]. Aladjcyan studied the influence of static magnetic fields with an intensity of 0.15 Tesla on some biological properties of maize [17]. They reported that the effect of magnetic field on germination percentage and root length was statistically significant and that the best time for exposing the seeds to the magnetic field was 10 minutes. Pal conducted a research to investigate the effect of light and low frequency magnetic fields on microscopic fungi [20]. It was reported that the magnetic fields could decrease the growth of fungus to 10%. Vashisth and Nagarajan reported a 46-71% increase in chickpea seed vigor, a 58-90% improvement in seedling root length and a 25-47% increase in seedling dry weight [21]. Onion and rice seeds exposed to a weak electromagnetic field for12h showed significantly increased germination as well as shoot and root length of seedlings [22]. Harich *et al*. also observed that seed treatment with a magnetic field (10 T; 40h) increased plant height, seed weight per spike and subsequent yield of wheat crops [23]. Exposure of maize seeds to a 150 mT magnetic field stimulated shoot development and led to an increase in germination, fresh weight and shoot length of maize plants [17]. Florez *et al*. reported that the germination and early growth of maize seedlings were enhanced when seeds were exposed to a stationary magnetic field [7]. Fischer *et al*., reported that sunflower seedlings exposed to vertical magnetic fields showed small but significant increases in total fresh weight, shoot fresh weight and root fresh weight, while the dry weight and germination rates remained unaffected[24]. Growth of germinated *Viciafaba* seedlings was enhanced by the application of power frequency magnetic fields (100 T), supported by an increased mitotic index and 3H-thymidine uptake [25]. Aksenov *et al.* ascertained that electromagnetic field with the frequency of 50 Hz stimulated imbibitions of wheat seeds and increased the length of seedlings by activating esterases[26]. Likholat *et al.* asserted that the influence of alternating magnetic field with the frequency of 30–35 Hz and maximum amplitude of about 30 mT on pea, sunflower and wheat seeds imbibing in water improved their germinating [27]. Sirotina *et al.* observed an enhanced formation of lateral roots in millet after seed treatment with a weak pulsating field (50 Hz) with the intensity of 8 A/m[28]. Hitherto, little work has been reported on investigation of effects of different duration of electric field on plant seeds. Thus, the objective of this study was to evaluate the possible effect of stationary electric field intensity and exposing time on germination of maize seeds and first stages of growth of the seedlings.

A B

Fig. 1. Overall view of the electric field generator (A); Exposing maize seeds to electric field (B).

MATERIALS AND METHODS

Experimental setup

Maize seeds with germination percentage of 28% were selected for conducting the experiments. Prior to germination, seeds were disinfected with 3% Formaldehyde for 10 minutes and washed thoroughly with distilled water. The electric field was applied to the seeds using a capacitive type electric field generator with variable field intensity (Fig. 1). The diameter of plates and distance between the electrode plates of the electric field was 25 cm and 5 cm, respectively.

The intensity of the applied electric filed and also the safety of the operator during experiments was controlled using a control panel (Fig. 2).

Fig. 2.Control panel of the electric field

At each test, 100 seeds were poured into polyethylene bags and subjected to the electric field resulted from the field supplier. The samples were placed at a distance between the electrodes in which a uniform electric field for the required exposing duration was achieved. Four levels of field intensity, including 2, 4, 9 and 14 kv/m, and five levels of exposing time, namely 15, 30, 45, 80 and 150 s were selected to perform the tests. After setting and establishment of primary conditions, each treatment was replicated three times. After subjecting the seeds to the electric field under described conditions, the samples were transferred to the Plant Science Laboratory and kept in a refrigerator with 4 °C temperature for further physiological assessments. The physiological analysis was conducted on the treated seeds to determine the germination and growth specification according to International Seed Testing Association (ISTA) standards. The germination ability tests were carried out by covering the seeds using filter-papers and placing them in Petri dishes containing distilled water. The seeds were then placed in an oven in the dark, at the constant temperature of 25 °C for a time period of 4-7 days. After the mentioned period, the numbers of normal and abnormal seedlings were counted in the samples. The germination percentage was calculated based on normal seedlings. The normal seedlings from each replication were randomly selected to measure shoot and root length. Dry weight was also evaluated after drying the specimens (10 seeds) for 72 hours at 76 °C. During the experiment, germinated seeds were counted on a daily. Seed germinability was assessed by the final cumulative percentage of germination at the end of the tests. In this case, germination was considered only when the radicles were longer than 2 mm.

Mean germination time (*MG*) was calculated according to the following formula [29]:

$$MG = \sum\left(\frac{N_i \times 100}{D_i}\right)$$

Where $D_i$is the number of days after starting the experiment, and N_i represents the total number of germinated seeds on the *i*th day.

The height of stem, length of leaf, and length of seedlings were also measured during the first stages of seedlings evolution.

Experimental design and statistical analysis

The tests were performed based on a factorial experiment. Totally, 20 treatments were conducted on the basis of completely randomised design. At each treatment, the experiments were replicated three times and the average values were reported. The mean, standard deviation and correlation coefficient of the physiological specifications of maize seeds were determined using Microsoft Excel 2010 software program. The effects of electric field intensity and exposing time on physiological characteristics were evaluated using analysis of variance (ANOVA), and mean significant differences were compared using the least significant difference test at 5% significant level using SPSS 18 software (version 18, SPSS, Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

The results of statistical analysis revealed that the effects of electric field intensity and exposing time and also the interaction effect of the two factors on the physiological properties of maize seeds were significant (Table 1).

Table 1 – Analysis of variance indicating the effects of electric field intensity and exposing time on physiological properties of maize seeds

		Mean Squares of Dependent Variables									
Source	DF	*GP*	*MG*	*GS*	C_u	L_{Ro}	L_{Ra}	S_l	L_p	W_w	W_d
Field Intensity (A)	4	93.96*	167.60**	543.46**	0.705**	6.55**	10.61**	12.38**	5.43**	3.95**	3.95**
Exposing time (B)	4	63.28^{ns}	167.60*	12.46*	1.53*	24.55**	39.45**	1.84^{ns}	8.65**	12.97**	12/97**
A*B	16	15.11^{ns}	119.7^{ns}	10.17^{ns}	0.48^{ns}	17.03^{ns}	25.08^{ns}	1.05^{ns}	5.83^{ns}	10.18^{ns}	10.56^{ns}
Error	24	30.17	128.9	11.32	1.80	20.19	32.01	1.54	7.32	11.18	11.54

*** Significant on the 1% probability level, * significant on the 5% probability level, ns: not statistically significant. GP: Germination percentage, MG: Mean germination time, GS: Germination speed,Uc: Coefficient of uniformity, L_{Ro}: Length of root, L_{Ra}: Length of radical, S_l: Leaf size, L_p: Length of plant, W_w: Wet weight of plant, W_d: Dry weight of plant*

The mean comparison of physiological properties of maize seed considering individual effects of electric field and exposing time are presented in Table 2 and Table 3, respectively.

Table 2 – Comparison of means of physiological properties of maize seed at different electric fields using Duncan's test method

Electric field intensity (kv/m)	*GP*	*MG*	*GS*	C_u	L_{Ro}	L_{Ra}	S_l	L_p	W_w	W_d
0	28.00 a	2.51 d	34.97 dc	0.7 c	10.25 a	3.53 c	5.00 a	13.78 c	6.13 d	5.62 d
2	21.25 b	3.54 c	33.09 d	0.86 bc	9.57 b	6.68 b	2.39 c	16.26 b	7.64 c	7.14 c
4	25.83 ab	7.25 b	35.63 c	1.00 b	10.50 a	7.12 b	3.79 b	17.62 a	7.83 c	7.33 c
9	27.83 ab	11.21 a	48.36 a	1.33 a	9.35 b	8.38 a	2.53 c	17.73 a	8.93 a	8.43 a
14	24.00 ab	11.40 a	40.68 b	1.35 a	8.72 c	8.60 a	1.31 d	17.32 a	8.28 b	7.78 b

Means followed by different letters are significantly different from others in the same column ($P < 0.05$).GP: Germination percentage, MG: Mean germination time, GS: Germination speed, Uc: Coefficient of uniformity, L_{Ro}: Length of root, L_{Ra}: Length of radical, S_l: Leaf size, L_p: Length of plant, W_w: Wet weight of plant, W_d: Dry weight of plant

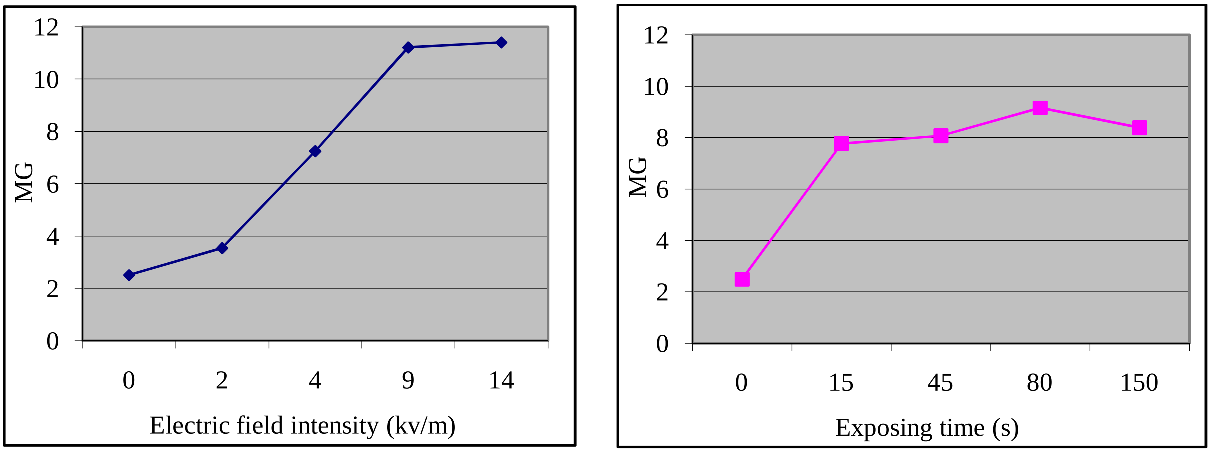
Table 3 – Comparison of means of physiological properties of maize seed at different exposing times using Duncan's test method

Exposing time (s)	*GP*	*MG*	*GS*	C_u	L_{Ro}	L_{Ra}	S_l	L_p	W_w	W_d
0	28.00 a	2.5 d	34.97 b	0.69 d	10.80 a	3.53 e	5.00 a	13.77 c	6.13 e	5.63 e
15	24.33 a	7.77 c	38.38 a	0.85 dc	10.57 ab	5.62 d	2.94 a	16.19 c	6.90 d	6.40 d
45	25.25 a	8.07 bc	38.94 a	1.16 b	10.25 b	7.12 c	2.30 a	18.00 a	7.76 c	7.26 c
80	22.83 a	9.17 a	40.73 a	1.63 a	7.90 d	9.94 a	2.71 a	17.84 a	9.13 a	8.63 a
150	26.5 a	8.39 b	39.71 a	0.90 c	8.78 c	8.11 b	2.07 a	16.90 b	8.90 b	8.40 b

Means followed by different letters are significantly different from others in the same column ($P < 0.05$). GP: Germination percentage, MG: Mean germination time, GS: Germination speed, Uc: Coefficient of uniformity, L_{Ro}: Length of root, L_{Ra}: Length of radical, S_l: Leaf size, L_p: Length of plant, W_w: Wet weight of plant, W_d: Dry weight of plant

Mean germination time

Results of multiple ranges Duncan's method indicated that increasing the electric field intensity to 9 kv/m caused an increasing trend in the MG value. As shown in Fig. 3a, the highest value of MG was obtained in 9 kv/m intensity. Increasing the exposing time resulted an increase in the value of MG. The highest MG was attributed to the 80 s exposing time (Fig. 3b).

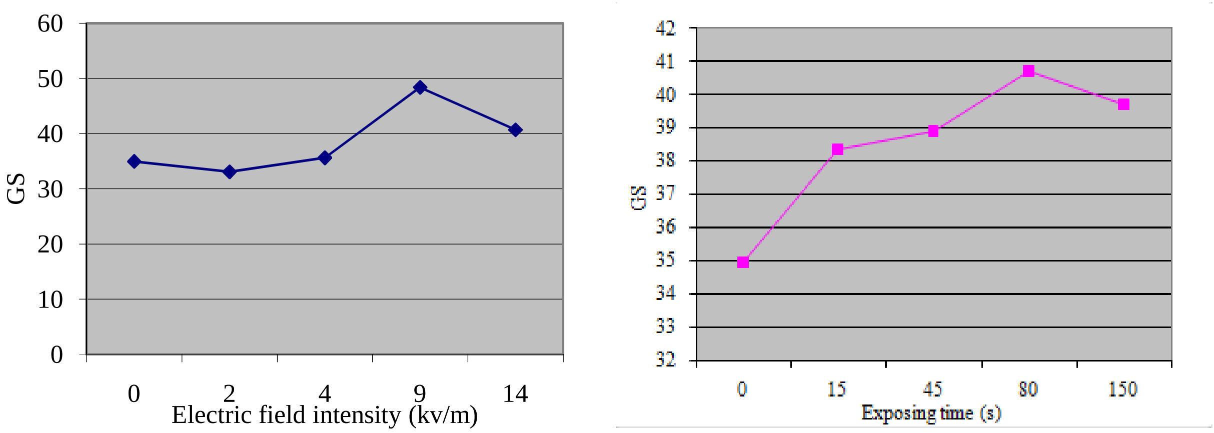


A B

Fig. 3. Mean germination time of maize seed as a function of: A) Electric field intensity, and B) Exposing time

Germination rate

The effects of electric field intensity and exposing time on the *GS* value are illustrated in Fig. 4. A significant increase in *GS* was obtained with increasing the electric field intensity from 2 to 9 kv/m and further increase in the field intensity caused a decrease in *GS*.



A B

Fig. 4. Germination speed of maize seed as a function of: A) Electric field intensity, and B) Exposing time

Coefficient of uniformity

The maximum C_u was observed at 9 and 14 kv/m field intensities. Increasing exposing time resulted an increasing trend in C_u value till 80 s level, while by increasing the exposing time from 80 to 150 s, the C_u value decreased (Fig. 5).

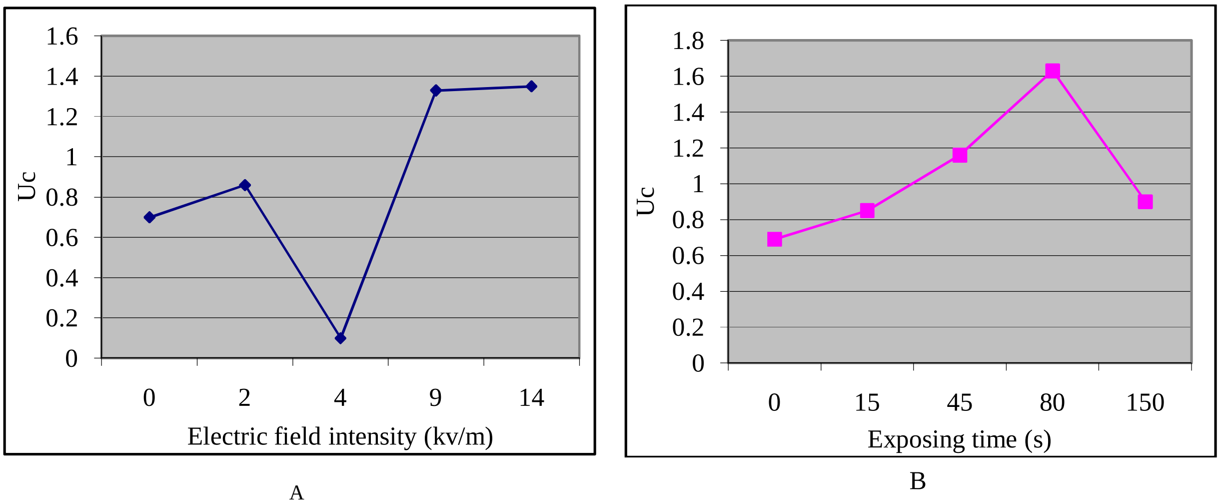


Fig. 5. Coefficient of uniformity of maize seed as a function of: A) Electric field intensity, and B) Exposing time

Root length

The effect of electric field intensity on the length of root was statistically significant at the 1% probability level ($P<0.01$). With increasing the field intensity, the length of root increased to an extent and then started to decrease. Increasing the exposing time caused the length of root to be decrease. The highest decrease was belonged to the 80 s exposing time (Fig. 6).

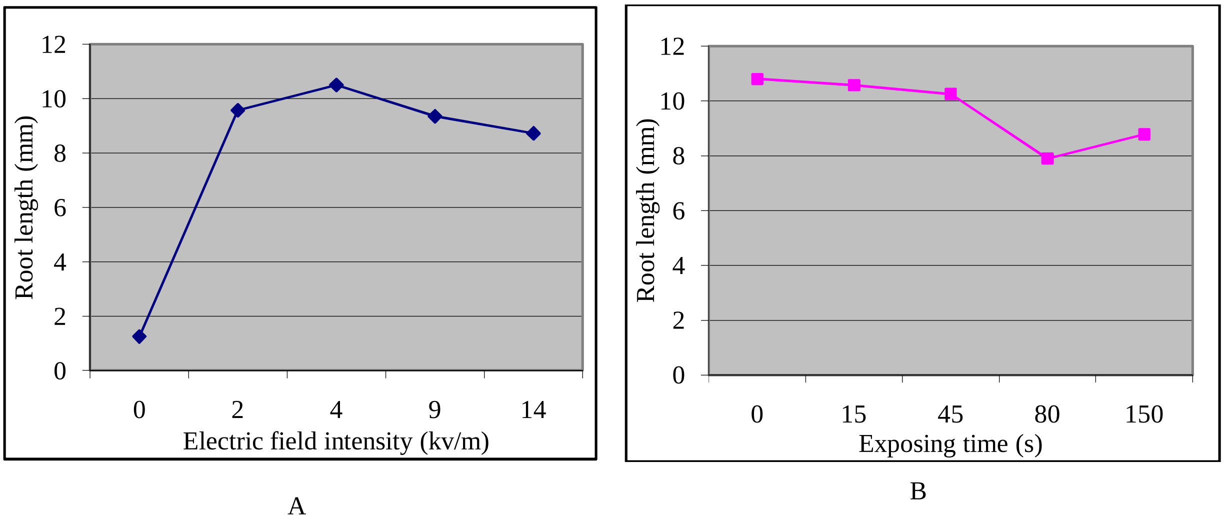
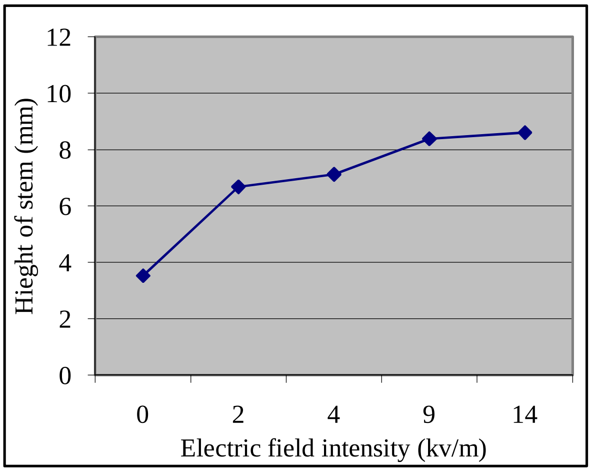


Fig. 6. Root length of maize seed as a function of: A) Electric field intensity, and B) Exposing time

Stem height

The effect of electric field intensity on the height of stem is shown in Fig. 7. It can be observed that with increasing the field intensity, the height of stem increases and the highest increase belongs to the 14 kv/m intensity.



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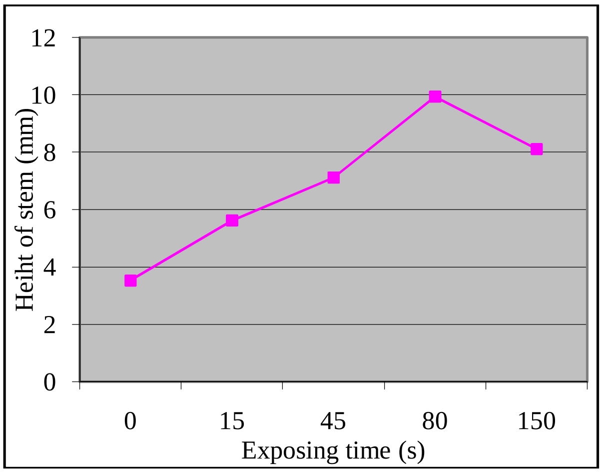
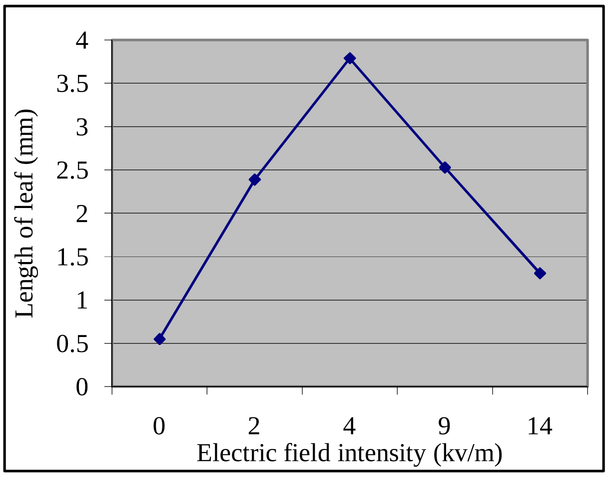


B

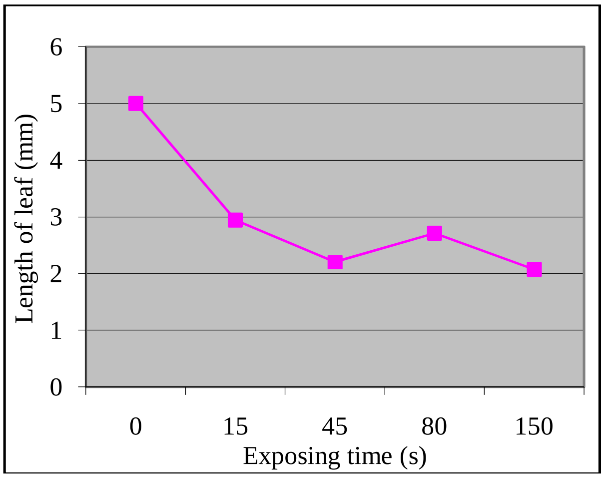
Fig. 7. Stem height of maize as a function of: A) Electric field intensity, and B) Exposing time

Leaf length

According to statistical analysis, the effect of electric field on the length of maize leaf was significant at the 1% level of probability. As shown in Fig. 8, increasing the field intensity from 0 to 4 kv/m resulted an increase in the leaf length, whilst with further increase in the field intensity the length of leaf started to decrease. It can also be seen that with increasing the exposing time, the length of leaf tends to decrease.



A

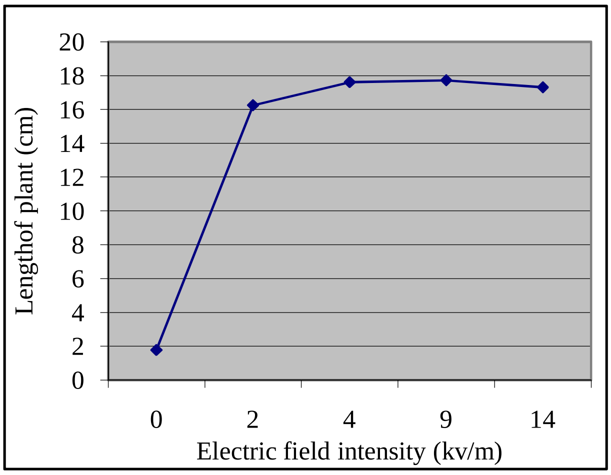


B

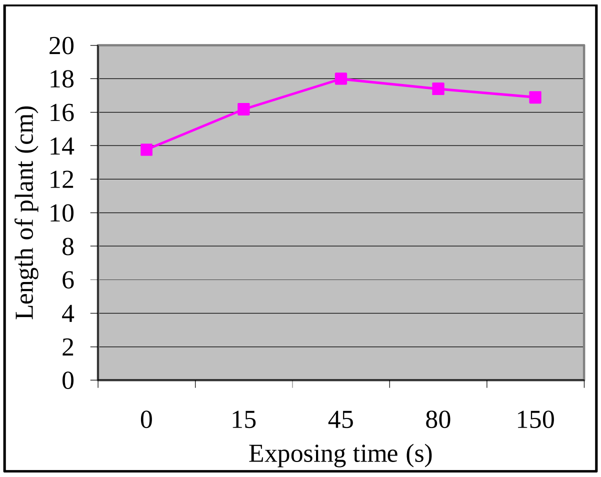
Fig. 8. Leaf length of maize as a function of: A) Electric field intensity, and B) Exposing time

Length of plant

As mentioned in previous sections, the length of stem and root increased with increasing the electric field intensity. Therefore, it can be expected that with increasing the field intensity, the length of plant increases. This result is illustrated in Fig. 9. The highest plant length, considering the individual effect of electric field intensity, was obtained at the 9 kv/m field intensity. A minor decrease was observed in the plant length with increasing the field intensity from 9 to 14 kv/m which was not significant statistically. The results also indicated that the length of plant increased with increasing the exposing time. The highest increase in plant length, considering the individual effect of evaluated factors, was obtained at the 45 s exposing time.



A



B

Fig. 8. Length of plant as a function of: A) Electric field intensity, and B) Exposing time

CONCLUSION

This research was performed to study the physiological properties of maize seeds as affected by electric field intensity and exposing time. The physiological properties were evaluated in terms of plant dry weight (W_d), plant wet weight (W_w), length of plant (L_p), length of leaf (L_l), length of stem (S_l), length of root (L_{ro}), coefficient of uniformity (C_u), germination rate (*GS*), mean germination time (*MG*), and germination percentage (*GP*). The following conclusions are derived from the research:

o The effects of electric field intensity and exposing time and also the interaction effect of the two factors on the physiological properties of maize seeds were statistically significant.
o Results of multiple range Duncan's method indicated that increasing the electric field intensity to 9 kv/m caused an increasing trend in the MG value.
o A significant increase in *GS* was obtained with increasing the electric field intensity from 2 to 9 kv/m and further increase in the field intensity caused a decrease in *GS*.
o The maximum C_u was observed at 9 and 14 kv/m field intensities. Increasing exposing time resulted an increasing trend in C_u value till 80 s level, while by increasing the exposing time from 80 to 150 s, the C_u value decreased.
o With increasing the field intensity, the length of root increased to an extent and then started to decrease. Increasing the exposing time caused the length of root to be decrease. The highest decrease was belonged to the 80 s exposing time.

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