EFFECT OF LOW FREQUENCY ELECTRIC FIELD ON GROWTH CHARACTERISTICS AND PROTEIN MOLECULAR STRUCTURE OF WHEAT PLANT

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Abstract. Two exposure systems of an extremely low frequency electric field were used, the first was an experimental model (50 Hz, 6 kV/m strength) and the second was the high voltage transmission lines passing through an open agricultural field (50 Hz, 66 kV/11 m = 6 kV/m). The effects of the two exposure systems were investigated on mitosis, meiosis and pollen grains viability in the wheat plant. Also, the effect of those two fields on some morphological characters and some physiological parameters were estimated. Classification of the water soluble protein (WSP) extracted from the exposed and unexposed grains as well as their molecular weight distributions were also investigated by using SDS polyacrylamide gel electrophoresis (PAGE) technique. The absorption spectra of the WSP were also measured at wavelength range 200–600 nm. The results indicated that the electric field of both systems showed a high frequency of chromosomal abnormalities and the treated wheat flower buds showed a marked increase in the frequency of the nonviable pollen grains. The results also indicated remarkable changes in the morphological characters where the stem length increased but the spike weight and the number of grains in the spike decreased. Further, the data showed an increase in the total chlorophyll content and the total carbohydrates in the grains. On the other hand, the data indicated that the molecular structure of the extracted WSP changed the amount of protein in the bands of exposed grains decreased and their molecular weights changed.

Key words: electric field, wheat plant, cytological, morphological, physiological analysis, protein molecular structure.

INTRODUCTION

The effect of electric field on living cells during decades is mainly attributed to its guide in throwing light on major unsolved biological problems such as morphology, uncoiling immune defense and regulation of the cell division. These electric fields are, practically, produced in all places by numerous sources,

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including nearby high voltage transmission lines, primary and secondary overhead utility distribution lines and the electrical grounding system.

Electric field is one kind of stress, which can affect directly or indirectly the plant exposed to it. Plant species vary in their sensitivity and response to environmental stresses because they have various capabilities for stress perception, signaling and response [5].

The cytogenetic effects of the electric field were tested on different plant systems as a valid model for monitoring the hazardous effects of electric field. Electric field showed a significant decrease in mitotic indices, and caused an increase in the percentages of chromosomal aberrations such as stickiness, bridges, disturbances, fragments, lagging chromosomes and micro nuclei [18, 26]. In addition, the high voltage electric field has irreversible mutagenic effects on wheat and clover plants [30].

Several researches tried to define the effect of such field on the growth rate of the plant. Rabold [27] showed that extremely low frequency (60 Hz) 360 V/m electric field can inhibit growth in plant root model cell systems. Also, stimulation of the biological processes and nutrient metabolism has been observed in plants as a result of the exposure to a high voltage electric field [16, 35]. Electric field can cause deformation inside grain through compression or tension of particular layers. Compression and tension of objects are the most visible effects that can occur in laminar and elastic objects such as wheat grains [31]. On the other hand, it has been proved that the electric field inhibited the biological properties of the membrane protein [13, 17, 24, 33].

Also, by exposing the broad bean seeds to definite exposure periods (1, 3 and 5 days, respectively) of electric field (6 kV/m, 50 Hz), Hanafy *et al*. [9] recorded a considerable increase in both of the chlorophyll content and the carbohydrate amount that increased at longer exposure periods, and also many changes in the elements level were recorded for the exposed seeds.

Bai [3] investigated the original mechanism of the biological effects of the electrostatic field (4 kV/m) on barley and (4.5 kV/m) sugar beet seeds for 10 minutes. Their results showed that the electrostatic fields with certain intensity could increase the content of free radicals in seeds.

Electric field exerts forces on charged particles in an electrically conductive material such as a living tissue. Tenforde and Kaune [32] mentioned that the electric field of an extremely low frequency induces electrical potentials and resultant current flows in the aqueous medium that surrounds the living cells. Because the membranes of these cells form a dielectric barrier to the passage of current in an extremely low frequency (ELF) range, only a small fraction of the induced current penetrates the cell surface. Yet, it is generally believed that the

per-cellular current induced by an ELF produces electrochemical alterations in components of the cell membrane surface.

Such induced current in turn sends signals across the cell membrane barrier that produce alterations in intracellular biochemical and physiological functions. Saunders [29] introduced a mechanism for this biological interaction. They proposed that the electric field induces an electric charge on the surface of conducting bodies such as animals, humans. The electric charge on the surface of the bodies induces electrical potentials within tissue, which result in a current flow. In the extremely low frequency range <300 Hz the electrical impedance of cell membrane is high. The current flows mainly through the extra cellular fluid of tissue and induces changes in the electrical potentials that exist across the cell membranes and affects electrically excitable tissue.

Therefore, and due to the presence of the high voltage transmission lines (high voltage electric field) over the fields plant until complete germination, the aims of this investigation to study the effect of two exposure systems of AC electric field through three parameters on wheat plant 1) the cytogenetic changes in mitosis, meiosis stages and pollen grains viability, 2) the morphological characters on the plants and physiological parameters on the grains and 3) the biophysical properties of water soluble protein (WSP) by using SDS polyacrylamide gel electrophoresis(PAGE) technique.

MATERIALS AND METHODS

PLANT MATERIAL

Wheat grains *Triticum aestivum* L. (Giza 7) were kindly obtained from the Agriculture Research Center, Cairo, Egypt. The grains were selected for uniformity in size and soaked over night in pure water.

ELECTRIC FIELD EXPOSURE

Our investigations were followed both in the laboratory (experimental model), and in open agriculture field. For this purpose, we divided the grains into four groups, each of 100 grains, as follows:

Group A – experimental model – grains placed at 100 m from the field source;

Group B – experimental model – in an electric field of 6 kV/m;

Group C – in agriculture field – 100 m away from the high voltage lines;

Group D – in agriculture field – under the high voltage transmission lines (50 Hz, 6 kV/m).

THE EXPOSURE FACILITY MODEL

In the laboratory, the grains were exposed to an alternating electric field of 50 Hz frequency and 6 kV/m strength (Fig. 1) generated between two parallel aluminum electrodes of dimensions 60 × 50 × 2 cm fixed horizontally above and below the grains, The electric field was derived directly from 50 Hz high voltage set-up transformer, manufactured by the "Center of Scientific and Electronic Equipment Maintenance, Faculty of Science, Cairo University".

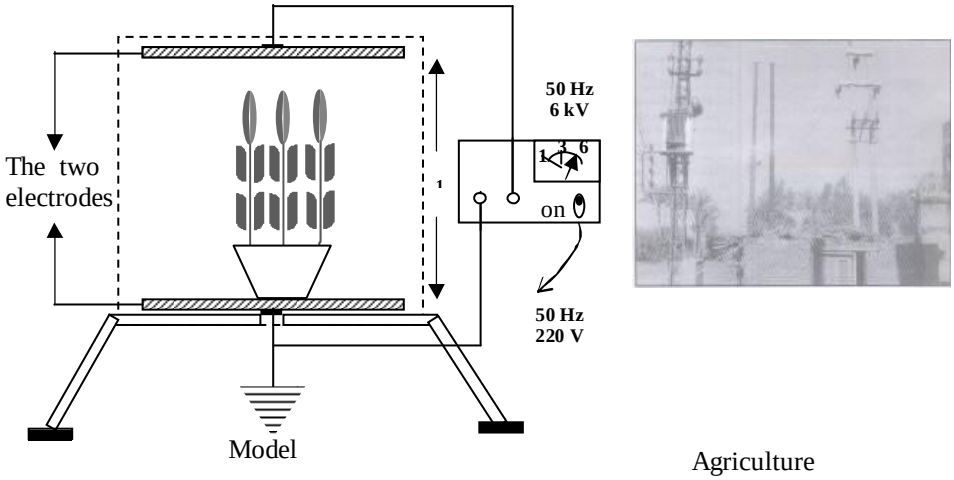

Fig. 1. The exposure facility.

In the agriculture field, the source of the electric field was the high voltage transmission lines (50 Hz, 6 kV/m).

GRAIN SOWING AND GROWING

The four groups were divided into two subgroups each, for different sowing and growing conditions.

Subgroups A_1 and B_1 were sown in earthenware pot 60 cm in diameter, in the same soil as in the agriculture field, and irrigated with tap water and lasted until harvest. The subgroups A_2 and B_2 were put on moist cotton until the length of the roots reached 1–2 cm. Subgroups C_1, C_2 and D_1, D_2 were sown in the agriculture field and irrigated. Subgroups C_1, D_1 lasted until harvest and subgroups C_2–D_2 until the length of the roots reached 1–2 cm, to be used as control and treated roots for the cytological measurements. The grain groups were exposed in the above-described conditions.

THE CYTOLOGICAL ANALYSIS

For mitotic analysis, when the wheat roots reached a length of 1–2 cm, roots were cut and fixed immediately in Carnoy's solution (6 volumes ethanol: 3 volumes chloroform: 1 volume glacial acetic acid) for 24 hours. After fixation the roots were stored in 70% ethanol at 4 °C. For cytological analysis three replicates were performed for each treatment and control. Root tips were macerated in 4% pectinase enzyme (Fluka-0.01 U/mg Chemie AG, CH-9470 Buchs) for 2 hours, then hydrolyzed in 1N HCl at 60 °C for 15 minutes, stained using feulgen squash technique according to Darlington and Lacour [7] and examined microscopically.

For meiotic analysis, flower buds of wheat plants from the two treatments and their control were collected and fixed in acetic acid absolute ethyl alcohol (1:3 v/v) for 24 hours. After fixation the flower buds were stored in 70% ethanol at 4 °C. For cytological analysis, six replicates were performed for each treatment and control, where, the content of the anthers of the flower buds were squeezed out on the slides and stained using the aceto-carmine smearing technique [4].

Also, stain ability of the pollen grains of wheat plants in aceto-carmine stain for the two treatments were performed as an index of determining pollen viability.

All cytological data obtained from the different treatments were statistically analyzed using t-test [21].

THE MORPHOLOGICAL AND PHYSIOLOGICAL MEASUREMENTS

A known fresh weight of leaves from exposed and unexposed grains was taken to define the chlorophyll amount according to Metzaner *et al.* [20].

At the harvest, the plants from each treatment were sampled and the following parameters were measured: stem length (cm), number of spikes per plant, spike weight, number of grains per spike, and weight of 100 grains. Total sugar contents were measured calorimetrically according to Nelson [23] and determination of the total protein content was made [15].

QUALITATIVE ANALYSIS OF WSP

The water-soluble protein (WSP) was extracted in the form of concentrated solution from wheat grains by the method of Irvin [12]. The molecular weights of the components of such WSP of the grains were estimated through the use of SDS polyacrylamide gel electrophoresis (PAGE) according to the technique of Laemmli [14]. The molecular weights of the protein bands were estimated by SDS (PAGE) according to Weber [34]. The gel was stained with Coomassie brilliant blue R-250.

Eight markers of known molecular weights were used as a standard protein, myosin 205 kDa, β-galactosidase 119 kDa, bovine serum albumin 98 kDa, ovalbumin 52.3 kDa, carbonic anhydrase 36.8 kDa, soybean trypsin inhibitor 30.1 kDa, lysozyme 22 kDa, and aprotinin 7.6 kDa.

The disc electrophoresis pattern was analyzed by using gel pro analyzer version 3 Media Cybernetics imaging software, which compare the absorbance of each sample in each band, molecular weight and the rate of mobility of each band for the samples relative to the standard markers.

RESULTS AND DISCUSSION

The treatment of *Triticum aestivum* L. with the two exposure systems of an extremely low frequency electric field revealed a highly significant increase in the percentage of mitotic abnormalities after treatments of the wheat root tip cells with the two exposure systems of electric field as shown in Table 1. Each of the two systems induced a wide range of chromosomal abnormalities covering all mitotic stages. Among the mitotic irregularities induced by the applied electric field were stickiness, disturbed phases, laggards, bridges, fragment and micronuclei in interphase cells (Table 1 and Fig. 2). These results indicate the potentiality of the applied electric field to induce mitotic irregularities, which agree with the findings of many authors [18, 26].

Table 1

The percentages of abnormal mitotic phases, types and frequency of abnormal mitotic phases and mean percentage of total abnormal mitosis after exposure of *Triticum aestivum* L. root tips to the two exposure systems of electric field

Exposure case	The percentages of abnormal mitotic phases			Types and frequency of abnormalities						Total % of mitotic abnormalities
	Pro	Meta	Ana-telo	Stick.	Dist.	Lag.	Brid.	Frag.	Mn. in inter-phase	Mean ± SE
Group A_2	1.82	1.30	2.47	0.75	0.75	–	0.37	–	–	1.84 ± 0.31
Group B_2	41.86	73.08	69.39	13.57	14.29	7.14	12.86	16.43	1.5	64.31^{**} ± 0.91
Group C_2	1.90	2.30	2.41	0.36	1.09	–	0.36	–	–	2.18 ± 0.02
Group D_2	33.33	66.00	60.71	9.38	13.13	6.25	10.63	13.75	1.2	53.18^{**} ± 1.62

** Significant from control at 0.01 level (t-test).

The exposure under the experimental model showed further increase in the percentage of the mitotic abnormalities than the exposure through an open agricultural field. The effects of the two applied systems of electric field on the frequency of meiotic aberrations in wheat (*Triticum aestivum* L.) pollen mother cells (PMC_s) are demonstrated in Table 2 and expressed graphically in Fig. 3. A highly significant increase in the percentages of the abnormal pollen mother cells

was observed in the two systems of electric field applied. The two treatments induced a considerable percentage of abnormal pollen mother cells in the first meiotic division, which remained high in the second one. The frequency of meiotic aberrations reached a maximum value of 20.61% in flower buds collected after the exposure under the experimental model, compared to the control value of 0.52%. The recorded abnormalities are stickiness, laggards, bridges, disturbed phases, ring chromosome, fragments and micronuclei.

Table 2

Number of abnormal PMCs and percentage of the different types of meiotic abnormalities after exposure of *Triticum aestivum* L. plants to the two exposure systems of electric field

Exposure case	Total No. of exam PMCs	Total No. of ab. PMCs	% of total value of PMCs	% of total ab.	Types and percentages of meiotic abnormalities						
				Mean ± SE	St.	Dist.	Brid.	Lag.	Ring.	Frag.	M.n.
Group A_2	7364	37	0.50	0.52 ± 0.04	2.08	0.46	0.58	–	–	–	–
Group B_2	6775	1397	20.62	20.61^{**} ± 0.64	57.16	10.21	34.37	7.57	3.18	2.34	8.81
Group C_2	6692	36	0.54	0.55 ± 0.06	1.97	0.34	0.93	–	–	–	–
Group D_2	6344	1061	16.72	16.71^{**} ± 0.80	50.92	5.34	27.03	4.56	1.48	2.18	6.64

** Significant from control at 0.01 level (t-test).

Figs. 2–3 represent some of cytological anomalies observed after electric field treatments. Generally, its percentage was increased in the treatment under the experimental model than the treatment through the open agriculture field in both mitotic and meiotic cell division.

Chromosomal stickiness was the most pronounced phenomenon observed in both mitotic and meiotic cell division. Stickiness had been attributed to the depolymerization of DNA. McGill [19] interpreted stickiness as a result of physical interference with chromosome condensation. Such abnormal sub-chromatid connections finally cause many chromosomes to adhere to one another resulting in stickiness. Patil and Bhat [25] suggested that stickiness is a type of physical adhesion involving mainly the proteinaceous matrix of chromatin material. Such type of irregularity was also reported by Promila [26].

Bridges represent one of the most common types of abnormalities observed in both mitotic and meiotic cell divisions. Bridges might have been formed due to the stickiness of chromosomes at anaphase or due to the formation of dicentric chromosomes as a result of breakage and reunion. The stickiness of chromosomes made the separation of daughter chromosomes incomplete and thus they remain

connected by chromatin bridges [10]. Also disturbed phases were observed after all treatments. The formation of disturbed phases was due to inhibition in the respiratory pathways resulting in low energy production necessary for chromosome movement [2], or it may be induced due to spindle disturbance [11].

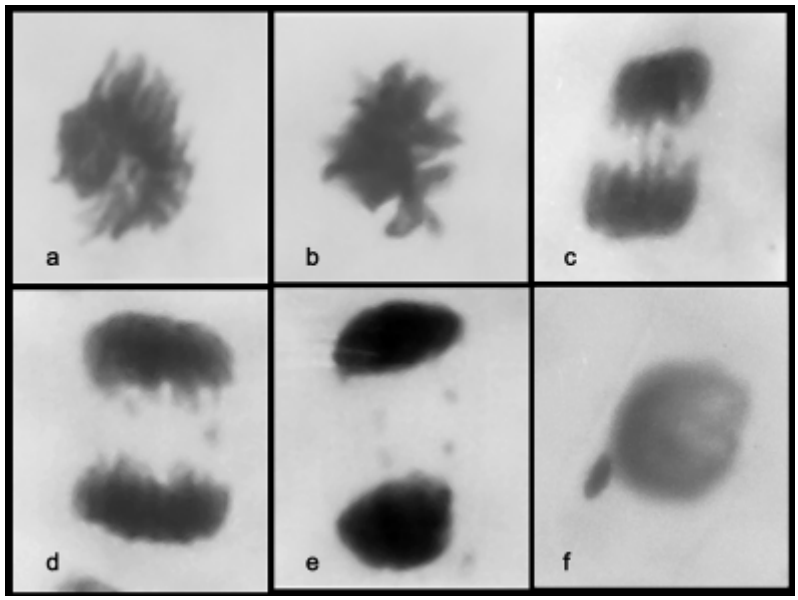

Fig. 2. Mitotic abnormalities induced by electric field (50 Hz) in two applied exposure systems in root tips of wheat; a) partial sticky and disturbed metaphase; b) sticky and disturbed metaphase; c) anaphase with bridge; d) anaphase with fragments; e) telophase with fragments; f) interphase with micronuclei.

Lagging chromosomes were recorded at metaphase and ana-telophase stages in both mitotic and meiotic division after all treatments. Laggards may be attributed to hindrance of the prometaphase movement accompanied by the adhesion of the centromeres of one or more chromosomes to the inner surface of the plasma membrane and movement of the others towards the equatorial plate leading to the appearance of such lagging chromosomes. Patil and Bhat [25] stated that laggards are the result of irregular orientation of chromosomes. The induction of laggards may lead to micronuclei formation. Also, the treatments induced chromosomal fragments which were noticed with high frequencies in mitotic division. Ring chromosome recorded with low frequency in metaphase I in the meiotic division after exposure to the two applied systems of electric field, that due to the sticky ends of bivalents, they fuse together to form a ring-like association at metaphase stage [26].

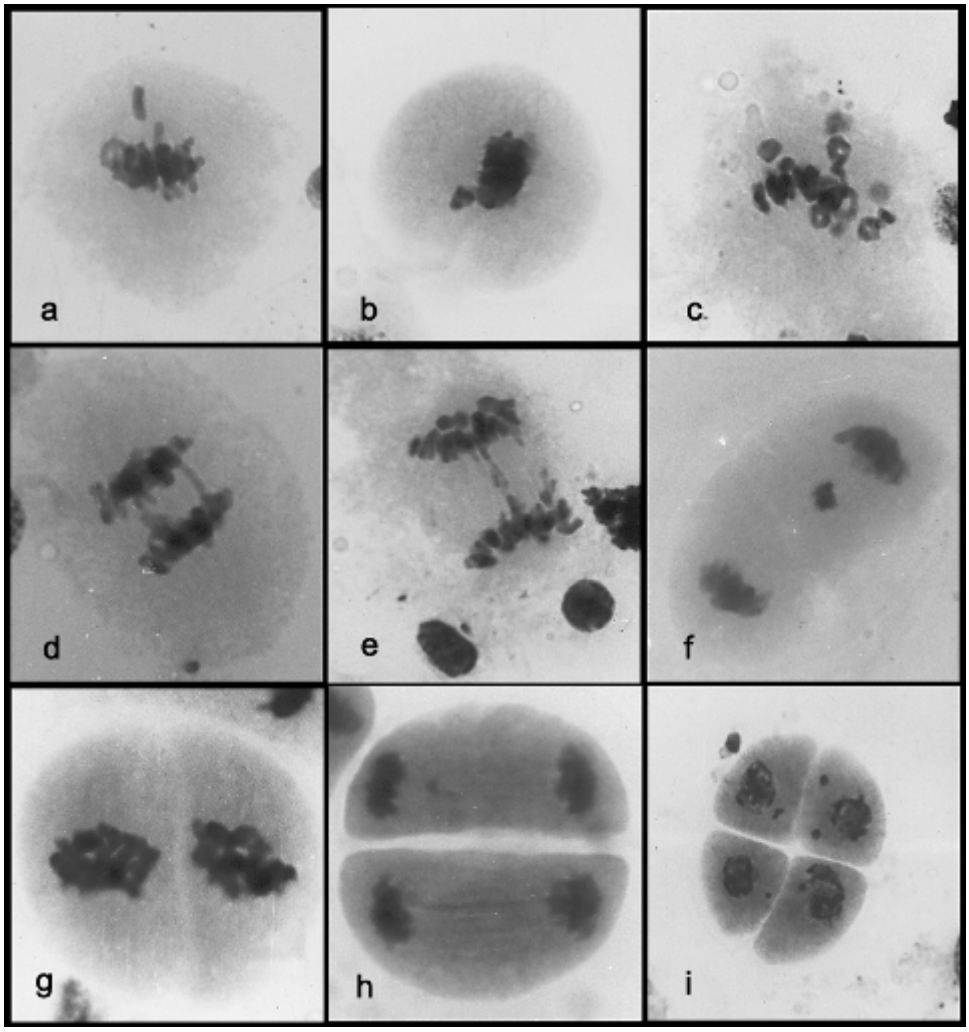

Fig. 3. Meiotic abnormalities induced by electric field (50 Hz) in two applied exposure systems in flower buds of wheat plants; a) partial sticky metaphase I with laggard chromosome; b) sticky metaphase I with laggard chromosome; c) metaphase I with ring chromosome; d) sticky metaphase I with two bridges; e) anaphase I with broken bridge; f) late anaphase I with laggard chromosome; g) sticky metaphase II; h) anaphase II with bridges and fragment; i) telophase II with micronuclei.

Micronuclei were observed at both mitotic and meiotic cell divisions. Micronuclei can be originated either from centric fragments or from laggards. Micronuclei are indicators of mutagenic aspects, which may lead to the loss of genetic material and have been regarded as an indication of the mutagenicity of their inducers [28].

Table 3 represents the effect of the two applied systems of electric field on pollen grains viability of *Triticum aestivum* L. flower buds. All treatments induced

a highly significant increase in the frequency of non-viable pollen grains. It was 35.08% after treatment under the experimental model as compared to its control with a value of 1.12%. A similar result was obtained by Bondar and Chastokolenko [6] where they found an increase in the percentage of sterile and semi sterile flower buds in *Vicia cracca* L. plants growing near high voltage electric power lines. They indicated that the sterility was due to a reduction in the anther and archesporial tissue or an increase in chromosome aberration frequency at various stages of meiosis. Figure 5 showed the viable and nonviable pollen grains, which appear after treating the flower buds of wheat plants with the two applied exposure systems of the electric field.

Table 3

Percentages of nonviable pollen grains in *Triticum aestivum* L. flower buds, which were exposed to the two electric field systems

Exposure Case	No. of examined pollen grains	Percentage of nonviable pollen grains / plant						Mean % of non viable pollen grains ± SE
Group A_2	6000	1.60	1.00	0.90	1.10	0.80	1.30	1.12 ± 0.12
Group B_2	6000	40.00	31.00	38.00	32.00	34.50	35.00	35.08^{**} ± 1.40
Group C_2	6000	1.10	0.70	1.50	0.90	0.70	1.40	1.05 ± 0.12
Group D_2	6000	20.00	21.50	24.00	26.00	28.00	25.00	24.08^{**} ± 1.20

**Significant from control at 0.01 level (t-test).

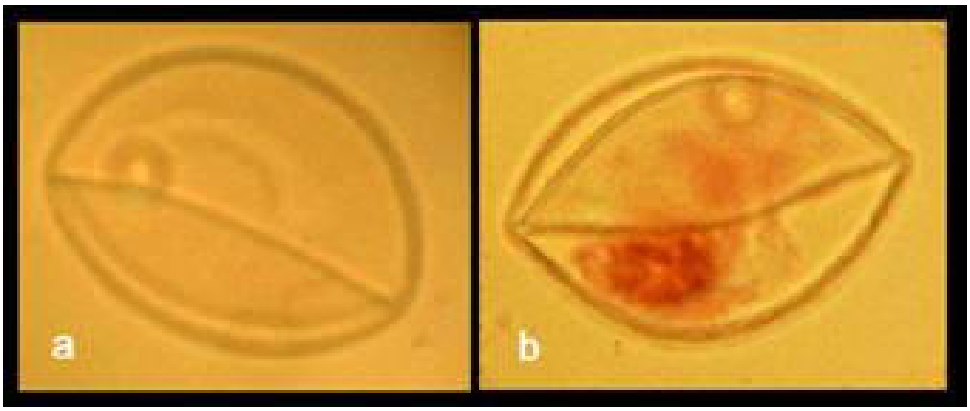

Fig. 4. Viable and nonviable pollen grains after the exposure of the flower buds of wheat to the applied systems of electric field (50 Hz); a) nonviable pollen grains; b) viable pollen grains.

Concerning the morphological parameters represented by the number of spikes per plant, the spike weight, the number of grains per spike and the average weight of 100 grains decreased for the exposed grains but the values of the stem length of the plant of the exposed grains increased relative to the unexposed ones.

For the morphological properties (Table 4), it is obvious that the number and the weight of the yield grains of the exposed grains were lower than those unexposed. The same trend was previously found by [27].

The morphological results explained that exposure of the grains to the electric field resulted in a significant inhibition in all the parameters except for the stem length, that was highly increased (Fig. 5a), changes that might be due to the increase in chlorophyll content. Figure 5b showed the deformation in the shape of the exposed grains as a result of the exposure to electric field, which causes deformation inside grains through compression, or tension of particular layers. The most visible effects of compression and tension of objects that occur in laminar and elastic objects such as wheat grain [31].

Table 4

Morphological characters of the unexposed and exposed grains to the electric field

Exposure case	Spike wt. (gm)	Stem length (cm)	Average weight of 100 grains(gm)	No. of spike per plant	No. of grains per spike
Group A_1	1.9±0.12	76.2±2	0.314±0.02	4.0±0.2	50±10
Group B_1	1.6±0.13**	85.1±2.5**	0.273±0.02**	3.0±0.2**	30±5**
Group C_1	2±0.2 1	75.2±2	0.310±0.02	4.2±0.2	58±10
Group D_1	1.8±0.1 2**	82.1±3**	0.280±0.02**	3.8±0.2**	35±5**

** Significant from control at 0.01 level (t-test).

Table 5

Chlorophyll content of unexposed and exposed grains to the electric field

Exposure case	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Total chlorophyll (mg/g)
Group A_1	0.443±0.01	0.360±0.01	0.803±0.01
Group B_1	0.458±0.01**	0.395±0.01**	0.853±0.01**
Group C_1	0.440±0.01	0.352±0.01	0.792±0.01
Group D_1	0.448±0.01**	0.387±0.01**	0.835±0.01**

** Significant from control at 0.01 level (t-test).

Generally the results explain that there is increase in all the parameters of the exposed grains under the experimental model as compared to the exposed grains through the open agriculture field (Fig. 5a and 5b).

a. b.

Control plant Exposed plant Control grains Exposed grains

Fig. 5. The plants and grains shape.

This external energy field produced electrochemical alterations in the components of the cell membrane surface and also produced alterations in its intracellular biochemical and physiological functions [32]. The chlorophyll content in the leaf of the plant of the exposed and unexposed grains is shown in Table 5. The amount of chlorophyll in the leaves of the plants of the exposed grains is higher than in the unexposed plant. Increasing the chlorophyll content in the exposed plant may be due to the inhibition of the degradation of the chlorophyll due to the exposure to the electric field [9, 35]. The carbohydrate content of the exposed and unexposed grains is shown in Table 6, which indicates that the carbohydrate content of the exposed grains is higher than the unexposed grains, this indicating that exposure to high voltage electric field stimulates the biological process and the nutrient metabolism [27]. Increasing carbohydrate content may be due to increasing in total chlorophyll, which increases the photosynthesis process. Increasing the photosynthesis process leads to increasing the vegetative stage and the flower stage and finally produces mature grains.

Table 7 explains the total protein content of the exposed and unexposed grains, the results indicate that the amount of the total protein decreased for the exposed grains as compared with the unexposed ones as a result of decreasing the nitrogen element [24]. Our results are in good agreement with Walter, Laberg and MacGinitic [13, 17, 33]; they reported that the electric field inhibits the biological properties of the membrane protein. These results are in agreement with our result of decreased WSP and the loss of genetic material, which occur due to the chromosomal aberration in cytological measurement.

Table 6

The total carbohydrate mg/gm of the unexposed and exposed grains to the electric field

Exposure case	Monosacch. mg/g dry wt.	Disacch. mg/g dry wt.	Polysacch. mg/g dry wt.	Total carbohydrates mg/g dry wt.
Group A	0.098±0.01	0.2543±0.01	1.349±0.01	1.7013±0.01
Group B	0.1015±0.01**	0.480±0.01**	1.37±0.01**	1.9515±0.01**
Group C	0.09±0.01	0.2765±0.01	1.33±0.01	1.696±0.01
Group D	0.1295±0.01**	0.2986±0.01**	1.36±0.01**	1.788±0.01**

** Significant from control at 0.01 level (t-test).

Table 7

The total protein of the unexposed and the grains exposed to the electric field

Exposure case	Amount of crude protein mg/100 mg
Group A	10.88±2.1
Group B	5.06±4.1**
Group C	6.78±3.2
Group D	4.69±2.1**

** Significant from control at 0.01 level (t-test**).**

The disc electrophoretic pattern and the molecular weight distribution of WSP extracted from the unexposed and the exposed groups (A, B, C and D) are shown in Fig. 6 (a & b).

The scanning profiles of the electrophoretic preparation Fig. 6 (a & b) showed that the components of WSP of group A separated into 35 bands having molecular weight in the range 234–1.5 kDa, but for group B the number of bands decreased to 33 bands. For group C the number of bands is 36 and for group D the number of bands decreased to 35. Also, it was observed that the optical density of the protein bands of the exposed grains decreased and from the same figure one ca see changes in their molecular weights and fluctuation in the electrophoretic mobility.

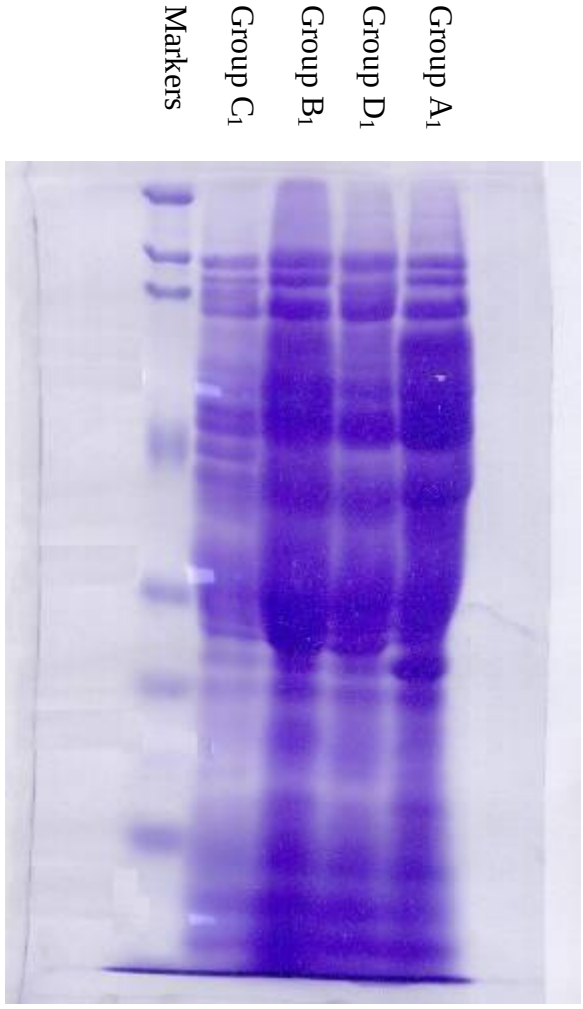

Fig. 6a. The disc electrophoretic pattern.

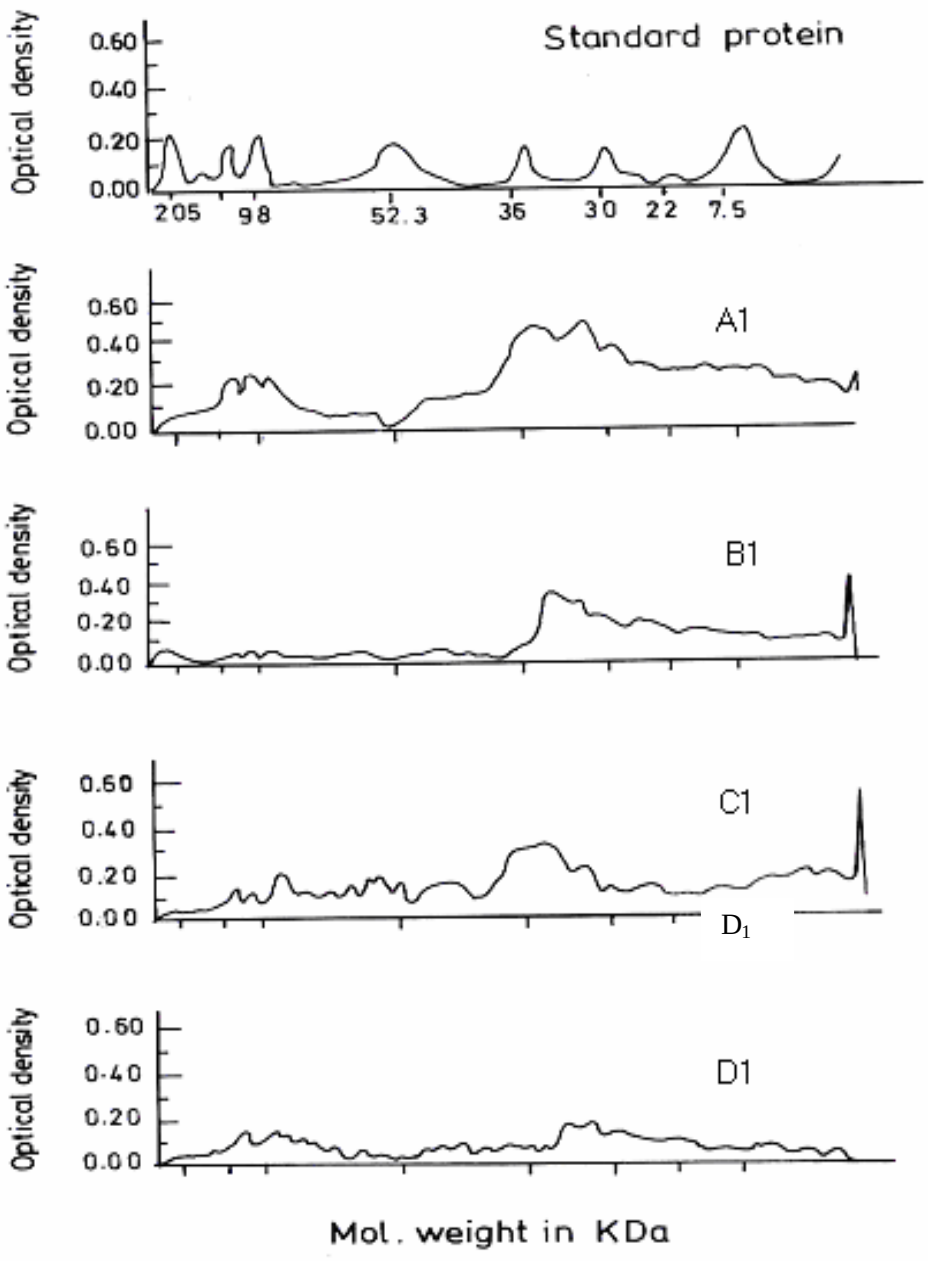

Fig. 6b. The electrophoretic profile of WSP extracted from groups A_1, B_1, C_1 and D_1.

The results of the gel electrophoresis technique of the extracted WSP from the exposed and unexposed grain indicated that the WSP content decreased for the exposed grains (groups B and D) and also its molecular structure changed where the molecular weights of their bands changed; this result is in a good

agreement with Hassan [11], where the changes in the grain protein electrophoretic profiles have been attributed to the occurrence of either gene mutation or indication of cytological aberrations. Also, the increase or decrease in band's intensity in the present study after exposure to electric field can be interpreted on the basis of the gene mutation at regulatory systems that control the concerned structural genes [1, 22]. Also, changes in band's intensity were due to gene duplication resulted from bridges and laggards that are observed at cytological analysis. Therefore, the bridges would lead to gene duplication at one pole and deletion at the other pole, while laggards may be distributed randomly to either poles producing monosomic (gene deletion) or trisomic (gene duplication) cells [1]. In addition, breaks, bridges, laggards and micronuclei may lead to a loss of some genetic material [8]. Disappearance of some bands can be explained also on the basis of protein degradation. These results are supported by the absorption spectra shape where the WSP content decreased by exposing the grains to the electric field (Figs. 7–8).

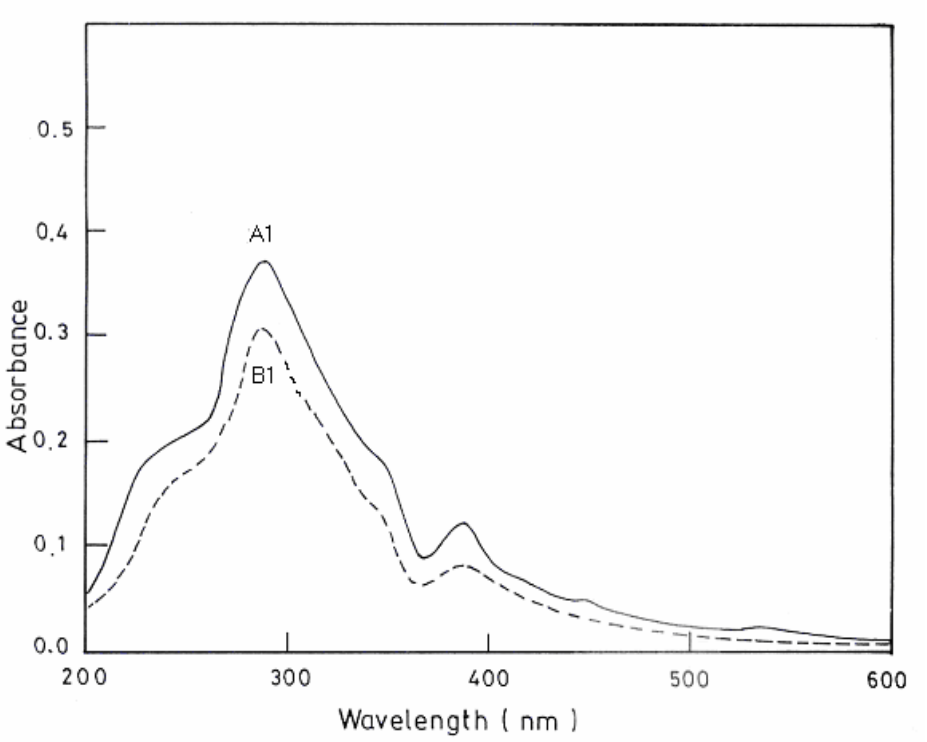

Fig. 7. The absorbance of the WSP of the unexposed grains and grains exposed to electric field group (A_1) and (B_1).

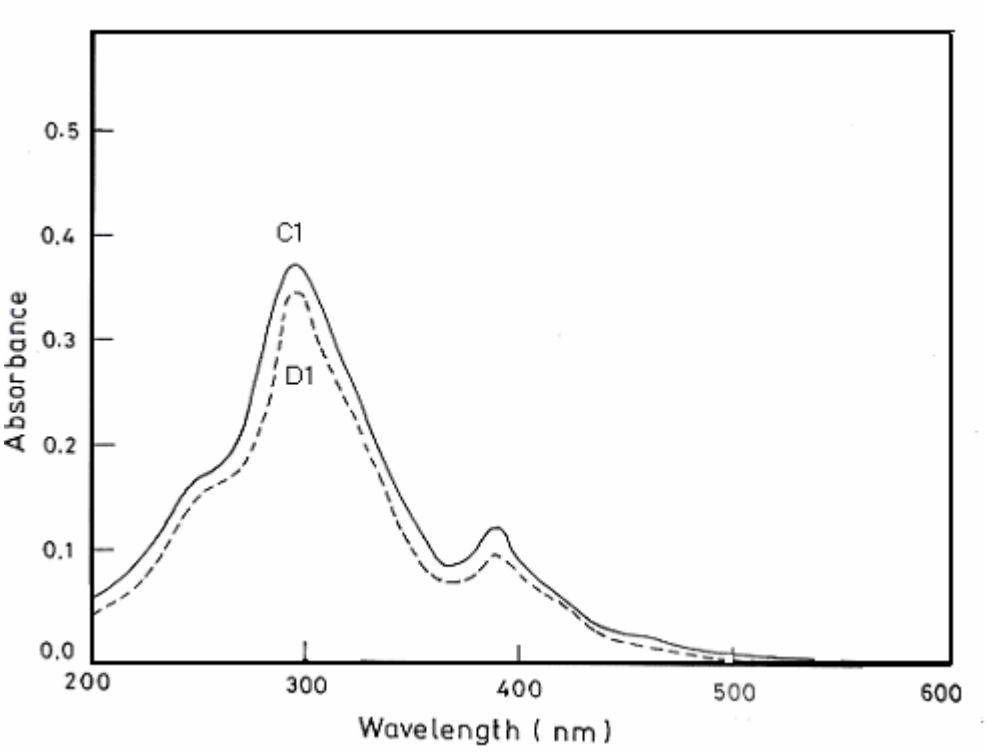

Fig. 8. The absorbance of the WSP of the unexposed grains and grains exposed to electric field group (C) and (D).

CONCLUSION

From the present work, it is concluded that growing plants under high voltage transmission lines change their growth characteristics and protein molecular structure and also decreases plant yield. Therefore, the electric field is considered pollutant to the environment. Hence, it is recommended to insert such transmission lines under the ground to minimize their hazardous effects.

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