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EFFECT OF ALTERNATIVE ELECTRIC FIELDS OF DIFFERENT DIRECTIONS ON THE CRESS ROOTS GRAVITROPIC REACTION IN VERTICAL STATIC MAGNETIC FIELD

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The gravitropic reaction of cress roots was investigated in static vertical magnetic field and alternative electric field of different directions. The alternative electric field was tuned to cyclotron frequency of $Ca2^+$ ions in vertical magnetic field. Three variants were investigated. In the first one the magnetic field and the electric field are parallel between themselves and gravitational vector. So the roots were located perpendicular to all of them. In second and third variants the magnetic field and the electric field are perpendicular to each other and roots were located either perpendicular to electric field (second variant) or parallel to it (third variant). In the first and second variants the essential inhibition of gravitropic reaction was observed.
Keywords: static magnetic field, alternative electric field, gravitropic reaction, roots direction, cyclotron frequency.

INTRODUCTION

The investigation of combined magnetic field (CMF, static and parallel to it alternative magnetic field) influence on the plants roots gravitropic reaction was studied in details before for different relative orientation of fields and roots [1-4]. It was shown that the effect developed essentially on the orientation of roots relatively the CMF[3]. It was shown that the roots direction relatively B_{DC} and B_{AC} (B_{DC} and B_{AC} are inductances of static and alternative magnetic fields) are essential for negative gravitropic reaction and decreasing of gravitropic reaction observation [4]. The effect we obtained may be explained by our theory based on Liboff's hypothesis (the electric field was taken in consideration) and ours previous work [3,4] The breathing of the membrane is important only in the cases when the ions direction of moving is not parallel either for B_{DC} or B_{AC}.

To confirm or deny our hypothesis we change the alternative component of magnetic field by alternative electric field of different orientations. In the work the following variants of roots location relatively to static component of magnetic field and alternative component of electric field were studied.

- At first variant the static magnetic field was directed parallel to the gravitation vector, the alternative electric field was directed parallel to static magnetic field, roots were directed perpendicular to both two fields components and gravitation vector;
- At second variant the static magnetic field was directed parallel to the gravitation vector, the alternative electric field was directed perpendicular to static one, roots were directed parallel to alternative electric field;
- At third variant the static magnetic field was directed parallel to the gravitation vector, the alternative electric field was directed perpendicular to static one, roots were directed perpendicular to both two fields components and gravitation vector.

MATERIALS AND METHODS

The materials and methods of the investigation were described before [2, 3].

The only distinction is the possibility to obtain the electric field that was parallel or perpendicular to gravitation vector. For the purpose the samples were located in capacitance between two non-magnetic planes (fig1,2).

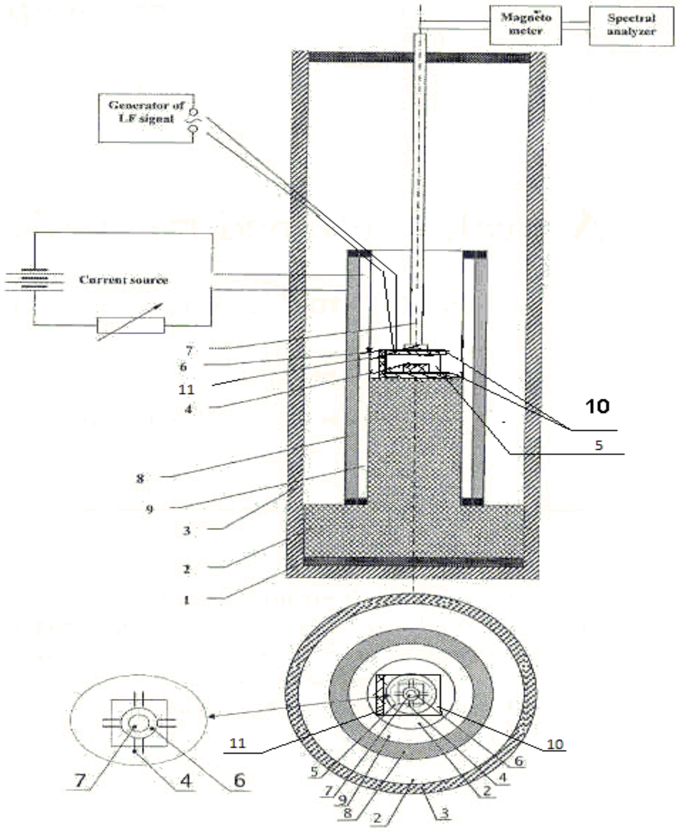


Fig.1. The damping rubber (1) supported the holder of dielectric material (2). The μ-metal shield (3) surrounded the samples (4) that were mounted inside a moist chamber of non-magnetic plastic material (5) and solenoids (8, 9). The magnetic field was measured

and controlled by sensor elements (fluxgate magnetometer or SQUID), (6) inside a holder (7). The solenoids (8, 9) have a cylindrical shape and comprise the system that generates the static magnetic field (9). Two flat plates from non-magnetic material(10) were sourced from LF generator. They are divided by dielectric plate (11). The enlarged central part of the top view shows the orientation of 4 pairs of roots (4), arranged around the magnetic field sensor (7). The coils of solenoids (8, 9) are the spaces between the circles in the bottom part. The space between the innermost circles is the holder of dielectric material (2).

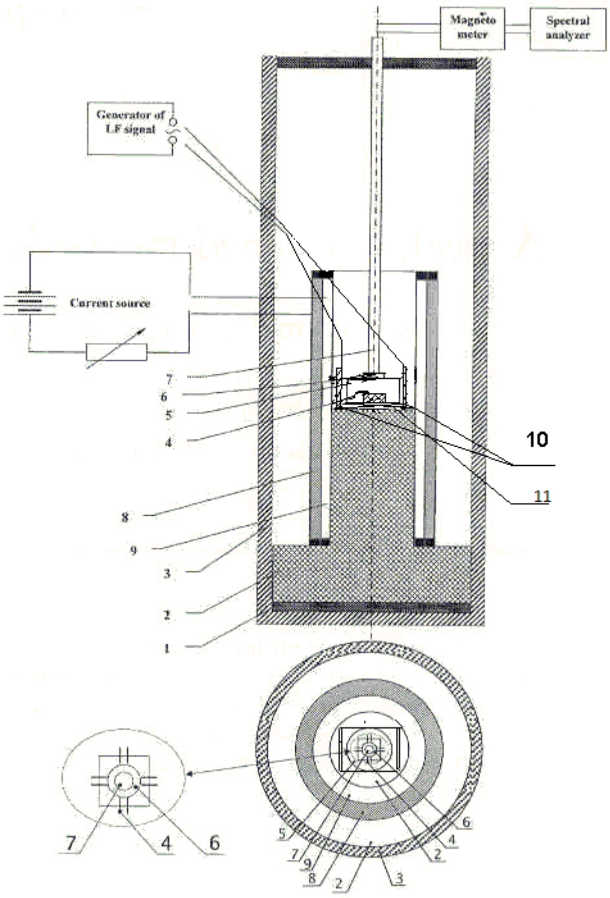
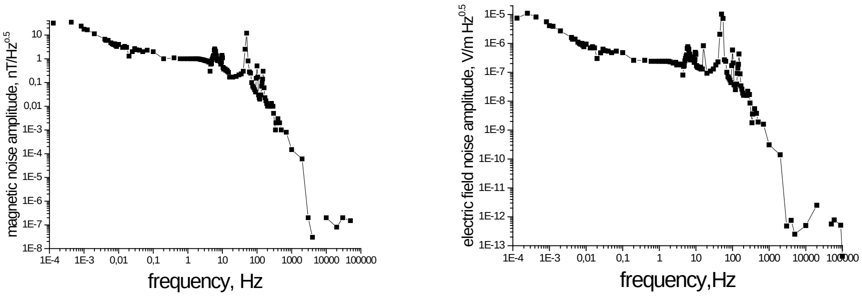


Fig.2. The damping rubber (1) supported the holder of dielectric material (2). The μ-metal shield (3) surrounded the samples (4) that were mounted inside a moist chamber of non-magnetic plastic material (5) and solenoids (8, 9). The magnetic field was measured and controlled by sensor elements (fluxgate magnetometer or SQUID), (6) inside a holder (7). The solenoids (8, 9) have a cylindrical shape and comprise the system that generates the static magnetic field (9). Two flat plates from non-magnetic material(10) were sourced from LF generator. They are divided by dielectric plate (11)/ The enlarged central part of the top view shows the orientation of 4 pairs of roots (4), arranged around the magnetic field sensor (7). The coils of solenoids (8, 9) are the spaces between the circles

in the bottom part. The space between the innermost circles is the holder of dielectric material (2).

The only difference between fig.1 and fig.2 was the orientation of the electric field created by non-magnetic planes.



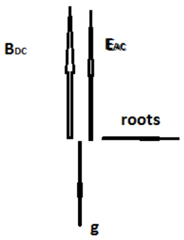
a b

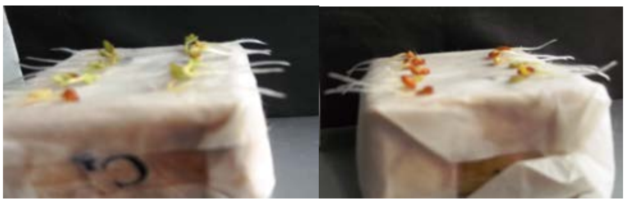
Fig.3. The magnetic (a) and electric (b) fields' noises' dependencies on frequency.

RESULTS AND DISCUSSION

The results obtained are shown on fig. 4, 5 and 6.

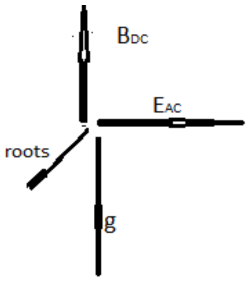
First variant.

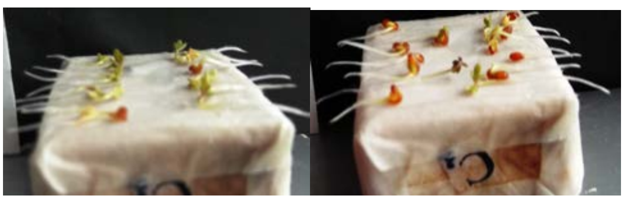




a b

Second variant





c d

Third variant

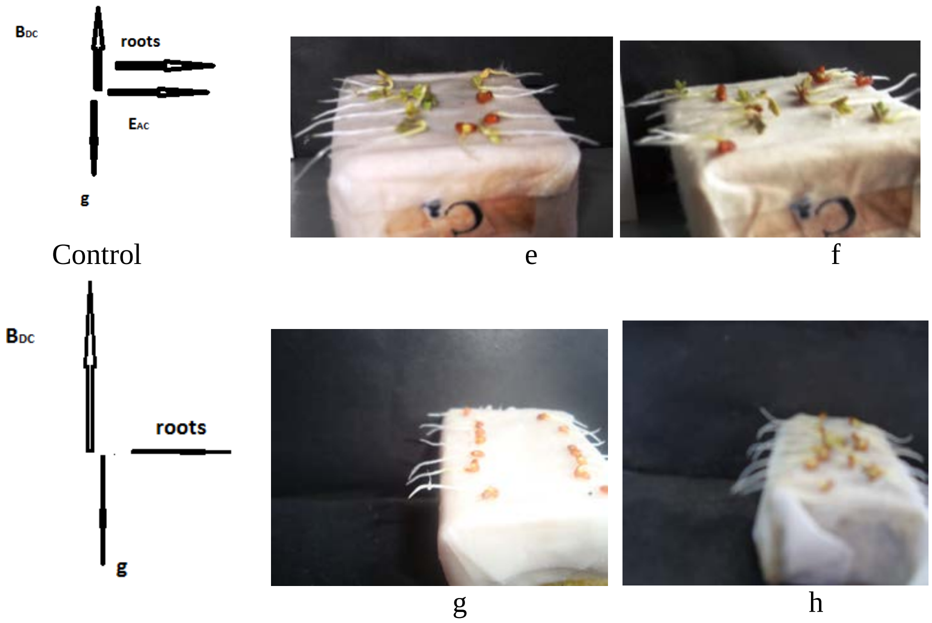


Fig.4. The gravitropic reaction of cress roots for 0.5 (a, c, e, g) and 1 hour (b, d, f, h). The value of static magnetic field induction was equal to 40μT, the frequency of alternative electric field was equal to 31.75 Hz, and the amplitude of electric field was equal to 100 V/m.

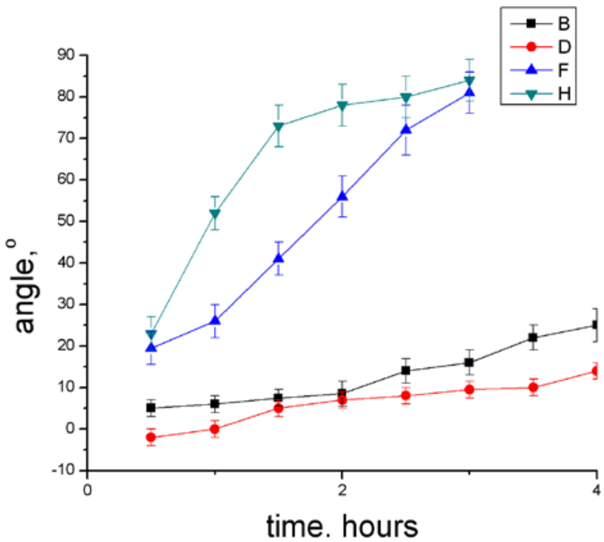


Fig.5. The dependences of divergences of cress roots from the horizontal plane on time. Curve B corresponds to the first variant (alternative electric field is parallel to static

magnetic field and gravitrpic vector and roots' direction is perpendicular to all of them) curve D corresponds to the second variant (alternative electric field is perpendicular to static magnetic field and gravitrpic vector and roots' direction is perpendicular to all of them), curve F relates to the third variant(alternative electric field is perpendicular to static magnetic field and gravitrpic vector and roots' direction is parallel to electric field) and curve H relates to the control experiment. The value of static magnetic field induction was equal to 40μT, the frequency of alternative electric field was equal to 31.75 Hz, and the amplitude of electric field was equal to 100 V/m.

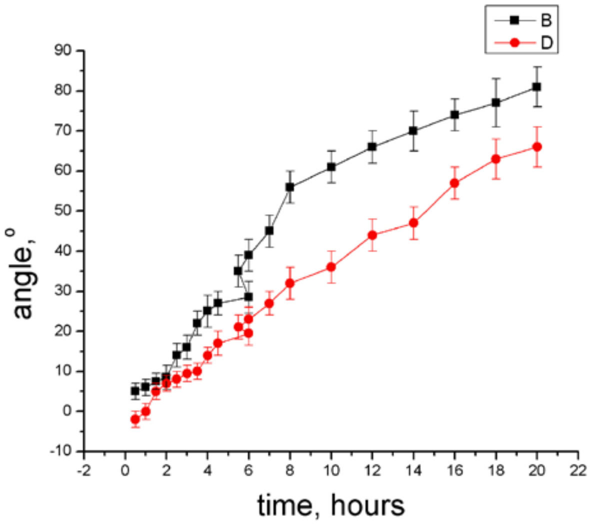


Fig.6. The dependences of divergences of cress roots from the horizontal plane on time. Curve B corresponds to the first variant (alternative electric field is parallel to static magnetic field and gravitrpic vector and roots' direction is perpendicular to all of them) curve D corresponds to the second variant (alternative electric field is perpendicular to static magnetic field and gravitrpic vector and roots' direction is perpendicular to all of them).

As it is clear from fig.5 the gravitropic reaction velocity depended essentially on the direction of roots growing relatively the alternative electric field direction. At the first and second variants the speed of gravitropic reaction is decreased essentially while at the third variant does not differ from the control experiment. The biological effect was observed only for the amplitude of alternative electric field 100V//m. We didn"t observe any effect at the amplitude of alternative electric field 10V//m. We have to notice here that it is impossible to determine the exact value of amplitude of alternative electric field because of the wet environment. It depends on the humidity of the camera and the electric resistance of the root. .

The results obtained in this work confirm the results of our previous works [3, 4]. It was shown in the works [3, 4] that the biological effect on gravitropic reaction existed only in the cases when the roots direction was perpendicular to static or alternative magnetic fields or to both of them. In this work we showed that the same effect existed. The gravitropic reaction was sensitive to static magnetic field and alternative electric one only when the roots direction coincided with the perpendicular to both static magnetic and the alternative electric fields. So we could conclude that the effect was obtained only for cases when both fields changed the direction of ions moving. So as in the works [3, 4] the main direction of Ca^{2+} ions' moving was the moving along the roots

The effect we obtained may be explained by our theory based on Liboff's hypothesis (the electric field was taken in consideration) and ours previous works. The breathing of the membrane is important only in the cases when the ions direction of moving is not parallel either for B_{DC} or B_{AC} or E_{AC}. We have to notice that while the gravitropic reaction is absent, the roots become thicker. The effect may be connected with water detained in roots.

CONCLUSIONS

1. The direction of roots relatively both static magnetic field and alternative electric field is very important.
2. The effect may be explained by membrane breathing caused by alternative electric field.

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Богатина Н. И. Влияние переменных электрических полей различных направлений на гравитропическую реакцию корней кресс-салата в вертикальном постоянном магнитном поле / Н. И. Богатина, Н. В. Шейкина, А. С. Линник // Ученые записки Крымского федерального университета им. В. И. Вернадского. Серия «Биология, химия». – 2015. – Т. 1 (67), №1. – С.3–9.

Исследовалась гравитропическая реакция корней кресс-салата в постоянном вертикальном магнитном поле и переменном электрическом поле различных направлений. Переменное электрическое поле настраивали на циклотронную частоту ионов Ca^{2+} в вертикальном магнитном поле. Опыт проводился в при трех различных относительных направлениях магнитного, электрического полей и корней. В первом варианте магнитное и электрическое поля параллельны между собой и вектору гравитации. Таким образом, корни расположены перпендикулярно им всем. Во втором и третьем вариантах магнитное и электрическое поля расположены перпендикулярно друг другу, а корни расположены либо перпендикулярно электрическому полю (второй вариант), либо параллельно ему (третий вариант). В первом и втором варианте наблюдалось существенное угнетение гравитропической реакции.

Ключевые слова: постоянное магнитное поле, переменное электрическое поле, гравитропическая реакция, направление корней, циклотронная частота.

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