# Effect of Electrical Field on Barley Seed Germination Stimulation

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**Abstract**

The present paper provides the data on seed germination stimulation in the corona discharge field and energy content conveyed to seed. The effect of physical treatment on seed germination is discussed in the review of literature. Abundant experimental evidence suggests that the methods of physical treatment used at optimal doses have a positive impact on seed viability. However, many authors do not indicate the initial seed germination and viability.

Tests were carried out with barley seed following active experimental planning procedures for three factors – field strength, time from treatment to sowing and seed moisture. In compliance with the standard methodology germination tests were done in four replications, 100 seed per replication. Seed viability tests were conducted in two replications, 100 seed per replication.

Statistically processed experimental data suggest that the effect of electrical field in the first fraction of the electric separator significantly increased seed germination, compared with the untreated control. The difference between the seed germination in the second fraction and in the control was insignificant. It was also identified that viability and germination differences between the seed in the first fraction of the electric separator and in the control were significant. Experimental evidence indicates that the content of energy conveyed to seed depends on the strength of the electrical field and electrical properties of seed.

**Keywords:** electric separator, barley seed, viability, moisture, germination, energy.

## Introduction

The effect of physical treatment on seed manifests itself by its response to external stimulus, which invokes inductive effect, i.e. the effect that persists even after stimulus has been removed. The effect of the stimulus manifests itself only if it exceeds a certain critical value. Therefore the seed has to receive such content of energy which is necessary to induce reaction mechanism. Further reaction occurs at the expense of energy resources of a cell.

At optimal treatment doses all physical treatment methods create prerequisites for the manifestation of seed potentiality. While improving seed quality one should estimate the costs of the method used workability and efficiency of the machinery.

The use of ionised rays for carrot seed stimulation increases seed germination by 9-20% (Sirtautaite, 1996; Frolova, 1983; Borisov, 1994). The above mentioned authors maintain that the optimal irradiation doses used are very different when recalculated into the amount of energy conveyed per seed. The values reported by Sirtautaite (1996) are 44 - 50 J/m$^3$, by Frolova (1983) - 300 J/m$^3$ and Borisov (1994) - 220-340 J/m$^3$. When tomato seed is exposed to laser irradiation the conveyed energy amounts to 15 J/m$^3$, and the seed germination increases by 6-7% (Vasilenko, 1997). A number of authors indicate a similar content of conveyed energy but recommend exposing seed to laser irradiation from 3 to 9 times

(Suminov, 1995; Colakov et al., 1990; Koper, 1996). A yield increase of 3-14% is pointed out in the above mentioned studies. When 100-1000 Hz alternating current is used carrot seed receives up to 0.6 $J/m^3$ energy and germination increase makes up 9% (Palov et al., 1983; Belkovec, 1998). The content of energy conveyed to a wheat grain in the corona discharge field is 0.02-2 $J/m^3$ (Kotov et al., 1998; Szendro, 1995). In the magnetic field wheat seed receives 0.8 $J/m^3$ energy (Pietruszewski, 1996), tomato seed – 0.07 $J/m^3$ (Amaya et al., 1996).

It is known that when using any physical treatment method better results are obtained when viable seed that has not completed formation or dormant seed is stimulated (Putincev et al., 1997).

From the provided optimal treatment doses we can see that the content of energy conveyed to the seed varies within $10^{-2}$ – $10^2$ $J/m^3$ range. The volume of the smallest and largest treated seed varies from $3{\cdot}10^{-7}$ $m^3$ to $5{\cdot}10^{-6}$ $m^3$. From our review of literature we can conclude that the highest doses indicated give the greatest germination increase at certain initial seed parameters. This inference is affirmed by the fact that none of the references provides seed viability, initial germination and moisture content. In the cited literature references we did not find an answer to the question at which initial seed parameters it is expedient to stimulate seed with physical treatment methods. In our opinion, the energy content conveyed to seed is considered optimal if it enables the seed to realisation its potential energy, i.e. its germination becomes close to viability.

## Material and methods

The objective of the present study is to investigate and substantiate possibilities of seed potential energy realisation by using electrophysical treatment method (corona discharge field) and means (conveyor electric separator).

Tests were carried out with barley seed using a conveyor type corona discharge field electric separator. The scheme of the electric separator is provided in Figure 1.

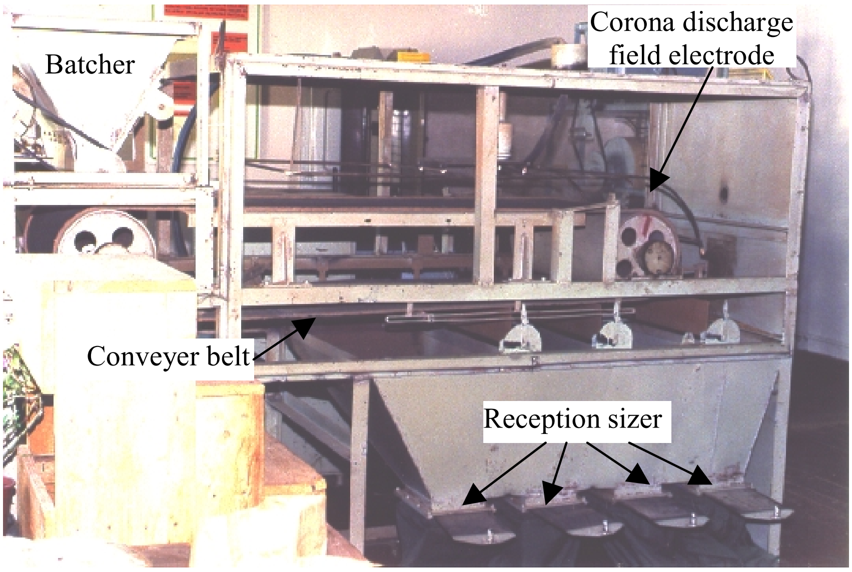


Fig. 1. Conveyer type electric separator

The tests were conducted using active experimental planning method (Maksimov, 1980; Spiridonov, 1981). The tests were conducted for three factors – field strength, time from treatment to sowing and seed moisture. In compliance with the standard methodology germination tests were done in four replications, 100 seed per replication. Seed viability tests were conducted in two replications, 100 seed per replication. Affecting factors, their levels and variation ranges are provided in Table 1.

Table 1. Factors, levels, variation ranges

| Factors | Notation | Levels | | | | | Variation range |
|---|---|---|---|---|---|---|---|
| | | Upper (+1) | Lower (-1) | Main (0) | Upper star ($+\alpha$) | Lower star ($-\alpha$) | |
| Strength of corona discharge field $E$, $10^5$ V/m | $x_1$ | 4 | 2 | 3 | 4.2 | 1.8 | 1 |
| Seed moisture $W$, % | $x_2$ | 19 | 13 | 16 | 20 | 12 | 3 |
| Time $\tau$ (days) from treatment with corona discharge field to sowing for germination testing | $x_3$ | 10 | 4 | 7 | 11 | 3 | 3 |

In order to achieve the desirable moisture the seed was artificially wetted. The necessary amount of water $Q$ was calculated according to the formula:

$$Q = \frac{m\left(W_2 - W_1\right)}{100 - W_1}, \qquad (1)$$

where: $m$ – seed weight (kg) taken for the test (in our case $m=0.6$ kg);
$W_1$, $W_2$ – required initial seed moisture, %.

Control seed was passed through the electric separator without switching on high voltage. During each test we estimated the seed output in the fractions of the sizer. The viability of the control seed and the seed that got into the fractions was determined according to the standard methodology in two replications, and germination was tested in four replications.

## Results and discussion

Table 2 provides the findings of the tests carried out according to the second line orthogonal central compositional plan.

Analysis of the experimental results leads to the conclusion that the seed characterised by a poorer germination and viability tends to get into the second fraction of the electric separator. Having verified by Student criterion we found that an increase in germination in the first fraction was significant compared with the control. The difference between seed germination in the control and in the second fraction was not significant. Looking at the difference between seed viability and germination we can see that this difference is smaller in the seed treated with electric field compared with the untreated seed.

Table 2. Experimental conditions and results

| No. of the experiment | Experimental conditions | | | Seed germination, % | | | Seed viability, % | | | Seed viability and germination difference, % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Field strength $E$, $10^5$V/m | Seed moisture $W$,% | Time from treatment to sowing $\tau$, (days) | 1st fraction $D_I$,% | 2nd fraction $D_{II}$,% | Control $D_K$,% | 1st fraction $G_I$,% | 2nd fraction $G_{II}$,% | Control $G_K$,% | $G_I$-$D_I$, % | $G_{II}$-$D_{II}$, % | $G_K$-$D_K$, % |
| 1 | 2 | 13 | 4 | 81 | 67 | 62 | 86 | 80 | 86 | 5 | 13 | 24 |
| 2 | 4 | 13 | 4 | 76 | 71 | 70 | 82 | 78 | 82 | 6 | 7 | 12 |
| 3 | 2 | 19 | 4 | 78 | 48 | 56 | 82 | 74 | 82 | 4 | 26 | 26 |
| 4 | 4 | 19 | 4 | 74 | 62 | 63 | 88 | 86 | 88 | 14 | 24 | 25 |
| 5 | 2 | 13 | 10 | 76 | 60 | 64 | 82 | 74 | 82 | 6 | 14 | 18 |
| 6 | 4 | 13 | 10 | 74 | 68 | 69 | 80 | 78 | 80 | 6 | 10 | 11 |
| 7 | 2 | 19 | 10 | 78 | 46 | 55 | 84 | 70 | 84 | 6 | 24 | 29 |
| 8 | 4 | 19 | 10 | 66 | 56 | 57 | 84 | 76 | 84 | 18 | 20 | 27 |
| **Average** | | | | **75** | **60** | **62** | **84** | **77** | **84** | **8** | **17** | **22** |
| 9 | 1,8 | 16 | 7 | 72 | 70 | 70 | 88 | 72 | 88 | 16 | 2 | 18 |
| 10 | 4,2 | 16 | 7 | 63 | 63 | 59 | 86 | 82 | 86 | 23 | 19 | 27 |
| 11 | 3 | 12 | 7 | 69 | 64 | 69 | 82 | 82 | 82 | 13 | 18 | 13 |
| 12 | 3 | 20 | 7 | 67 | 59 | 59 | 80 | 76 | 80 | 13 | 17 | 21 |
| 13 | 3 | 16 | 3 | 51 | 46 | 46 | 86 | 74 | 86 | 35 | 28 | 40 |
| 14 | 3 | 16 | 11 | 73 | 53 | 68 | 84 | 68 | 84 | 11 | 15 | 16 |
| 15 | 3 | 16 | 7 | 83 | 59 | 75 | 84 | 74 | 84 | 1 | 15 | 9 |
| **Common average** | | | | **72** | **60** | **63** | **84** | **76** | **84** | **12** | **16** | **22** |

Student criterion was used to estimate the effect of electrical field on seed germination and to measure the difference between seed viability and germination. The hypothesis was checked whether the averages of the respective parameters of the control and treated seed were equal. The results are presented in Table 3.

As was already mentioned, our tests were done following second degree model. Having checked the adequacy of the model according to Fisher's criterion at probability $p$=0.95, first degree model was found to be adequate. Parameters of the model are presented in Table 4.

The relationship between seed germination in the first fraction and affecting factors (in the encoded form)

$$D_I = 75.54 - 2.58x_1 - 1.33x_2 - 1.96\,x_3 - 1.21x_1 x_2 - 1.46\,x_1 x_2 x_3. \quad (2)$$

According to the values of the coefficients preceding the factors we can judge that the seed germination of the first fraction is most markedly affected by: 1) strength of the electrical field; 2) length of the period from treatment to sowing; 3) combination of field strength, seed moisture and length of the period from treatment to sowing.

Table 3. Assessment of the effect of electrical field on seed germination and on viability-germination difference

| Treatment | $\overline{x}$ | $s^2$ | $T_{calc.}$ | $T_{tabl.}$ | Comment |
|---|---|---|---|---|---|
| Assessment of the results of the first line plan (1-8 tests) | | | | | |
| Germination in the control, % | 62.0 | 32.6 | | 2.15 | |
| Germination of the 1st fraction treated with electrical field, % | 75.4 | 19.7 | 5.23 | | Germination increase was significant |
| Germination of the 2nd fraction treated with electrical field, % | 59.8 | 84.8 | 0.59 | | Germination decline was not significant |
| Viability and germination difference in the control | 21.5 | 48.3 | | 2.15 | |
| Viability and germination difference in the 1st fraction | 8.1 | 25.3 | 4.41 | | Viability and germination difference between the control and 1st fraction was significant |
| Viability and germination difference in the 2nd fraction | 17.2 | 51.6 | 1.20 | | Viability and germination difference between the control and 2nd fraction was not significant |
| Assessment of the results of the second line plan (1-15 tests) | | | | | |
| Germination in the control, % | 63.0 | 57.9 | | 2.15 | |
| Germination of the 1st fraction treated with electrical field, % | 72.0 | 64.8 | 3.24 | | Germination increase was significant |
| Germination of the 2nd fraction treated with electrical field, % | 59.5 | 68.7 | 1.15 | | Germination decline was not significant |
| Viability and germination difference in the control | 21.1 | 69.9 | | 2.15 | |
| Viability and germination difference in the 1st fraction | 11.8 | 77.6 | 2.95 | | Viability and germination difference between the control and 1st fraction was significant |
| Viability and germination difference in the 2nd fraction | 16.8 | 51.5 | 1.5 | | Viability and germination difference between the control and 2nd fraction was not significant |

Note: $\overline{x}$ – arithmetic mean; $s^2$ – standard deviation; $t_{calc.}$ – calculated Student criterion; $t_{tabl.}$ – Student criterion value from the table at 0.95 probability level and number of respective degrees of freedom.

Table 4. Parameters of the first degree model

| Fraction | Dispersion | | Fisher's criterion | | Number of degrees of freedom | |
|---|---|---|---|---|---|---|
| | tests $s^2$ | adequacy $s^2_{ad}$ | calculated | from tables | tests | adequacy |
| I | 10.07 | 5.6 | 0.6 | 3.4 | 24 | 2 |
| II | 32.5 | 57.9 | 1.8 | 2.8 | 24 | 4 |

Relationship between germination of the first fraction and affecting factors with true values:

$$D_I = 130.09 - 14.29E - 2.64W - 8.43\tau + 2.59E\tau + 0.49W\tau - 0.16EW\tau. \quad (3)$$

The relationship between seed germination in the second fraction and affecting factors (in the encoded form):

$$D_{II} = 59.65 + 4.41x_1 - 6.59x_2 - 2.22x_3. \quad (4)$$

As one can see moisture has the greatest effect on the seed germination in the second fraction, while the effect of field strength is in the second place. The relationship of germination in the second fraction and affecting factors with true values:

$$D_{II} = 85.71 - 4.41E - 2.19W \ -0.74\tau. \quad (5)$$

Germination values obtained by the equation (3) and (5) were verified experimentally. According to Excel function RANDBETWEEN three experiments (No. 1, 4, 6) were randomly selected from the interval of eight experiments. The experiments were conducted following the methodology described in this paper. The findings are presented in Table 5.

Analysis of the experimental results provided in Table 5 shows that seed germination values obtained experimentally and the ones calculated by the equations (3) and (5) do not exceed the standard deviation.

Table 5. Experimental results

| No. of experiment | Germination, % | | | Permissible deviation from the average % | Fraction |
|---|---|---|---|---|---|
| | of the experiment | calculated by equations | verification | | |
| 1 | 81.0 | 81.67 | 85.0 | ±11 | I |
| | 67.0 | 63.0 | 65.0 | ±13 | II |
| 2 | 76.0 | 76.0 | | ±12 | I |
| | 70.0 | 71.81 | | ±13 | II |
| 3 | 78.0 | 78.5 | | ±12 | I |
| | 48.0 | 49.81 | | ±14 | II |
| 4 | 74.0 | 73.83 | 72.0 | ±12 | I |
| | 62.0 | 58.62 | 67.0 | ±14 | II |
| 5 | 76.0 | 74.83 | | ±12 | I |
| | 60.0 | 58.56 | | ±14 | II |
| 6 | 74.0 | 75.0 | 76.0 | ±12 | I |
| | 68.0 | 67.37 | 71.0 | ±12 | II |
| 7 | 78.0 | 77.5 | | ±12 | I |
| | 46.0 | 45.37 | | ±14 | II |
| 8 | 66.0 | 67.0 | | ±13 | I |
| | 56.0 | 54.18 | | ±14 | II |

The amount of energy ($\lambda$, J/m$^3$) conveyed to seed is expressed by

$$\lambda = E^2 A^2 \left( \frac{1}{2} \varepsilon \varepsilon_o + \gamma t \right), \quad (6)$$

where: $A$ – reference, $A = \dfrac{1}{1+\Phi\left(\gamma / \left(k\,\rho\right) - 1\right)}$;

$E$ – strength of electrical field, V/m;
$\varepsilon$ - dielectric permittivity of seed;
$\varepsilon_o$ – electric constant permittivity, $\varepsilon_o = 8{,}85\cdot10^{-12}$ F/m;
$\gamma$ - relative volumetric seed conductance, $\Omega^{-1}\,m^{-1}$;
$t$ – exposure time, s;
$\Phi$ - depolarisation coefficient;
$k$ – mobility of ions, $m^2\,V^{-1}\,s^{-1}$;
$\rho$ - volumetric density of ion charge, $C/m^3$.

## Conclusions

Seed treatment with electrical field gave a significant increase in seed germination in the first fraction of the electric separator compared with the untreated control. The differences in seed germination in the second fraction and in the control were not significant.

Viability and germination difference between the control seed and the seed that passed into the first fraction of the electric separator was significant. The same difference between control seed and second fraction's seed germination averages was insignificant.
The strength of the electric field had the greatest effect on the seed germination of the first fraction, while seed moisture had the greatest impact on the seed germination of the second fraction.

The difference between the germination values obtained experimentally and by equations did not exceed permissible deviation from the mean.

Energy content conveyed to seed depended on the strength of the electrical field and seed electrical properties.

## References

Amaya J.M., Carbonell M.V., Martinez E. 1996. Effect of stationary magnetic fields on germination and growth of seeds. Agriculture. Vol.65 (773), pp.1049-1050, (in Spanish).
Borisov A.M.1994. Activating the growing and development of plants by ionic-radiant processing // New materials and technologies: thesis of research conf. Moscow, pp. 163, (in Russian).
Cholakov D., Kartalov P.1990. The research on efficiency of using the glass processing by laser for pre-plant cucumber. Vegetation science. Vol. 27, no. 2, pp. 81-86, (in Bulgarian).
Frolova N.P.1983. The influence of the ionising irradiation over the carrot fecundity // The science works of the Russian Science Academy, Komia branch. № 60, pp. 97-98, (in Russian).
Koper R. 1996. Effect of the laser exposure of seeds on the yield and chemical composition of sugar beet root. Int. Agrophysics. Vol.10, no. 2, pp. 103-108, (in Polish).
Maksimov V.H.1980. The multi-factor experiment in biology. Moscow; *Moscow University Press.* 280 pp, (in Russian).
Palov I. et al. 1983. The research on pre-plant electronic processing regime, which influences the yearling onion seeds. Farm Machinery. Vol. XX, no 5, pp. 22-26, (in Bulgarian).

Pietruszewski S.1996. Effects of magnetic biostimulation of wheat seeds on germination, yield and proteins. Int.Agrophysics. Vol.10, no 1, pp. 51-55, (in Polish).
Putincev A.F., Platonova N.A.1997. The seed processing by electromagnetic field // Agriculture. No 4, pp. 45-46, (in Russian).
Bielkoviec E.M.1998. The way of pre-plant processing of corny and vegetable seeds and potato tuber. Russian patent no 2083074, (in Russian).
Kotov B.S., Gavinski J.V.1998. The way and equipment for processing the pre-plant seeds. Russian patent no 2108028, (in Russian).
Shendro P.1995. The seed irradiance by coronary discharge. Electro-physics.Vol. 8, pp.36-41.
Sirtautaite S.1996. Influence of seeds gamma-irradiation on the yield, quality and seed productivity of carrots. Agricultural engineering. *Research papers of LIAgEng.&LU of Ag.* Vol. 28, no 2, pp. 195-202, (in Lithuanian).
Spiridonov A.P.1981. Planning the experiment in technological processes research. Moscow, Mechanical engineering. 184 pp, (in Russian).
Suminov V.M.1995. The usage of laser in agriculture, while producing the ecological, energy-saving technologies, which helps to intensify the production. New materials and technologies. Technological processes and materials for gear production and microelectronics: the thesis of the report, which was done in Russian science-technical conference, Moscow, pp.13-14, (in Russian).
Vasilenko V.F.1997. New glass irradiance technology for pre-plant tomato. Agriculture. No 1, pp.34, (in Russian).