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Comparative Study of the Influence of Electric and Magnetic Fields on Tomato Germination Performance

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Abstract: In the race of enhancing the efficiency of organic farming, several researches have been done on the use of electromagnetic waves in crop production. This work aims to study the effects of electric and magnetic waves of different kinds on the germination performance of tomato. The effects of six fields, namely the static upward magnetic field, the static downward magnetic field, the oscillating magnetic field, the oscillating electric field, the static electric field and the magnetic field produced by permanent magnets, were studied on the germination parameters of tomato seeds, such as the latency time, the germination rate and the germinative energy. The results obtained revealed that static electric field and permanent magnet have no influence on the latency time, germination rate and germination energy of tomato seeds. The oscillating electric field, oscillating magnetic field, static upward magnetic field and static downward magnetic with intensities of 150 v/m and 20 mT have a positive influence on the latency time of tomato seeds, their germination rate and their germinative energies; although this influence is more significant in the case of static upward and downward magnetic field who increased the germination rate to 45.21% and 41.10% respectively and reduced the latency time by around 3 days. Thus, statics magnetic fields are more suitable to enhance, tomato germination parameters in organic farming practice.

Keywords: Magnetic Fields, Electric Fields, Germination, Lag Time, Germination Energy, Germination Rate

1. Introduction

Organic farming has been widely discussed for many years in view of its benefits for human health and the environment. However, because of its relatively low yields compared to conventional agriculture, it is still unable to meet the global food needs. To overcome this weakness, new approaches are being studied to improve the yields currently obtained. The tomato, with its scientific name *Lycopersicon esculentum L.,* is one of the most targeted plants for electromagnetic field treatment because of its very high susceptibility to diseases and other pests. It is of major importance for human nutrition. For only that produced by the device. This reason, it has been rated as the most important vegetable after potatoes and the second most important food resource in the world after cereals [1]. Likewise, tomato has significant therapeutic properties. Therefore, Debjit B *et al.* [2] claim that it can improve human's health by reducing the risk of cancer, cardiovascular diseases, prostatitis etc. In recent years, there has been an increasing number of research studies on the use of magnetic fields and electromagnetic waves to boost the growth performance of plants and their ability to resist diseases [3]. Indeed, several studies show that the use of electromagnetic waves can increase the germination performance of seeds and seedlings [4-6]. This is possible because electromagnetic waves are able to increase the rate of water uptake in seed; increase cellular respiration in seeds and increase the number and size of mitochondria present in seed cells [7, 8]. Studies conducted by Belyavskaya [8] revealed that the electromagnetic field would be able to increase the activity of the enzyme glutathione-S-transferase in wheat. The latter being the enzyme responsible for the defence induced by pathogen attack, oxidative stress and heavy metal toxicity in plants. It also acts on ferritin cell in plant [9]. Improving the germination performance of plants results in more vigorous plants that are more able to face biotic and abiotic stresses and thus give higher yields [10-14] which is a huge advantage for farmers. Research aimed to show the importance of electromagnetic fields on plant development has been conducted mostly on seed germination or seedlings in view of the delicacy of the plant at this stage of development which needs more care and protection; knowing that a vigorous seedling will have more chance to become a healthy plant. Much of current research focuses on the effect of a particular electromagnetic field on living organisms. Indeed, work carried out on the exposure of tomato seeds to static magnetic fields reveals that the latter significantly increase the germination rate [9, 15-17]; reduce the latency time significantly [15, 16]; allow plants to better withstand water stress, [18]; increase the root length of seedlings by about 25% to 29%. [19]. Those performed on the use of oscillating magnetic field reveal that they also reduce the latency time and increase the germination rate of tomato [20, 21]. They promote greater root growth in seedlings [21]. They improve the yield of tomato crops [22]; reduce the transpiration rate of plants, allowing them to better withstand water stress [23]. Works on electromagnetic field shows that it increases tomato seed germination plant growth and yields [24-26]. Finally, studies conducted on static electric fields have shown that they increase nitrogen uptake, produce robust seedlings and improve yields [27]. The literature is thus rich in works dealing with the influences of electromagnetic waves of specific shapes on tomato plants. However, there are very few works that simultaneously address the performance of fields of different types on a specific crop. For this reason, the aim of this work is to study the influences of some of these electromagnetic fields on the germination performance of tomato. These are the static upward magnetic field (SUMF), the static downward magnetic field (SDMF), the oscillating magnetic field (OMF), the oscillating electric field (OEF), the static electric field (SEF) and the magnetic field produced by permanent magnets (PM). Indeed, previous works dealing with the influence of static magnetic fields on plants do not generally indicate the direction in which the field scans the plant. This work therefore targeted the influence of the static magnetic field first in the upward direction (SUMF) and then in the downward direction (SDMF). The fields produced by permanent magnets were also chosen because, although they are static magnetic fields, they are devoid of the electrical component which could be a determining factor in the influence of a magnetic field on a plant. The effect of oscillating magnetic fields was also studied to assess not only the influence of the latter on the germination of tomato seeds but also to compare their performance with SUMF and SDMF all taken at the same intensity. Furthermore, the literature does not address the influence of the type of electric field on the same crop, so this work also investigates the effects of static electric fields (SEF) and oscillating electric fields (OEF) on germination performance of tomatoes. The latency time, germination rate and germination energy are the characteristics that will be observed in the different trials. Furthermore, the literature does not address the influence of the shape of the electric fields on the same crop, which justifies the fact that this work also examines the effects of static electric fields (SEF) and oscillating electric fields (OEF) on germination performance of tomatoes. The latency time, germination rate and germination energy are the characteristics that will be observed in the different trials.

2. Materials and Methods

2.1. Experimental Setup and Tomato Seed Treatment

2.1.1. Presentation of Fields and Choice of Intensities

The experimental unit consist of 6 types of fields; 4 magnetic fields and 2 electric fields. Magnetics fields used are static upward magnetic field (SUMF), static Downward magnetic field (SDMF), oscillating magnetic field (OMF), and the magnetic field produced by permanent magnets (PM). Electric fields used are: Oscillating electric field (OEF) and the static electric field (SEF). Untreated pots were used as controls (CT).

The magnetic field intensity values used were 20 mT. In fact, researchers such as Diego *et al.* [28], through studies of the literature over a period of about 10 years, i e. from 2009 to 2019, have shown that the most conclusive results in terms of treating plants with magnetic fields were obtained for field values of between 1 and 50 mT. High magnetic field doses are a source of abiotic stress for plants [29-32]. The value of 20 mT was therefore chosen.

The electric field intensity values used were 150 V/m, since some research has shown that electric fields of less than 500 V/m have beneficial effects on living organisms. Electric field strengths of around 100 V/m (also known as physiological field strengths) [33] have an important role in the development and the control of living cells and tissues [34-36].

2.1.2. Production of Magnetic Fields

Static rising and falling magnetic fields (SUMF, SDMF, OMF)

The first three magnetic fields (SUMF, SDMF, OMF), are produced by following the principle of magnetic field produced by a solenoid.

For this purpose, copper wire with a diameter of 0.65 mm is wound around an aluminium cylinder with an internal diameter of 10 cm, height of 12.3 cm and thickness of 0.3 mm. In the case of static magnetic fields, the coils are supplied with DC current using a DC power supply, reference S-360-12, which produces a voltage of 12 V and can generate a current of up to 30 A. The right-hand rule is applied to select the direction of the current to obtain right direction of field lines. In the case of oscillating magnetic fields, the coils are powered using 220v / 12 v step-down transformers with a power of 250 VA.

After the magnetic fields have been generated, a Teslameter (with reference HGS-10C) is used to measure the magnetic field intensities in order to adjust them if they are not equal to the desired values. It measures values up to 2000 mT with an uncertainty of 2%. Before each reading, the device is set to zero in order to cancel the value of the earth's magnetic field, and consider.

Permanent magnet magnetic field (PM)

The magnetisation of tomato seeds with the magnetic field produced by permanent magnets was done by identifying the region around the magnet at which the magnetic field intensity is 20 mT. This was done using the teslameter.

2.1.3. Production of Electric Fields

The electric field were produced by powering two aluminium plates arranged in parallel. The magnitude of the electric field produced is a function of the voltage between the plates and the distance between them; as shown in equation 1.

$$E=V/D \tag{1}$$

With:

E: electric field (V/m)

V: the potential difference across the metal plates

D: the distance between the two metal plates

In a case of static electric fields, plates, were powered by a 12 volts DC generator and in a case of oscillating magnetic field, they were powered using a 12 volts step-down transformer. After the production of electric field, an electric field tester was used to check the actual value generated in order to make any necessary adjustments.

2.2. Seed Treatment and Conduct of Trial

Each field producer device is set up in the middle of plastic pots and filled with a soil. The plastic pots have holes at their bottom to allow the drainage of excess irrigation water. In each of the pots prepared in this way, 30 tomato seeds were carefully placed inside the spool and covered with a thin layer of soil about 5 mm thick. Some pots without any field device were seed and use as control.

The field test was carried out in the West region of Cameroon. Seeded pots were moved to a shaded area to protect the future seedlings from the sun's aggressive rays. For each of the planned treatments, four replications were carried out. Throughout the trial, the pots were carefully watered twice a day, in the morning and in the evening, to avoid water stress.

2.3. Data Collection

The germination parameters measured are: The lag time, germination rate and germination energy.

The lag time (LT) refers to the time in days (d) from the date of planting to the first germinations.

Germination Rate (GR) is the ratio of the number of germinated seeds (Ng) to the number of seeds planted (N), multiplied by 100;

It is given by equation 2:

$$GR= (Ng/N) \times 100 \tag{2}$$

With:

GR: germination rate

Ng: number of total seeds germinated

N: number of seeds planted

Germination Energy (GE) is the percentage of seeds (by number) that germinate up to the time of maximum germination. The latter is the 24 hours period when the greatest number of germinations occur.

It is given by the equation 3:

$$GE= (N_{gmax}/N) \times 100 \tag{3}$$

With:

GE: germinal energy

N_{gmax}: number of seeds germinated up to the day of maximum germination

The counting of germinated seeds was done on a daily basis for a fortnight (15 days) corresponding to the maximum germination time of tomato seeds [37]. In fact, under optimal conditions, the germination time of the seeds varies from 6 to 8 days [38], however, if they are subjected to a certain level of stress, the germination time can be slightly longer. The purpose of observing the germination of seeds over a longer period of time is therefore to investigate whether the electric and magnetic fields used do not induce an abiotic stress to the tomato seeds.

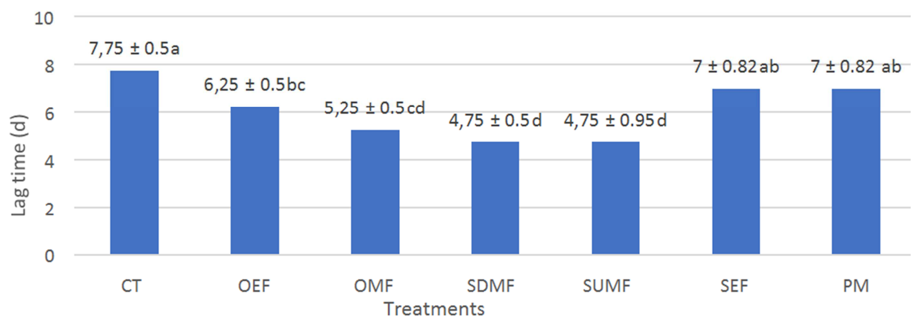
2.4. Analysis of Germination Performance

The averages of the germination parameters obtained were then compared using the ANOVA test (in case of normality) and the Kruskal Wallis test (in case of non-normality). The normality of the different samples is determined by the Shapiro-Wilk test due to the small size of the samples (size less than 50) [39]. The data were analysed using XLSTAT software.

3. Results and Discussion

3.1. Influence of Electromagnetic Field Types on Lag Time of Tomato Seeds

The observation of influence of different electromagnetic fields on the lag time of tomato plants (figure 1) reveals that the lag time is on average shorter for the static upward and downward magnetic fields and would be higher for seeds that have not received any electromagnetic field treatment.



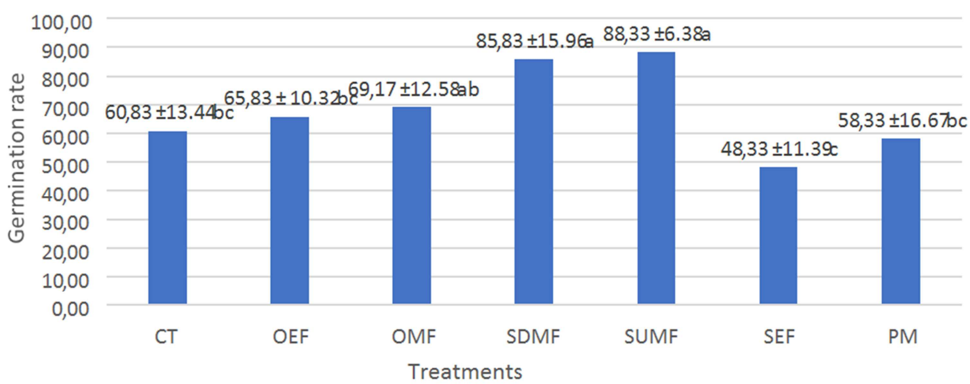
a, b, c, d: Values with identical letters or common letters are not significantly different (p>0.05)

Figure 1. *Latency of tomato seeds subjected to different electromagnetic fields.*

The Kruskal-Walis test on the lag time reveals that the difference observed visually on the data is significant at the 5% level, (P=0.015<0.05). This implies that at least one of the electromagnetic radiations significantly affects the lag time of the tomato. The pairwise comparison of the modalities with each other (Figure 1) confirms this result by showing that, apart from the fields produced by the permanent magnet and the static electric field, the other types of fields significantly influence the latency time of tomatoes. The latter made it possible to classify the fields according to their level of significance on the latency time of tomatoes. This shows that the rising and falling static magnetic fields reduce more significantly the latency time of tomatoes and they have the same performance levels, the next performance is observed in the oscillating magnetic field, followed by the oscillating electric field. Finally, the permanent magnet field and the static electric field have the worst performance, which is similar to that of the control. Work carried out by [19] shows that the treatment of tomato seeds with the permanent magnet field reduces the lag time from about 4 days (for the control treatment) to 2.5 days. The more pronounced reduction in lag time that they obtain, 1.5 days compared to about 0.5 days obtained in this work, would be due to the fact that they combine the magnetic field with a pre-treatment of the seeds with distilled water and the conditions of the production environments which are different. Jedlička *et al.* [20] shows that the use of oscillating magnetic fields of 20 mT intensity for tomato treatment results in latency reductions of about 2 days. This reduction in latency is similar to that obtained in our work, which is about 2.5 days. The work of Vashisth and Nagarajan in 2010 shows that the reduction in seed lag time by magnetic field treatment is due to the increase in enzyme activity within the seed and that of Pang and Den [40] and Aghamir *et al.* [41] reveals that fields improve factors that influence seed germination, such as the ability of water to soak into the seeds. The results obtained in this work reveal that the influence of the factors affecting seed emergence by the fields depends strongly on the nature of the fields. It would be more important for magnetic fields produced by coils than for electric fields and magnetic fields generated by permanent magnets.

3.2. Influence of Electromagnetic Field Types on the Germination Rate of Tomato Seeds

The effects of electric and magnetic fields on the germination rate of tomato seeds are shown in figure 2. This figure shows that the germination rate of tomato seeds is influenced when they are subjected to electric and magnetic fields. In fact, this figure reveals a trend whereby the germination rate would be lower for static electric fields and the permanent magnet; and it would be maximum with downward static magnetic fields and upward static magnetic fields.



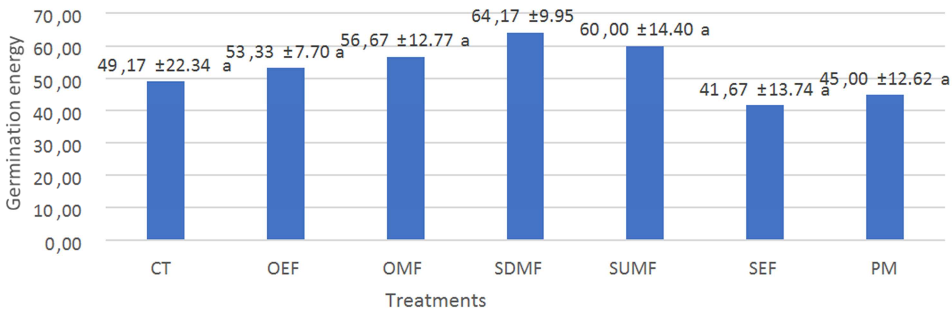
a, b, c: Values with identical letters or common letters are not significantly different (p>0.05)

Figure 2. *Influence of different electromagnetic fields on the germination rate of tomato seeds.*

The statistical analysis of the results of the influence of electric and magnetic fields on the germination rate of tomato seeds reveals that they have a highly significant influence (P=0.0021<0.05). This influence is negative in the case of static electric fields and magnetic fields produced by permanent magnets, as the germination rates obtained in these two cases are on average lower than those obtained in the control pots. It is positive in the case of OEF, OMF, SDMF, and SUMF. The negative influence of the AiP treatments on the germination rate is in contrast to the results obtained by Fu [42]. This difference may be due to the field strength used. Indeed, they used field strengths ranging from 330 to 449 mT tesla in opposition to those used in this work which were 20 mT. This suggests that there could be two thresholds of magnetisation using magnets, one below which magnetisation would have negative effects on the germination rate of the seeds and another above which it would have beneficial effects. Konefał-Janocha *et al.* [43] showed that both static and oscillating magnetic fields favoured high germination rates. With better performance for static magnetic fields. These results confirm those obtained in this work. The weaker performance obtained with oscillating fields corroborates the fact that there could be a threshold for which the effect of magnetisation is rather negative. Since oscillating fields take on values that vary according to a given amplitude, they would necessarily take on field strengths at certain times that have a negative effect, hence the poorer overall result with oscillating fields.

3.3. Influence of Electromagnetic Field Types on the Germination Energy of Tomato Seeds

The results of the influence of electric and magnetic fields on the germination energy of tomato seeds are presented in figure 3.



a: Values with identical letters or common letters are not significantly different (p>0.05)

Figure 3. *Influence of electric and magnetic fields on the germination energy of tomato seeds.*

This figure shows that the germinative energies of tomato seeds treated with static electric fields and magnetic fields produced by permanent magnets are lower than those of control seeds; in contrast to the germinative energies of seeds treated with other fields. However, the statistical analysis of the influence of different electromagnetic fields used in this work on the germinative energy revealed that they have strictly no influence on the germinative energy of the seeds (P=0.2916 > 0.05). These results indicate that the nature and intensity of the electromagnetic fields do not influence the vigour of the germinated seeds. However, Konefał-Janocha *et al.* [43], and Singh *et al.*, [44] observed that electric and magnetic fields could significantly influence seedling vigour. The opposite effect observed in this work suggests that the influence of fields on germinative energy could vary depending on the plant treated.

4. Conclusions

The results obtained in this work show that electric and magnetic fields influence positively the germination parameters of tomato seeds and depending on the nature of the field used.

More precisely, SEF and PM at the respective intensities of 150 V/m and 20 mT have a negative influence on the germination rate of tomato seeds, their latency time as well as on the germinative energy of tomato seeds (although this influence is not statistically significant in the last two cases). The OEF, OMF, SDMF and SUMF of intensities 150 V/m and 20 mT; have a positive influence on the latency time of tomato seeds and their germination rate; and this influence is more significant in the case of SDMF and SUMF than for OEF and OMF. CMSmo and CMSds increased the germination rate to 45.21% and 41.10% respectively and reduced the latency time by around 3 days.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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