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Electromagnetism as an Inductor of Biomass Synthesis in Brassica Napus L. Plants

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In recent times, the use of magnetic fields has been used to stimulate germination processes in vegetables seeds, without deepening in their interaction with the variables of growth, development and productivity of these. In this regard, this research characterized the effect of induced electromagnetic fields on the production and composition of the biomass of plants of *Brassica napus* L.; It is noteworthy that electromagnetic fields are generated from moving electrical charges, and the Tesla is the magnetic induction unit (or magnetic flux density) defined by the International System of Units (SI). Likewise, for the induction process of electromagnetic fields, coils were used, which with the help of a power source kept the variables of volts (V) and amps (A) fixed in time, thus guaranteeing the constant intensity of the field generated. A 3 x 4 bifactorial experimental design was used, where 3 are the field intensities and 4 the exposure times to be evaluated. In this context, biomass yield, growth and development characteristics, as well as bromatological characteristics of biomass were determined. For the study of these effects, a statistical analysis was performed using the Statgraphics 5.1 PLUS software, performing an analysis of ANOVA with 95% confidence to establish if there are significant differences between the treatments, as well as a multiple range test. In consequence of the experimental process, the results show a significant increase in the variables studied, mainly in biomass and synthesis of photosynthetic pigments at longer exposure times and lower intensities. Further, the variables studied for the growth and development of the plants of *B. napus* L.; confirming this way, a direct stimulation of these processes.

Keywords: electromagnetic fields, germination processes, biomass, Grown and development

1. Introduction

B. napus L., stands out for being a simple crop, given its high adaptability and low nutritional requirement, being considered by producers as a weed or undesirable plant that grows within an established crop (Westwood and Mulcock, 2012). Likewise, it is important to indicate that this crop probably has a greater validity in marginal or extreme areas, where the population is reduced due to the fact that the costs for the establishment of other crops in general are high; also, where adequate soils are available but are considered unproductive and where alternative land uses do not imply, therefore, the substitution of food intended for human consumption (Keim et al., 2015). On the other hand, starting from the premise of the fluctuations of the earth's magnetic field and the consequences that it brings on the physiological processes that develop naturally in plants, it is necessary to stabilize them. Then, low intensity induced electromagnetic fields become a viable technology for this, thus encouraging cells to express their full biological potential. For a small, medium or large producer, having quality botanical seeds has always been a determining factor in terms of food security when it comes to expecting good agricultural yields. Likewise, the decrease in the germinative power of the seed that occurs on some occasions may be associated with different factors of the product and the environment that surrounds it, among which is poor postharvest handling (Suárez-Rivero et al., 2017).

Therefore, it´s urgent to search for methods or technologies that allow improving the quality of botanical seed, which becomes a challenge of vital importance considering that this type of biological material is prone to loss of vigor and viability during long-term storage and is the subject of this research.

2. Materials and methods

2.1. Features of the vegetable material

The experiment was developed using certified seeds of *B. napus* L. acquired in the company Recolsemillas S.A.S., initially 100 seeds were placed in small paper filter bosses and exposed to electromagnetic fields before sowing; then, the sowing is done directly on clay soil, rich in organic matter and with the application of irrigation to field capacity during the crop's biological cycle. It should be noted that no fertilization amendments were made, nor was the application of chemical or biological pesticides necessary for the management of pests or diseases. A brightness regime of approximately 12 light hours a day was maintained.

2.2. Application of electromagnetic fields

Previous to sowing, it was carried the montage out for the application of electromagnetic fields to the botanical seeds (100 seeds per treatment), using coils of 1000, 2000 and 3000 turns respectively for each intensity (23.6 μT, 70.8 μT and 118 μT) and exposure time (3 hours) / day and permanent for 15 days); additionally, control seeds were available free of electromagnetic force exposure, but with equal experimental conditions. This is theoretically based on Maxwell's Laws.

The circuit consisted of 3 power sources and 6 coils, the final mounting of the circuit for the application of electromagnetic fields was arranged according to each treatment, in such a way, that the lines of force were oriented in the direction of the seeds packed in bags, which were located at the top of each coil.

2.3. Parameters of growth and development

In order, to establish the real effect on the culture of *B. napus* L., in the stage of growth and development the following morphological and physiological characteristics were measured: a) Area of the leaf (cm^2): three plants were used for each treatment (each independent); for this purpose, the silhouette of all sheets of high photosynthetic activity was marked on a bond paper (belonging to the same ream of paper) (Suárez-Rivero et al., 2017 and Suárez-Rivero et al., 2016). The silhouettes were cut and the analytical weight determined the weight of each unit; In addition, one (1) cm^2 of the waste paper was weighed, and the leaf area of each plant was determined for each treatment (using a rule of three); b) Fresh Mass (g): was determined with an analytical balance for each of the treatments.

This measurement was made at two times, fifteen (15) days after the start of germination (it was called T1) and sixty days after the first measurement (called T2); c) The dry matter (g) was determined according to the procedures indicated by Cortés-Castillo et al. (2010) cited by Ortiz-Aguilar J. et al. (2015) and taking as reference the two moments stipulated in the determination of the Fresh Mass; d) Growth and development rates: For this purpose, the following indicators were determined, as proposed in previous studies with corn and sunflower Suárez-Rivero D. et al. (2016): *Relative Growth Rate - RGR (g / (g day))*, *Net Assimilation Rate - NAR (g/(cm^2 day))*, *Leaf Area Index - LAI (Dimensionless according to the units)*, *Crop Growth Rate - CGR (g/(cm^2 day))*, *Absolute Growth Rate - AGR (g/day)*, *Leaf Area Duration - LAD (cm^2/day)* and *Specific Leaf Area - SLA (cm^2/g)*

2.4. Content of photosynthetic pigments

With the use of the spectrophotometric method the chlorophyll contents (A and B) were established, as Suárez-Rivero et al. (2016). To carry out the readings, an extraction is established by maceration of the foliar part of the plant (approximately 2 g in 10 ml of 80 % acetone). After the extraction of the solutions, the absorbance is read at 647 and 663 nm (with the use of a UV spectrophotometer). Subsequently, the pigment contents (mg / L) under study were calculated with equations 1 and 2.

$$\text{Chlorophyll a} = (12.25 * A_{663\text{nm}}) - (2.79 * A_{647\text{nm}}) \quad (1)$$

$$\text{Chlorophyll b} = (21.5 * A_{647\text{nm}}) - (5.1 * A_{663\text{nm}}) \quad (2)$$

These equations take into account the molar absorptivity coefficients of these pigments when the three are present in the same 80 % acetone solution.

2.5. Context of experimental design

The experiment was developed under a bifactorial design (induced field intensity x field induction time), the basis of the experimental design lies in the mounting of seven filter paper bags with 100 seeds per treatment per unit, exposed at three intensities of electromagnetic fields (L1 = 23.6 μT, L2 = 70.8 μT and L3 = 118 μT) and two exposure times (T1 = 3 hours daily for 15 days and T2 = permanent exposure for 15 days); applied to the seeds under study in their containers.

2.6. Statistical analysis

A single analysis of variance (ANOVA) between the averages of the samples by treatment at a significance level of 95% ($\alpha = 0.05$) was carried out to establish whether any differences exist for the variables under evaluation (Suárez, 2011). If there was no significant difference between the samples, a multiple range test was performed using the statistical package Statgraphics Centurion.

3. Results and discussion

3.1. Leaf area

When observing Figure 1, it becomes evident that the initial moment, although the treatments L3T1 and L2T1 have values of Leaf area higher to the rest of treatments and control, already for the second moment of evaluation (final leaf area) the panorama is different. It is then seen that the seeds subjected to electromagnetic fields of 118 μT of intensity for three hours a day had a significant stimulation in the formation of leaf blades, in more than double the leaf area than the rest of the treatments and the control.

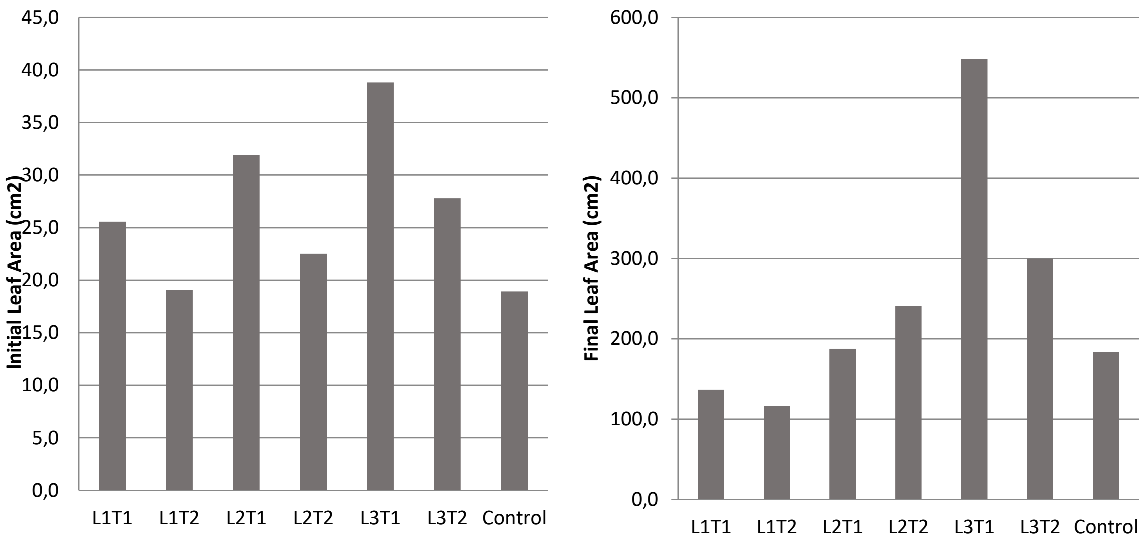

Figure 1: On the left the initial Foliar area and on the right the final leaf area.

To the regarding the leaf area Li, et al. (2014) point out that the leaves, as a whole, constitute the most important organ of the plant and play the main role in anabolic activities through chlorophyll, which possess in abundance, the only means for photosynthetic processes. The total leaf area, which has been directly related to the amount of chlorophyll, is an important parameter to estimate the ability of the plant to synthesize dry matter.

3.2. Dry Fresh Dough and Dry Mass

Figures 2 and 3 show the behavior of fresh and dry biomass in the two moments evaluated.

Everything seems to indicate that the seeds that were induced with higher intensity electromagnetic fields reacted positively to this stimulus, for the FM and DM indicators, which is closely related to Figure 1; on other word, the values of Dry Mass in the final process of the experiment exceeded the control plants by 6 times. In this regard, it should be noted that the accumulation of biomass depends on the kinetics of growth and the rate of distribution, in addition, to the parameters that are governed by the leaf area, climate and availability of nutrients.

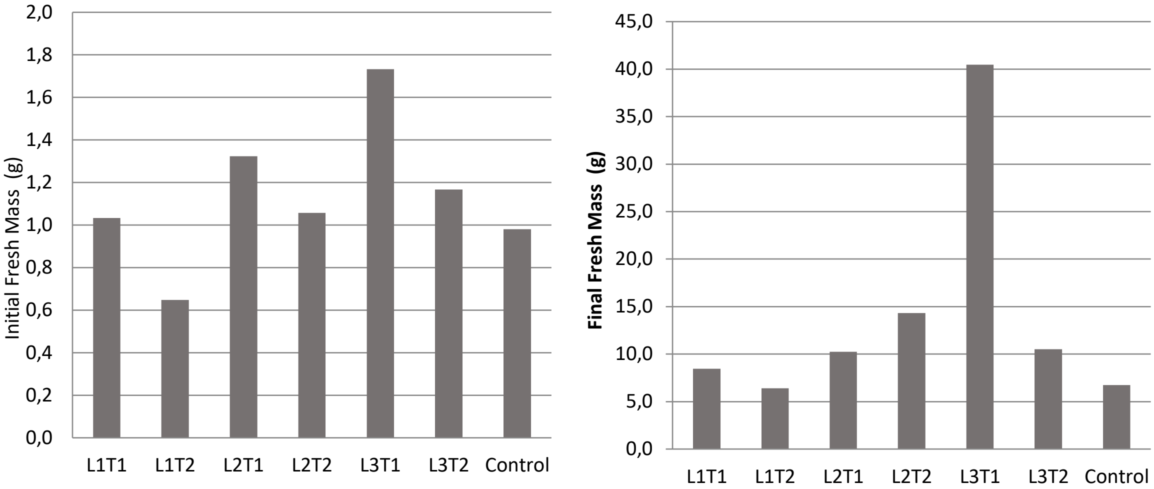

Figure 2: Initial and final fresh mass.

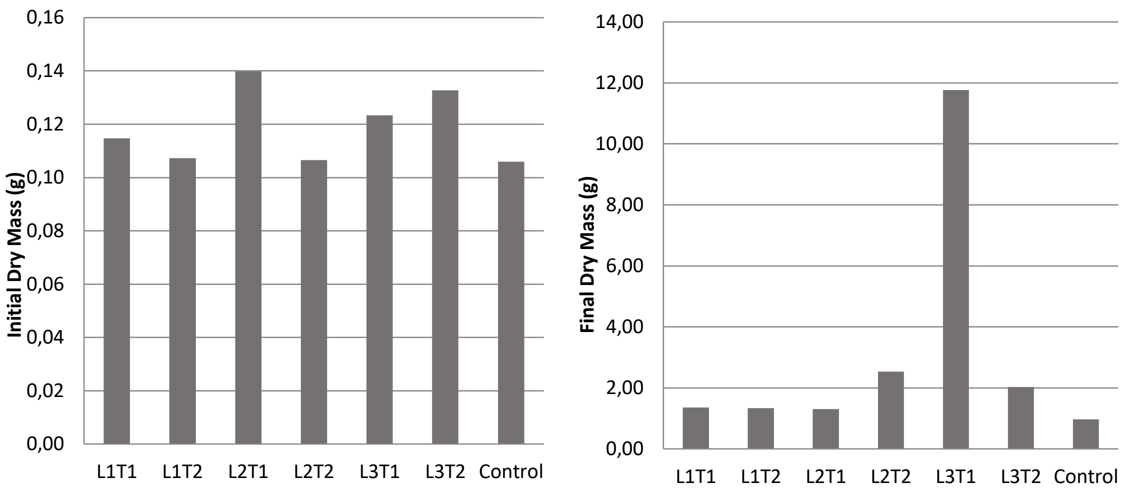

Figure 3: Initial and final dry mass.

It should be noted then that the yield of a crop is given by the ability to accumulate biomass as fresh and dry matter in the organs that are intended for harvesting, a proportional increase in the biomass allocated to these organs ensures an increase in yield. In this way Barrientos-Llanos H. et al. (2015) point out that the distribution of dry matter between the different organs of the plant plays a fundamental role in the production of a crop. The assimilated or assimilatos (carbohydrates, proteins, lipids and carbohydrates) produced by photosynthesis in the "source" organs (mainly the leaves), can be stored or distributed via phloem between the different organs "sinks" of a plant. So, to achieve a rapid initial growth of young plants, it is important to increase substantially the leaf surface in this phase, because a large part of the incident solar radiation is not intercepted. Therefore, at this moment, a large part of those assimilated should be destined to the formation of the leaves.

3.3. Rates of growth and development

By carefully observing the development indicators evaluated, the relation of these with figures 1 to 3 is well known, given that they depend to a large extent on the Fresh and Dry Masses, as well as on the leaf area or photosynthetically active area. Thus, plants subjected to 118 μT of intensity for three hours a day showed the best results in most development indicators, differing significantly from the rest of the treatments. These results (table 1) confirm what was mentioned by Moreno-Medina et al. (2016), who describe that the study of the growth of the plants and their subsequent analysis allows to relate the eco-physiology and the agronomy in order to improve the management activities in the crops. These authors also point out that the RGR and NAR should be seen as indicators of the landfill source relationship, which is important to establish agronomic activities tending to increase the amount of biomass or plant structure in a given period per unit area.

Table 1: Development indexes of B. napus L. plants subjected to electromagnetic fields.

Treatment	Physiological Indicators						
	RGR (g/(g day))	NAR (g/(cm^2 day))	LAI	CGR (g/(cm^2 day))	AGR (g/day)	LAD (cm^2/day)	SLA (cm^2/g)
Control	0,14740	2,30326	464,57560	0,01148	0,05738	1393,72681	76,65915
L1T1	0,16455	2,63304	346,56872	0,01652	0,08258	1039,70616	56,10092
L1T2	0,16801	2,34579	296,52978	0,01635	0,08174	889,58935	64,07515
L2T1	0,14864	3,16601	474,38240	0,01547	0,07734	1423,14721	54,52237
L2T2	0,21123	8,20008	607,00522	0,03236	0,16178	1821,01566	62,05670
L3T1	**0,30386**	**75,53884**	**1375,85574**	**0,15524**	**0,77622**	**4127,56721**	49,59441
L3T2	0,18194	7,54316	755,26055	0,02534	0,12671	2265,78164	72,84282

Hussaina et al. (2016) states that phenological studies allow a clear understanding of the behavior of a plant in relation to time, and from this obtain greater knowledge about the growth and development of plants and their different stages. In plants, the processes of growth and development are irreversible events, changes in size, number, mass and shape are evident. These parameters and their respective modifications are the result of the interaction of the genotype and the environment. This has as a consequence the quantitative increase in size and weight in the vegetables, mainly due to division and cellular elongation, facilitated by the photosynthetic, respiratory processes and by the dynamics that the plant generates with the absorption, transport and transpiration of water and nutrients. (Taiz and Zeiger, 2010; Tadeu et al., 2015).

3.4. Content of chlorophylls A and B

On the other hand, Figure 4 shows the behavior of the content of chlorophylls A and B in the two moments of evaluation, making clear the effect of the electromagnetic treatment on the synthesis of pigments. This is how all the treatments show values far superior to the control, differing in all cases significantly from this.

Likewise, it´s noteworthy that the content of photosynthetic pigments per unit area of the leaves, constitutes one of the indicators of the photosynthetic capacity of the plants, since it represents a measure of the dimensions of the photosynthetic system and its efficiency, which determines the biomass production of the plant in different conditions.

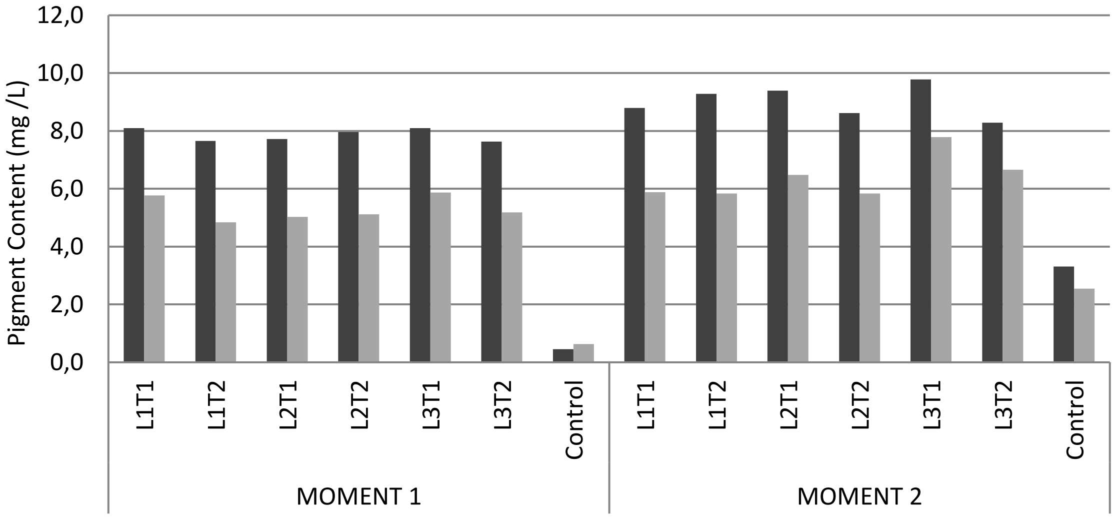

Figure 4: Behavior of the synthesis of Chlorophylls A and B of the two moments evaluated.

The importance of analyzing photosynthetic pigments lies in the relationship between their content and photosynthetically active radiation (Dow, Bergmann, 2014), for the transformation of light energy into chemistry to different wavelengths (P700 and P680); which allows a higher rate of CO_2 assimilation and synthesis of carbonados skeletons.

4. Conclusions

B napus L. reacted positively against electromagnetic induction, mainly evidenced by a greater deployment of leaves with a consequent development of leaf area and chlorophyll A and B content. In this sense, treatment with 118 μT of intensity during three daily hours for 15 days (L3T1) managed to surpass the rest of the treatments, thus becoming a viable productive alternative to strengthen the sustainable production of biomass.

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