

## Research Article

# Magnetic Field Stimulation Effect on Germination and Antioxidant Activities of Presown Hybrid Seeds of Sunflower and Its Seedlings

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Magnetic field biostimulation plays a significant role in enhancing the germination of seeds and increasing the metabolic rate. The low magnetic field effect for long exposure time and its effect on antioxidant profiling have not been studied. Therefore, in the recent findings, the static magnetic field's impact on sunflower seeds subjected to the magnetic field at varying intensity (millitesla) for different exposure times was examined. The effectiveness of magnetic biostimulation on presown sunflower seeds, growth parameters of seedlings (biomass, root and shoot length, fresh and dry weight of roots, shoots, leaf, and height of plants), and antioxidant activities were also studied. It has been revealed that magnetic treatment at 50 mT/45 min greatly influenced the growth parameters, including mean germination growth ( $100 \pm 0.02$ ) and final emergence rate. Concerning the antioxidant parameters, seed variety FH620 at 500  $\mu\text{g}/\mu\text{L}$  concentration showed significant results compared to other varieties. FTIR was employed to determine the conformational changes and functional groups of organic compounds from sunflower seedlings. Tocopherol analysis by HPLC showed that magnetic treatment at 50 mT/45 min had a higher concentration of vitamin E compared to the control group. These modifications indicated that magnetic field induction enhanced seeds' inner energy that led to seedlings' growth and development enhancement. Besides, magnetic field pretreatment has been shown to have a beneficial influence on sunflower seeds and their bioactive compounds. Future studies should be focused on growth characteristics at the field level and yield attributes.

## 1. Introduction

Presown magnetic biostimulation of sunflower seeds has a significant effect on germination parameters. Because of magnetic treatment, the mobilization of stored protein contents plays a significant role in antioxidant activity. In the present time, to support the agriculture system that has been considered as a backbone of the global economy and food chain, scientists are working on technologies including physical treatments, biotic and abiotic stress that have a great effect on the enhancement of crop production and seedling vigor [1, 2].

Therefore, seed priming is the most accessible approach that improves the germination and the nutritional value of seeds. This technique has replaced the old methods for germination of seeds as they cause environmental pollution [3]. For more than 20 years, several techniques have been used for seed improvement. These techniques comprise seed priming, magnetic induction, seed spray drying, and coating [4, 5]. It was hypothesized that treatment with magnetic stimulation results in the increase of free radicals in irradiated seeds that react with free oxygen and leads to hydrogen peroxide formation, which increases the mobilization of stored nutrients.

Pakistan is an agricultural country, and importance is also being given to ethnobotany [6–9]. Sunflower (*Helianthus annuus* L.) is an essential permissive oilseed crop. However, unfortunately, Pakistan is chronically low in edible oil and invests a significant portion of its foreign exchange imports. It is the second-largest food supply in Pakistan, with profitability rising from 0.30 million tons to 2.79 million tons in current history. Sunflowers in Pakistan have two seasons (i.e., spring and winter). The growth of sunflower planted in spring is reasonably slower compared to autumn crop, but the response to the agronomic parameters remains significant [10].

Physical priming is an easy and safe way to increase the germination of seeds using the magnetic field. Magnetic seed treatment brings numerous valuable biochemical, cellular, and molecular processes [11]. Presowing magnetic seed treatment also increases ascorbic acid contents [12]. Magnetic seed stimulation could be employed to recover seed potency by increasing enzymes and proteins' activity [13]. Consequently, without any alteration in the seed's chemical composition, biochemical functions such as ion concentration, electrical charges, and free radicals are enhanced and can make the membrane more permeable. Due to the increased metabolic pathway via ions' free movement, physiological and biochemical properties are also increased [14]. The remarkable increase in plant growth and productivity has been postulated in response to magnetic fields. The germination of seeds under magnetic fields has been studied under several levels of biostimulation. Magnetic field treatment significantly improves seed output in terms of germination velocity [15], seedling length [16], and seedling dry weight compared to unexposed seeds (control). Suitable magnetic field strength increases the germination potential of plant seeds [17].

The response of crops towards the magnetic field is associated with the intensity and exposure time of the magnetic field. It has been hypothesized that the magnetic field treatment would enhance the sunflower plant's nutritional and pharmaceutical value. Therefore, the present study was conducted to evaluate the effect of magnetic field on presown hybrid seeds of sunflower to check the growth parameters of seedlings and antioxidant activities. Treated and controlled seeds (i.e., untreated) were compared for this purpose. Moreover, the impact of treatment on the germination of sunflower seeds was also explored.

## 2. Materials and Methods

**2.1. Chemicals and Reagents.** The chemicals used were of analytical grade. Folin-Ciocalteu (FC) reagent, 1,1-diphenyl-2-picrylhydrazyl (DPPH), and trichloroacetic acid (TCA) were purchased from Merck (Darmstadt, Germany), whereas aluminum chloride, sodium carbonate, potassium ferrocyanide, and sodium hydroxide were purchased from Bio-Rad (USA), respectively.

**2.2. Magnetic Field Setup.** The presowing magnetic treatment of seeds was carried out using an electromagnetic seed stimulator specially designed in the Department of Physics,

University of Agriculture, Faisalabad, which was similar to Pietruszewski and Martínez's [18] stimulator in construction. The seed stimulator consisted of two pairs of cylindrical shape coils, each of which consisted of 4000 turns that were coated with copper. The seeds were exposed to magnetic field treatment with various intensities (50, 80, and 100 mT) at different exposure times (45, 30, and 15 min), respectively.

**2.3. Seed and Treatment Procedure.** Healthy and uniform seeds of different sunflower varieties (FH620, FH615, and FH545) were taken from Oil Seed Department, Ayub Agriculture Research Institute, Faisalabad, Pakistan. For magnetic treatment, seeds were treated with different field intensities (50 mT, 80 mT, and 100 mT) at various exposure times (45 min, 30 min, and 15 min), respectively. An intensiometer was used to measure the intensity of the magnetic field. The seeds were treated and sown in replicates for each dose. Untreated seeds were used as a control.

**2.4. Petri Dish Experiment.** The treated seeds were sown in sterilized Petri dishes having a diameter of 9 mm in three replicates (100 seeds of each variety and in each Petri plate 18 seeds were kept). A double-layer Whatman filter paper was used in each Petri dish. The filter paper was wet with 2.5 mL distilled water. Water was given daily for seven days [19].

**2.5. Antioxidant Activities.** The antioxidant activities, including total phenolic contents, total flavonoid contents, DPPH radical scavenging activity, reducing power ability, and total antioxidant activity, were performed.

**2.5.1. Extraction Method.** Extraction was done by taking (1 : 10 w/v) of the ground sample in the respective solvent (distilled water) in a sterile flask and put on an orbital shaker for three days at 120 rpm to homogenize the mixture. After three days, the filtrate was concentrated using a rotatory evaporator and placed in a refrigerator for 4°C for further study [20].

**2.5.2. Determination of Total Phenolic Contents.** The total phenolic contents of extracts of seedlings were measured by using Folin-Ciocalteu reagent. The reaction mixture comprised sample extract (200 µL), 10% Folin-Ciocalteu reagent (800 µL), and 7.5% sodium carbonate (200 µL). Mixtures were incubated in the dark at room temperature for 2 hours. The absorbance was taken at 765 nm by spectrophotometer [21]. Gallic acid was used as a standard [22].

**2.5.3. Determination of Total Flavonoid Contents.** Seedling extract (0.1 mL) was mixed with 0.3 mL distilled water, 0.3 mL (5%) NaNO<sub>2</sub> and 0.3 mL of AlCl<sub>3</sub> (10%). After incubation of 5 minutes, 0.3 mL of (1 mM) NaOH was added, and the absorbance was taken at 510 nm. The results were expressed as quercetin equivalent per dry matter (mg/g) [23].

**2.5.4. DPPH Radical Scavenging Assay.** The free radical scavenging activity of the extract was measured *in vitro* by 1, 1-diphenyl-2-picrylhydrazyl (DPPH) assay. The DPPH powder (0.005 g) was added in 100 mL (99.9%) methanol. DPPH solution (5 mL) was mixed with 50  $\mu$ L of sample extract. The mixture was incubated at room temperature for 30 min, and the absorbance was taken at 517 nm against a blank. A reaction mixture without sample extract served as a control. Ascorbic acid was used as a standard. The percentage of scavenging activity was calculated by the following equation [23]:

$$\% \text{ scavenging activity} = \frac{\text{control}_{\text{Abs}} - \text{test sample}_{\text{Abs}}}{\text{control}_{\text{Abs}}} \times 100. \quad (1)$$

**2.5.5. Reducing Power Ability.** The reducing power assay of extracts was measured by mixing 5 mL phosphate buffer (2 M, pH 6.6), 5 mL (1%) potassium ferricyanide, 5 mL trichloroacetic acid (10%), and 0.1 mL of sample extract. The mixture was incubated at 50°C for 20 min and then centrifuged at 3,000 rpm for 10 min. The upper layer of the solution (5 mL) was mixed with 5 mL distilled water and 1 mL ferric chloride (0.1%). The absorbance was taken at 700 nm. Increased absorbance of the mixture indicates increased reducing power [24]:

$$\% \text{ reducing power} = \frac{\text{test sample}_{\text{Abs}} - \text{control}_{\text{Abs}}}{\text{control}_{\text{Abs}}} \times 100. \quad (2)$$

**2.5.6. Total Antioxidant Activity.** The total antioxidant activity of the extract was calculated by the method of Murthy et al. [25]. Ammonium molybdate reagent solution was prepared in 0.6 M of H<sub>2</sub>SO<sub>4</sub> (1 mL). Sodium phosphate buffer (20 mM, pH 6.8) and ammonium molybdate (4 mM) were added in 20 mL of distilled water, and the final volume was made to 50 mL. The testing sample (1 mL) was mixed with 2 mL of ammonium molybdate reagent and incubated at 30°C for 60 min. The absorbance was taken at 665 nm against a blank, which contained reagent only. Total antioxidant activity (%) of the standard and extracts was determined using the following formula:

$$\text{total antioxidant activity \%} = \frac{\text{control}_{\text{Abs}} - \text{sample}_{\text{Abs}}}{\text{control}_{\text{Abs}}} \times 100. \quad (3)$$

**2.6. Fourier Transforms Infrared Spectroscopy (FTIR) Analysis.** By using an FTIR spectrometer, an assessment was conducted out. The KBr/Germanium beam splitter was found within this instrument. At a range of 4000–1000 cm<sup>-1</sup>, FTIR spectra have been acquired. ATR plates were washed thoroughly with *n*-hexane solution to avoid the traces of the previous samples. ATR cleanliness

was monitored by collecting previous sample spectra that were compared with previous ones [26].

**2.7. HPLC Analysis.** The HPLC analysis (Jasco PU-980 intelligent HPLC pump) was done by Sayban Group of Pharmaceuticals, Lahore, Pakistan, to detect the functional groups. The UV was used as a detector at 295 nm. The experimental settings were improved by column HSA chiral C18 (250 mm  $\times$  4.6 mm, 5  $\mu$ m). Acetonitrile and methanol were used as the mobile phase with a flow rate of 0.8 mL/min [27].

**2.8. Statistical Analysis.** All determinations were made in complete randomized designs. The presence or absence of significant difference among different factors was curtailed with the analysis of variances (ANOVA). The means were compared with least significant difference (LSD) at the level of significance of 0.01. Overall interaction of all the factors was checked for significance using computer software CoStat CoHort (6.4).

### 3. Results and Discussion

**3.1. Germination Parameters.** The application of different intensities of the magnetic field plays a significant role in sunflower seedling growth parameters. The effect of magnetic field stimulation on selected sunflower seed varieties' germination parameters is given in Table 1. Generally, response to the magnetic field induces the plant growth of sunflower seeds. Similarly, the treatment of seeds with different magnetic field intensities improves germination [28, 29]. The results of the present work showed that the magnetic treatments led to a slight increase in the germination of some varieties, which is in accordance with the results of Iqbal et al. [30]. The magnetic field interface and disclosure time, such as 50 mT/45 min and 80 mT/30 min, were most effective. It was found that the weak magnetic field at longer exposure (50 mT/45 min) resulted in an increased percentage of mean germination time when seeds were placed in a magnetic field [18]. As the magnetic field strength increases (e.g., 80 mT/30 min and 100 mT/15 min), the germination rate gets reduced [28, 29].

Similarly, in the case of final emergence percentage (FEP), the suitable combination of magnetic field stimulation with time exposure influenced greatly the final emergence percentage. Seed variety of FH620 showed a significantly high percentage of mean germination time and final emergence percentage.

**3.2. Effect of Magnetic Field on Phenolic and Flavonoid Contents of Sunflower Seed Varieties.** Total phenolic and flavonoid contents of selected sunflower seed varieties are given in Table 2. It was revealed that the treatment 80 mT/30 min of FH620 variety and control of FH615 variety gave the highest phenolic contents, while equal amounts of phenolic contents were found at treatments 50 mT/45 min and 100 mT/15 min for FH545 variety. Similarly, the highest

TABLE 1: Effect of magnetic field stimulation on germination parameters of sunflower seeds.

Sunflower seed varieties	Treatments	Final emergence % age	% age of mean germination time
FH620	50 mT/45 min	100 ± 1.00 <sup>a</sup>	50 ± 0.06 <sup>a</sup>
	80 mT/30 min	80 ± 1.3 <sup>b</sup>	40 ± 0.46 <sup>b</sup>
	100 mT/15 min	94 ± 0.89 <sup>c</sup>	47 ± 0.59 <sup>c</sup>
	Control	100 ± 1.00 <sup>d</sup>	50 ± 0.82 <sup>d</sup>
FH615	50 mT/45 min	80 ± 1.3 <sup>d</sup>	40 ± 0.24 <sup>d</sup>
	80 mT/30 min	80 ± 1.4 <sup>e</sup>	40 ± 0.83 <sup>f</sup>
	100 mT/15 min	80 ± 1.7 <sup>f</sup>	40 ± 0.40 <sup>g</sup>
	Control	93 ± 0.89 <sup>d</sup>	34 ± 0.24 <sup>e</sup>
FH545	50 mT/45 min	68 ± 1.67 <sup>d</sup>	47 ± 0.51 <sup>e</sup>
	80 mT/30 min	68 ± 1.64 <sup>g</sup>	34 ± 0.83 <sup>f</sup>
	100 mT/15 min	68 ± 1.76 <sup>g</sup>	34 ± 0.44 <sup>h</sup>
	Control	86 ± 0.97 <sup>h</sup>	43 ± 0.87 <sup>h</sup>

The data presented in the table are the mean values of three replications ± stander error. Level of significance is indicated by different alphabetical letters.

TABLE 2: Effect of magnetic field on total phenolic and total flavonoid contents of sunflower seed variety extracts.

Sunflower seed varieties	Treatments	Total phenolic contents (mg/g of dry matter)	Total flavonoid contents (mg/g of dry matter)
FH620	50 mT/45 min	76.22 ± 0.21 <sup>b</sup>	61.31 ± 0.71 <sup>c</sup>
	80 mT/30 min	81.68 ± 0.51 <sup>a</sup>	49.78 ± 0.46 <sup>e</sup>
	100 mT/15 min	71.68 ± 0.32 <sup>c</sup>	67.80 ± 0.51 <sup>b</sup>
	Control	70.77 ± 0.34 <sup>c</sup>	60.1 ± 0.82 <sup>c</sup>
FH615	50 mT/45 min	48.05 ± 0.30 <sup>h</sup>	67.80 ± 0.24 <sup>b</sup>
	80 mT/30 min	63.04 ± 0.11 <sup>e</sup>	51.31 ± 0.83 <sup>d</sup>
	100 mT/15 min	57.59 ± 0.54 <sup>f</sup>	78.79 ± 0.11 <sup>a</sup>
	Control	63.5 ± 0.89 <sup>e</sup>	68.90 ± 0.24 <sup>b</sup>
FH545	50 mT/45 min	68.95 ± 0.61 <sup>d</sup>	51.38 ± 0.51 <sup>d</sup>
	80 mT/30 min	58.95 ± 0.54 <sup>f</sup>	51.31 ± 0.83 <sup>d</sup>
	100 mT/15 min	68.95 ± 0.61 <sup>d</sup>	78.79 ± 0.11 <sup>a</sup>
	Control	58.95 ± 0.54 <sup>f</sup>	66.70 ± 0.68 <sup>b</sup>

Level of significance indicated by different alphabetical letters.

amounts of total flavonoid contents were observed at treatment 100 mT/15 min for all three selected varieties. Polyphenols are chemical substances that contain aromatic compounds with hydroxyl groups. Phenolic compounds found in plants act as natural sources of antioxidants. Phenolic compounds inhibit auto-oxidation and prevent lipid oxidation by inhibiting the lipoxygenase enzymes [31, 32]. Phenolic and polyphenolic compounds contribute directly to antioxidative action and are found as natural antioxidants present in plants [33, 34]. Therefore, it is necessary to calculate the total phenolic contents in plant species. From the findings, it is clear that there is a clear relationship between the total phenolic composition of various sunflower hybrids and their antioxidant capacity. It indicates that seeds also have potent antioxidant activity if they have more phenolic content, and likewise. Numerous findings on the relationship between phenolic content and antioxidant properties have been recorded [29].

Plants contain a complex of antioxidant system including phenolic and flavonoid contents that help to protect the reactive oxygen species. Usually, antioxidant activities are high at a lower concentration of sample that decreases with increasing concentration of the sample and becomes pro-oxidant that

inhibits the reactive oxygen species strongly. Flavonoid components and tocopherol are the most important antioxidants for storage stability in sunflower seeds [34].

The diffusion of charged biological particles in a solution can be oriented with a magnetic field current under the effect of Lorentz force or Maxwell stress. The interaction between the external magnetic field and the internal magnetic field resulting from free radicals' nonpaired electrons has a significant impact on the biological system [35]. The impact of magnetic field energy excitation can be directed positively by distributing energy that accelerates metabolism and leads to better germination [36]. Magnetic field treatment induces molecular transformation to provide cells with better conditions for growth and further development. Flux and intensity and exposure period affect different plant systems positively or negatively [11].

*3.3. Effect of Magnetic Field on Antioxidant Parameters.* Effect of magnetic field on antioxidant parameters such as DPPH activity, reducing power assay, and total antioxidant activity of selected sunflower seed varieties is given in Table 3. 1, 1-Diphenyl-2-picryl-hydrazyl (DPPH) is a strong oxidant

TABLE 3: Effect of magnetic field on antioxidant parameters of sunflower seed varieties.

Sunflower seed varieties	Treatments	DPPH activity (%)	Reducing power assay (%)	Total antioxidant activity (%)
FH620	50 mT/45 min	59.17 ± 0.21	76.85 ± 0.71**	40.38 ± 0.21
	80 mT/30 min	59.55 ± 0.31	23.14 ± 0.21	62.30 ± 0.21
	100 mT/15 min	60.67 ± 0.41**	42.00 ± 0.32	55.76 ± 0.61
	Control	40.07 ± 0.21	58.85 ± 0.21	64.61 ± 0.82**
FH615	50 mT/45 min	59.17 ± 0.21	49.41 ± 0.30	45.76 ± 0.24
	80 mT/30 min	59.92 ± 0.11	77.42 ± 0.61**	53.07 ± 0.21
	100 mT/15 min	62.17 ± 0.41**	64.85 ± 0.21	55.38 ± 0.61
	Control	58.42 ± 0.21	56.57 ± 0.21	58.84 ± 0.21**
FH545	50 mT/45 min	53.93 ± 0.61	74.85 ± 0.61	60.76 ± 0.51**
	80 mT/30 min	55.80 ± 0.21	56.00 ± 0.21	58.07 ± 0.21
	100 mT/15 min	61.17 ± 0.41**	55.14 ± 0.76	48.46 ± 0.61
	Control	59.17 ± 0.21	83.14 ± 0.21**	60.76 ± 0.21**

Level of significance indicated by “\*\*.”

at one atom of the Nitrogen Bridge with an unbound valence electron. Free radical scavenging activity is the basis of the common DPPH antioxidant assay [37]. In sunflower oil, as well as in its shell, antioxidant compounds are found [38]. Many other investigations using the DPPH assay to determine the radical scavenging activity of oilseeds, particularly sunflower, have found significant antioxidant potential values for these seed extracts [39, 40], and these studies are in accordance with the findings for the DPPH assay. The aqueous extract's radical scavenging activity was found to be 58.8 percent by DPPH in striped sunflower seeds.

The yellow color of the reaction mixture changed to different shades of green in the reduction power assay, which is dependent on the sample's reduction power. The antioxidant radicals modify the ferrous form of the Fe<sup>3+</sup>/ferricyanide complex. An enhanced absorption spectrum at a wavelength of 700 nm is observed with rising ascorbic acid and perillaldehyde amounts. This shows the reduction (electron donation) potential of the test samples, which is a property of the sample concentration [41].

The reducing power of active compounds has been reported to be correlated with antioxidant activity. Therefore, the reducing power of polyphenolic compounds must be calculated to illustrate the connection between their antioxidant effects and the reducing power [42]. The magnetic field has also been documented to stimulate the action of enzymes such as alpha-amylase, dehydrogenase, and protease in seeds [43]. De Souza et al. [44] suggested that when the seeds were handled with a magnetic field, the mean fruit weight, fruit yield, and tomatoes' biological yield were enhanced. When the seeds were subjected to a magnetic field, enhanced germination rate, fresh shoot weight, and seedling length of maize were recorded.

Huang et al. [45] examined the reduction of the strength of sunflower extracts as neutralization of DPPH radicals. By changing the sample's color from purple to yellow because of the electron donation, neutralization of the DPPH radicals could be seen and calculated. By accepting a hydrogen atom from the hydroxyl group of phenolic compounds, the stable DPPH is neutralized, resulting in a reduced shape (DPPH-H). Complete phosphomolybdenum-dependent antioxidant activity based on sample analyte reduction of Mo (VI) to Mo

(V) and subsequent formation of a green phosphate/Mo (V) complex at acidic pH typically detects antioxidants such as certain phenolics, ascorbic acid, alpha-tocopherol, and carotenoids [46]. Sunflower is a potential source of natural antioxidants, closely associated with a reduced risk of chronic diseases and protection against harmful free radicals. These natural plant products' antioxidant activity is due to their antioxidant capacity, which enables them to act as reducing agents, donors of hydrogen, and quenchers of single oxygen and chelators of metal [3, 47–49].

### 3.4. Characterization of Sunflower Hybrid Seed Varieties

**3.4.1. Fourier Transforms Infrared Spectroscopy Studies.** Fourier Transform Infrared Spectroscopy (FTIR) spectra have been used to evaluate the structural changes and functional groups of sunflower seedling organic compounds. The average wavelength of the spectrum was 1000–3500 cm<sup>-1</sup>, as shown in Figure 1. The FTIR profiling of untreated sunflower seed extracts shows different functional groups, such as the characteristic absorption band at a broad signal of 3500 cm<sup>-1</sup> (N-H stretching from amine superimposed to C-H stretching), while C-H (Arene) stretching at 3000 cm<sup>-1</sup> has been observed. In the seed extract, the abovementioned data indicated the separation of C=O into two peaks. The carboxylic group O-H expanding was overlapped by a 2500 cm<sup>-1</sup> spectral range that emerged from the alkane group as a band comparable to C-H bending. The FTIR seed extract spectrum showed negligible variations compared to the control group at the most efficient (50 mT/45 min) magnetic field strength (Figure 1). In Table 4, the identified organic groups were described.

These spectra typically consist of several bands that originate from the vibration of carbohydrates, proteins, lipids, and nucleic acids of different functional groups and give different configurations. Generally, spectra consist of many bands originating from the biochemical arrangement of plant species. In general, the band centered around 3500 cm<sup>-1</sup> illustrates N-H stretching vibrations induced primarily by proteins. The bands among 3000 and 2500 cm<sup>-1</sup> significantly influence lipid-caused C-H stretching

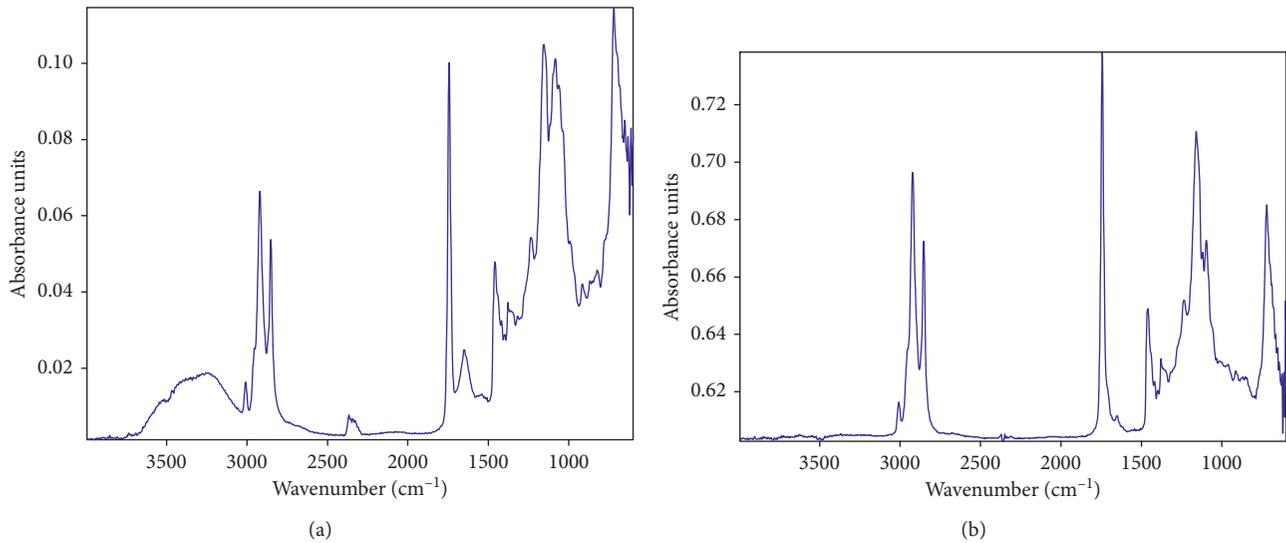


FIGURE 1: FTIR profile of sunflower seed variety FH620 at 50 mT/45 min magnetic field intensity, (a) control group, (b) magnetically treated.

TABLE 4: Functional groups detected by FTIR spectra.

Control group		Seed variety FH620 treated at (50 mT/45 min)	
Functional group	Wavenumber (cm <sup>-1</sup> )	Functional group	Wavenumber (cm <sup>-1</sup> )
Amine (N-H group)	3500	—	3500
Arene (C-H)	3000	Arene (C-H)	3000
Carboxylic acid (O-H)	2500	—	2500
—	2000	—	2000
Arene (C=C)	1500	Arene (C=C)	1500
Ester sp <sup>3</sup> (C-O)	1000	Ester sp <sup>3</sup> (C-O)	1000

vibrations. Overall, in the absorption range, the control spectrum and magnetic field handled samples vary, suggesting apparent differences in the structure and quality of the biological spectrum due to the static magnetic field [35].

**3.4.2. Tocopherol (Vitamin E) Analysis by HPLC.** HPLC analysis of tocopherol from the most effective sunflower seed variety FH620 is shown in Figure 2. Vitamin E is a major lipophilic antioxidant that has remarkable scavenging activity due to alkoxy and peroxy radicals. It protects other plant tissues and the cell membrane from oxidation and helps protect from damage caused by free radicals.

Peak areas of  $\alpha$ - and  $\beta$ -tocopherols detected by HPLC are given in Table 5. It was revealed that the concentration of tocopherol had been increased compared to the control group. It was further noticed that by treating seeds with low magnetic field intensity (i.e., 50 mT/45 min) the mobilization of organic molecules increased as many of them play roles in antioxidant activity. Therefore, it has been observed that the antioxidant potential increases as seeds are treated with low magnetic field intensity.

The low intensity of the static magnetic field at a longer exposure time (50 mT/45 min) significantly influenced the biochemical changes, especially antioxidant profiling. A low magnetic field improved the cellular leakage and electrical conductivity that improved the antioxidant potential, including tocopherol contents in sunflower oil extracted from the seeds treated with (50 mT/45 min) magnetic field intensity. The plant growth and the germination of the sunflower were significantly enhanced to respond to the magnetic field. In a study, increased seed germination and seedling growth was observed at a low temperature of 15°C after the application of gamma radiation and magnetic field strength [50]. Similarly, Bahadira et al. [51] reported that seed tubers of potato treated with 150 mT magnetic field strength for 72 h gave the best results for different parameters including plant height, total chlorophyll content, tuber number/plant, and mean tuber weight. An increase in the yield and antioxidant activity was also observed in this study. The magnetic field treatment enhanced the plant's overall growth, and its nutritional value was also found to be improved.

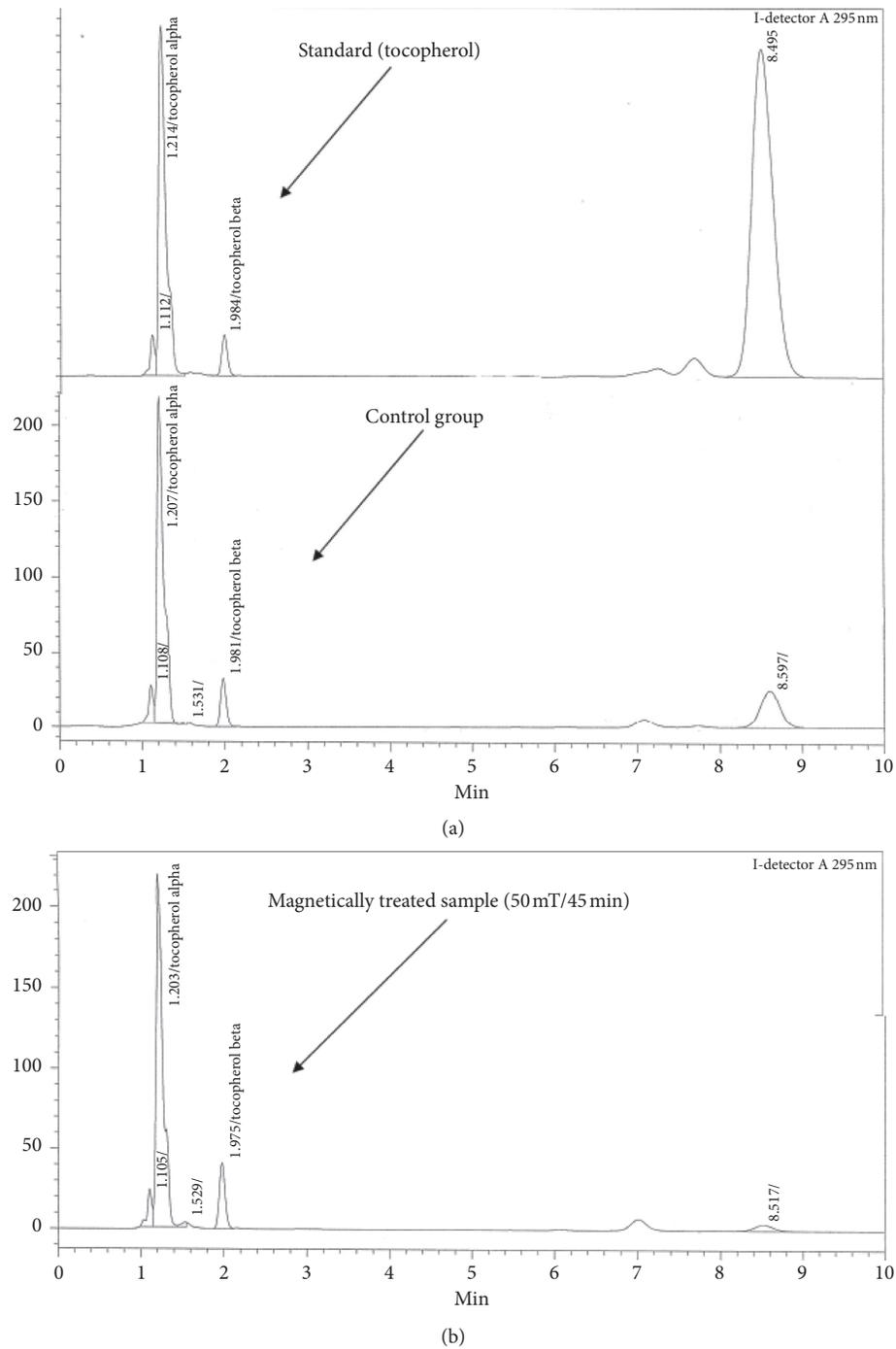


FIGURE 2: HPLC analysis of tocopherol from sunflower seed variety FH620, (a) control group, (b) at 50 mT/45 min magnetic field intensity.

TABLE 5: Peak area  $\alpha$ -tocopherol and  $\beta$ -tocopherol of FH620 seed variety detected by HPLC.

Sr. no.	Sample	$\alpha$ -Tocopherol			$\beta$ -Tocopherol		
		Ret. time	Peak area	% age	Ret. time	Peak area	% age
1	Control	1.207	1242937	27.33	1.98	155590	14.02
2	Magnetic treatment (50 mT/45 min)	1.203	1239891	27.05	1.97	200922	48.32

## 4. Conclusion

The effects of magnetic field treatment on presowing sunflower seed varieties were checked on total phenolic contents, total flavonoid contents, DPPH radical scavenging activity, reducing power, total antioxidant activity, FTIR, and HPLC of tocopherol analyses. This study concluded that the magnetic field intensity (50 mT and 80 mT) is more effective for sunflower seeds. Magnetic field effects at different intensities showed variable effects on the measured parameters. The biostimulation of presowing sunflower seeds positively affected the seed germination and development stages, which led to accelerated germination, yield, and an increase in the percentage of antioxidant activity. Treatment of low magnetic field (50 mT/45 min) improved the antioxidant profile of sunflower seeds that were not studied before and therefore opened a new path to study the metabolic changes. The magnetic field treatment also improved vitamin E, inner energy of seeds, and bioactive compounds present in the plant.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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