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Effect of Magnetic Field and Electric Current Treatments on Growth, Yield and Seedling Parameters in Buckwheat (*Fagopyrum esculentum* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Effect of pre-sowing magnetic field (MF) and electric current treatments on germination, seedling parameters and yield attributes in Buckwheat (*Fagopyrum esculentum* L) was investigated in this experiment. This study was designed to check the response of magnetic and electric treatments with different intensities and durations on buckwheat on different growth, yield and seedling parameters such as field emergence, leaf surface area, plant height, days to first flowering, seed yield per plant, biological yield, harvest index, germination per-cent, root length, shoot length, seedling fresh weight, seedling dry weight, vigour index Ⅰ, seed metabolic efficiency and chlorophyll content (a & b). Seeds of Buckwheat (IC-329456) treated by using an AC magnetic flux intensities 75mT, 100mT, 125mT for 3 and 5 minutes in the magnetic field and AC electric current ranging from 75mA, 100mA, 125mA for 30,60,90 seconds. In this study, it found that among various treatments T_6 (Magnetic field @ 125mT for 5 minutes) performing better in terms of field emergence

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(96.04%), leaf area (30.87m^2), days to first flowering(46days), seed yield per plant (8.80g), while lowest was found in control. Results showed that the seeds treated with magnetic field demonstrated remarkable effects on growth and yield parameters of buckwheat. Germination per-cent (99%), seedling fresh weight (0.177g), seedling dry weight (0.035) and chlorophyll (a & b) content was maximum in T_6 (Magnetic field @ 125mT for 5 minutes) which performed better among the other treatments. Effect of treatments on seedling parameters were found to be non-significant. Both the electric current and magnetic field treatment of seeds is likely to play an important role in production of food which is free from toxic and chemical residues were beneficial for human consumption.

Keywords: Magnetic field; electric current; buckwheat genotypes; growth and yield parameters.

1. INTRODUCTION

Buckwheat has been a crop of secondary importance in many countries and yet it has persisted through centuries of civilization and enters the agriculture of nearly every country where cereals are cultivated. The Range of distribution of buckwheat extends from the mountainous regions of China, USA, Nepal, Bhutan, Myanmar, Japan, Korea, India, Iran and Afghanistan. This crop is not a cereal, but the seeds (strictly achene) are usually classified among the cereal grains because of their similar usage, hence it is known as pseudocereal. The grain is generally used as human food and as animal or poultry feed. The productivity of Indian buckwheat is quite low as compared to that of Korea and other buckwheat growing countries, for achieving increased production in buckwheat, it is essential to develop new high yielding varieties. Though it is a minor crop it has a tremendous nutritional and medicinal value. Buckwheat is having high nutritional value. Starch is the major component of buckwheat, ranges from 59-69% of grain composition with 15-25% of amylose and 7-35% resistant starch and remaining portion is amylopectin. The grain contains 11-15% protein, 7.4g fat, 2.4% mineral matter, 15% fibre, 1.5%-3.7% lipid, 355 kcal energy (Narain, 1979 and Ram et al., 1979).

The primary necessity and concern in modern times is mass production of crops for the human population. Due to urbanization and industrialization, the environment has become poisoned and polluted with harmful chemicals, making environmental safety a global concern. In recent years, there has been a lot of research on the effects of magnetic and electric fields on seed germination, plant growth, biochemical changes, and yield; however, a comprehensive investigation is required to uncover the mechanisms in tissues and to determine its practical uses (Radhakrishan et al., 2013). It has been proposed that the polarization of dipoles and ion activation in living cells are affected by the external electric and magnetic fields (Moon and Chung, 2000). Soyabean seeds exposed to pulsed MF at varying frequencies significantly increased germination rate, with 10 and 100 Hz pulsed MFs being most effective (Radhakrishan et al., 2013). Magnetic field treatment (125mT) increased seed germination in rice, wheat, maize, and barley seeds, enhancing biochemical processes and protein activity. Seed vigour was measured by counting germinated seeds for each treatment. Rice, wheat, maize, and barley seeds germination was boosted by 125mT magnetic treatment, which also improved biochemical reactions and protein activity. By counting seeds that germinated for each treatment, seed vigor was calculated [1]. Experiments show electric fields positively affect plant biological behavior, roots, seeds, pollen, and buds, with rice seeds showing higher growth rates but no effect on germination [2]. Magnetic field (MF) treatment significantly increased germination parameters, growth parameters, root length, leaf area, chlorophyll contents, fruit length, weight, and yield in bitter gourd, enhancing growth and yield [3]. Root length increased by 28.6%, leaves increased by 25.3%, but flowers dry weight and seed weight did not significantly increase under different voltage treatments [4,5-9].

Multiple research studies and reports from researchers have found that magnetic field-treated vegetable and grain crops seeds performing well in terms of germination, plant growth, height, seed dry masses, chlorophyll contents, enzymatic activities, and yield (Iqbal et al., 2013; Iqbal et al., [10] Jamil et al., [11] Jamil et al., [12] Naz et al., [13] Perveen et al., [14] Zia ul Haq et al., [15] Biochemical and physiological changes in biological objects are caused by electromagnetic fields. Together, increased photosynthesis and water uptake improves seed germination and growth [16]. There are many theories explaining how MF affects biological systems at the cellular level, but the particular process is not well understood. According to research in this area, ferromagnetic particles in living things, changes in energy levels, and variations in electron spin in atoms and molecules. Various studies believe that MF have the ability to have an impact on biological processes by changing the location of electron spins during chemical reactions (Souza De, 2014, Iqbal et al., [17]. This present study aimed to investigate the effect of magnetic field and electric current treatments on growth and yield of buckwheat seedlings.

2. MATERIALS AND METHODS

2.1 Soil Description and Experimental Area

The experiment was conducted in *Rabi* season of 2022, both in the Laboratory and in the field of Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (25 24' N, 810 51' E). The soil was of sandy clay loam in texture, pH was 7.1, Organic matter (0.50%) and Electrical conductivity (0.37 dsm^{-1}). The meteorological data regarding rainfall, Relative humidity and Temperature were recorded from meteorological observatory cell.

2.2 Seed Collection and MF and EC Treatment

Buckwheat seeds of genotype IC-329456 were obtained from the Department of Seed Science and Technology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (Uttar Pradesh). For magnetic field treatment, seeds were exposed to electromagnetic field with intensity 75, 100, 125 mT with various durations of 3 and 5 minutes. A gauss meter was used to measure the magnetic field strength between the poles and the variation recorded was 0.003% for each treatment (75,100,125mT) using a DC power supply (80V/10A) with continuously variable output current was used for the electromagnet. A digital gauss meter OMEGA DGM-20 (230V AC$\pm$10% at 50 Hz). For electric current treatment seeds were soaked overnight. Soaked seeds are placed on metallic plate and connected to the power source. Electric current of DC 24V was passed at required intensities for different duration as per treatment requirement through the seeds of 75mA, 100mA, 125mA for 30, 60, 90 seconds.

2.3 Seed Sowing and Cultural Practices

The experiments were carried out in Randomized Block Design (RBD) for field experiments in 3 Replications and 4 Replications in Completely Randomized Design (CRD) [18] for laboratory parameters. The plot size is 1m X 1 m. Row to row is 30 cm and plant to plant is 10 cm seeds were treated and sowing in field with regular spacing and irrigation given weekly basis in such a way that the moisture content remained > 80%. Four hoeings were done to keep the plots free from weeds.

3. METHODOLOGY FOR FIELD PARAMETERS

Field emergence (%): Field emergence was recorded on 15^{th} day after sowing. The seedling appearance on the surface of the soil were considered as emerged. The percent emergence of seedlings was calculated as rate of field emergence by using following formula.

Field emergence (%)= Total number of seeds emerged on 15th day / total number of seed sown ×100

Leaf surface area(cm^2): Estimates of leaf area were obtained by the equation (Pandey and Singh, 2011).

Leaf area (cm^2) = x/y; where x is the weight (g) of the area covered by the leaf outline on a milli-meter graph paper and y is the weight of one cm^2 of the same graph paper.

Seed yield per plant(g): Seeds from randomly selected five plants from each treatment were collected and weighed individually to get seed yield per plant and expressed in grams.

Biological yield (g): Biological yield refers to the total dry matter accumulation in a plant system. The five randomly selected plants in each treatment (without roots) were dried along with seeds and weighed to obtain biological yield.

Harvest index (%): The ratio of the economic yield to biological yield is referred as harvest index and it can be used to measure the reproductive efficiency. Harvest index of five randomly selected plants was recorded (Donald and Hamblin, 1963).

Harvest index= Economic yield / Biological yield ×100

3.1 Methodology for Seedling Parameters

3.1.1 Germination percent (ISTA, 2004)

The germination percentage of buckwheat was measured [19] and percent germination was calculated using the following relation:

$$germination(\%) = \frac{seeds\ germinated}{total\ seeds\ sown} \times 100$$

Vigor Index I: It was calculated by adopting the method suggested by Baki and Anderson (1973).

Vigor Index I = $germination\,\% \times total\ seedling\ length(cm)$

Vigor index-II: It was calculated by adopting the method suggested by Baki and Anderson (1973).

$$\text{Vigor index} - \text{II} = germination\,\% \times total\ seedling\ dry\ weight(g)$$

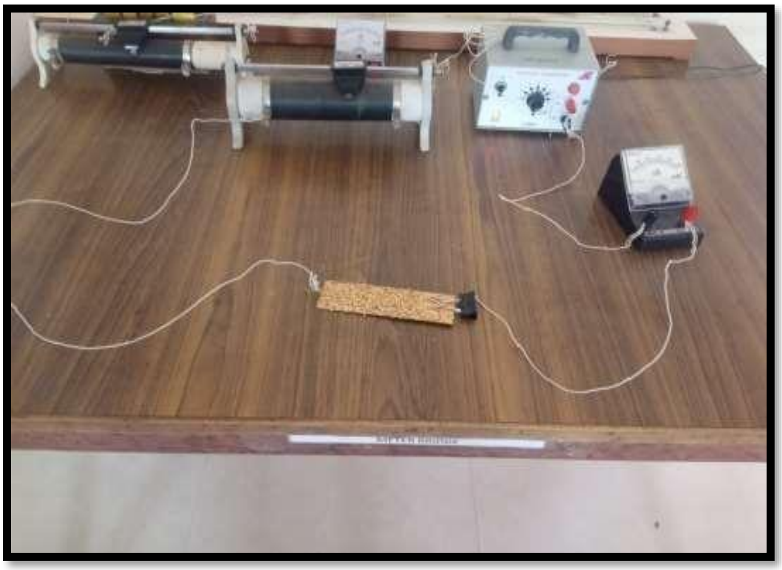

Plate 1. Electric current field

Plate 2. Magnetic field

3.1.2 Seed Metabolic Efficiency (SME)

It may be defined as the amount of shoot and root dry matter(g) produced from 1 unit (g) of dry weight that was respired. Thus higher the value of Seed Metabolic Efficiency, higher the efficiency of seed as more seed reserves would be used for producing roots and shoots. Amount of speed respired (SMR) was calculated as below,

SMR = SDW-(SHW+RTW+RSW**)**

Where, SDW – Seed dry weight before germination
SHW – Shoot dry weight
RTW – Root dry weight
RSW – Remaining seed dry weight.

Seed Metabolic Efficiency (SME) was calculated using the following formula (Rao and Sinha, 1993)

$$SME = \frac{SHW + RTW}{SMW}$$

Higher the SME value, higher the efficiency of seed as seed resource used for producing root and shoot.

3.1.3 Chlorophyll content(mg/g) (Arnon, 1949)

For measuring the chlorophyll contents, fresh leaves, 20-day old (0.1 g) were ground in the presence of 1 mL acetone and the volume was made up to 5 mL by adding more acetone. The slurry was then centrifuged for 5 min. The supernatant was collected and its absorbance was measured at 645 and 663 nm using UV/visible spectrophotometer-CE Cecil 7200, UK. The chlorophyll “a” (chl a) and chlorophyll “b” (chl b) were calculated using relations. Where V = volume, W= weight of fresh leaves taken and abs = absorbance [20].

$$chla = \frac{\{12.7\ (\ abs\ 663) - 2.69(abs645)\}}{1000 \times w} \times v$$

$$chlb = \frac{\{22.9(abs645) - 4.68\ (abs\ 663)\}}{1000 \times w} \times v$$

3.2 Statistical Analysis

All treatments of field parameters were performed in triplicate under RBD and all treatments under lab parameters were performed in 4 replications under CRD and data regarding germination, growth, yield and physiological characteristics were statistically analyzed by one-way ANOVA at 95% confidence level.

4. RESULTS AND DISCUSSION

4.1 Field Parameters

Field emergence (%): Maximum field emergence was observed 100 % in seed treatment T6 (MF, 125mT, for 5min) followed by 98.33 % in T14 (EC, 125mA, for 60sec) and minimum field emergence was observed 90 % in control(T0) [21]. When seeds were treated with MF 125mT for 5min due to electromagnetic exposure, minute cracks were formed on the surface of the seed coat. These minute hair cracks make it

Table 1. Treatment details

S.NO	TREATMENT CODE	TREATMENTS	INTENSITY	DURATION
1	T_0	Control	–	–
2	T_1	Magnetic field	75mT	3min
3	T_2	Magnetic field	75mT	5min
4	T_3	Magnetic field	100mT	3min
5	T_4	Magnetic field	100mT	5min
6	T_5	Magnetic field	125mT	3min
7	T_6	Magnetic field	125mT	5min
8	T_7	Electric current	75mA	30sec
9	T_8	Electric current	75mA	60sec
10	T_9	Electric current	75mA	90sec
11	T_{10}	Electric current	100mA	30sec
12	T_{11}	Electric current	100mA	60sec
13	T_{12}	Electric current	100mA	90sec
14	T_{13}	Electric current	125mA	30sec
15	T_{14}	Electric current	125mA	60sec
16	T_{15}	Electric current	125mA	90sec

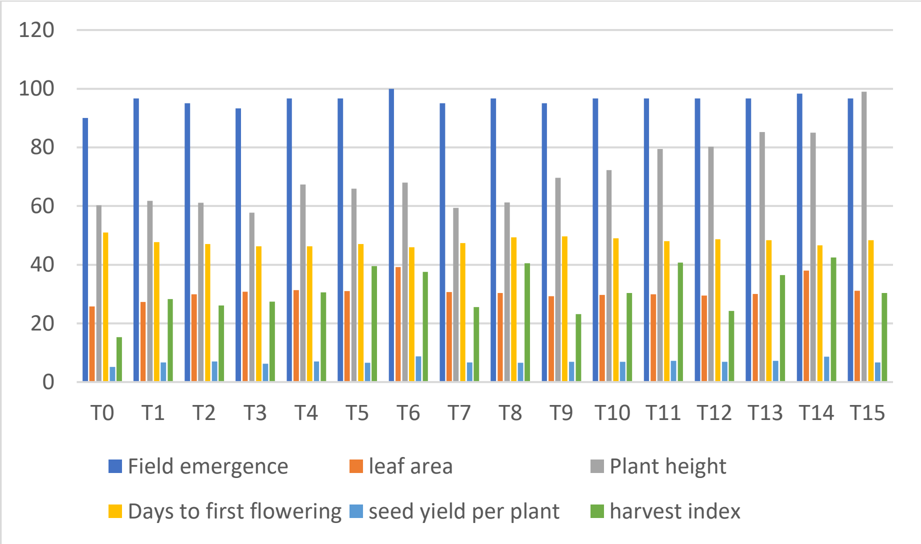

Fig. 1. Representing the mean values of field parameters of buckwheat

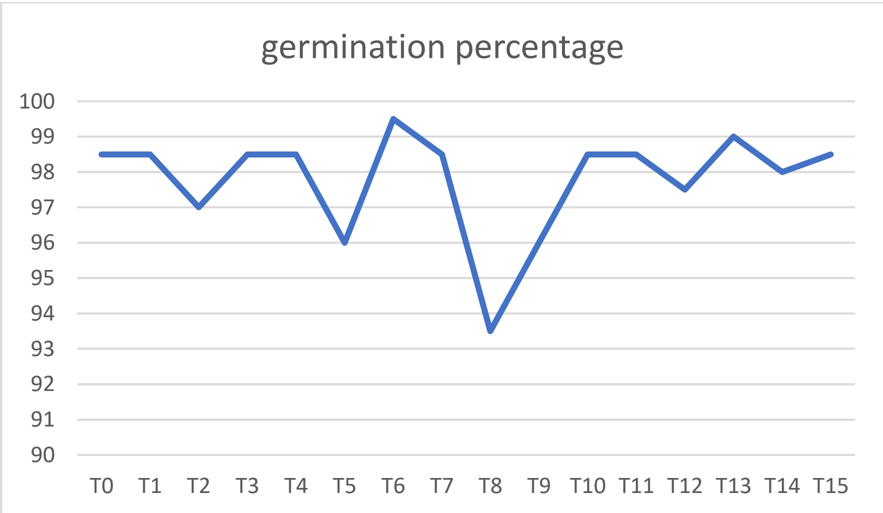

Fig. 2. Representing the germination percentage after seeds were treated with magnetic and electric treatments

Maximum germination percent was recorded by T6(MF, 125mT for 5min) (99.5%) followed by T13(EC, 125mA for 30 sec) (99 %) and minimum germination percent was under seed treatment T8(EC, 75 mA for 60sec) (93.5 %).

permissible for the exchange of gases and water from the environment to the seeds which enhances the maximum field emergence in Buckwheat (Singh et al., 2021) [22].

Plant height(cm): It was observed from the data represented in Table-2 that there was enhancement in plant height at 85 DAS when seeds were exposed to magnetic and electric treatments. Maximum plant height at 85 DAS was under T15(EC, 125mA, 90 sec) (98.94 cm) followed by T13(EC, 125mA, for 60sec) (85.19 cm) and lowest was recorded under T3(MF, 100mT, for 3min) (57.78 cm) this is due ion accumulation mechanism and also internal auxin production [4].

Leaf area(cm^2): It was concluded from the data represented in Table-2 that there was enhancement in leaf area when seeds were exposed to magnetic and electric treatments. Maximum field emergence was noticed in T6 (MF, 125mT, for 5min) (39.23 cm^2) which was followed by T14(EC, 125mA, for 60sec) (37.96 cm^2). Whereas minimum among the treatments was recorded under control (25.74 cm^2). when seeds were treated with MF,125mT for 5 min, due to greater interception of light and greater amount of assimilates available for vegetative growth that increased surface leaf area, which had a strong influence on crop growth. Similar results were reported by De Souza et al., 2006.

Days to first flowering: From present investigation it was observed that minimum days taken for first flowering was under T6(MF,125mT, for 5min) (46 days) followed by 46.33 DAS in T3(MF,100mT, for 3min) and maximum days taken for first flowering was under control (51 days). Similar results were reported by Joseph et al. [23].

Seed yield per plant(g): It was observed that there was enhancement in seed yield per plant when seeds were exposed to magnetic and electric treatments. Maximum seed yield per plant 8.8g was noticed under T6 (MF, 125mT for 5 min) followed by T14 (EC,125mA for 60 sec) (8.67 g) and minimum was under control T0 (5.2g). This might attributed to the favourable germination, higher growth and enhanced photosynthetic rate that enhances flowering, fruit formation and ultimately yield [3].

Biological yield: From the data mentioned in Table-2 observed that there was no enhancement in biological yield when seeds were exposed to magnetic and electric treatments. Maximum biological yield was observed in control (474 g) followed by seed treatment T7(EC,75mA for 30 sec) (348.3 g) and the minimum was under seed treatment T14 (175.3 g). Similar results were reported by Anatolii Ivankov et al. [24].

Harvest index (%): From present experiment it was observed that the maximum harvest index was noticed in T14 (EC 125mA for 60 sec) (42.46 %) followed by seed treatment T8(EC,75 mA for 60sec) (40.55 %) and the minimum harvest index was under seed treatment T0 (15.32 %). Due to electric and magnetic field treatments seed yield per plant is rapidly increased but biological yield decreased so that harvest index automatically increased in these treatments significantly [23].

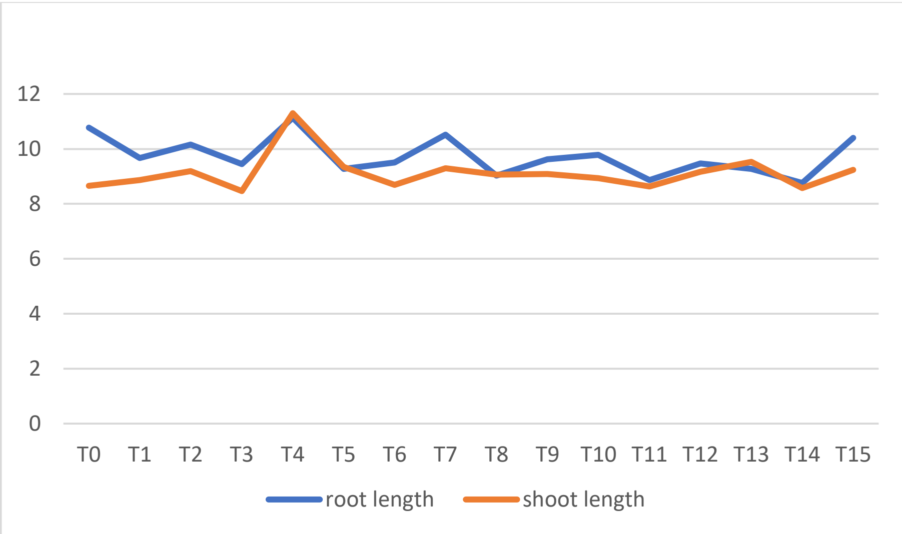

Fig. 3. Representing the variations in mean values of root and shoot length of buckwheat after treating with magnetic and electric field treatments

Table 2. Analysis of Variance for different field parameters of buckwheat

Parameters	SS	MSS	F-Value	Remarks
Field emergence	214.58	14.30*	0.75	NS
Plant height	6267.70	417.84*	4.95	S
Leaf area	503.11	33.5*	2.84	S
DFF	87.00	5.80*	3.37	S
SYPP	31.62	2.10*	3.83	S
Biological yield	261551.33	17436.75*	2.87	S
Harvest index	2670.16	178.01*	1.68	NS

**indicates 5% level of significance; S – Significant; NS – Non significant*
DFF-days for first flowering, SSYP-seed yield per plant

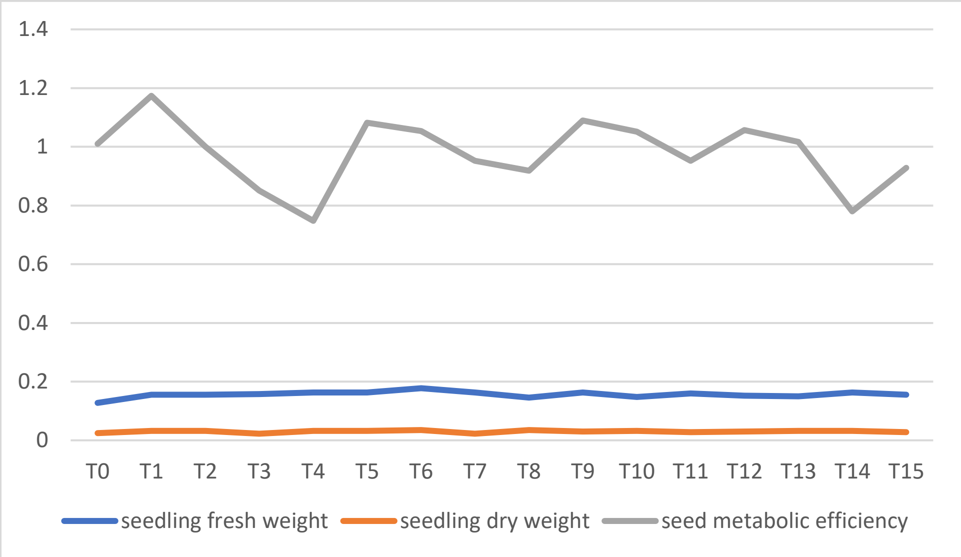

Fig. 4. Representing the variations observed in mean values of seedling fresh and dry weight and seed metabolic efficiency of buckwheat after treating with magnetic and electric field treatments

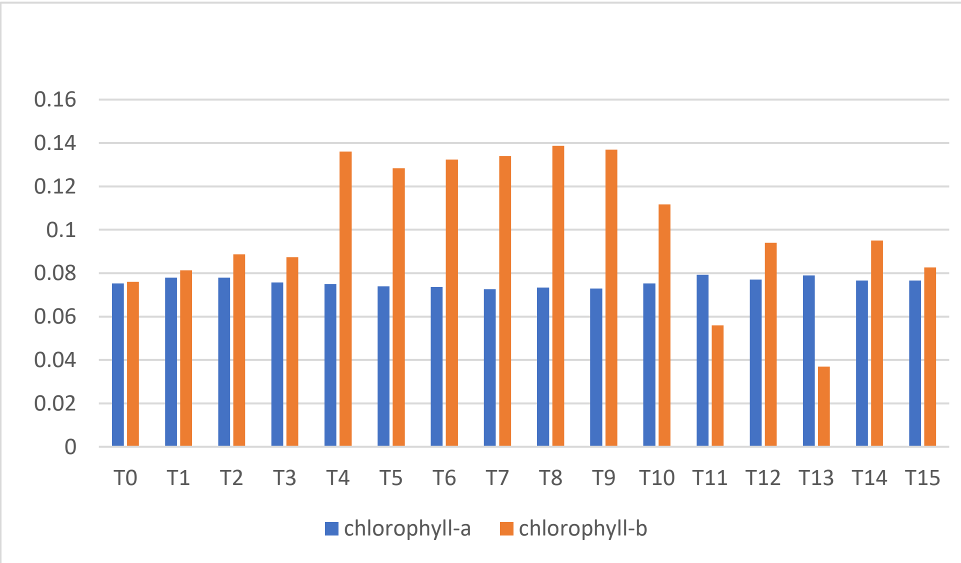

Fig. 5. Representing the chlorophyll(mg/g) contents present in the buckwheat

Maximum chlorophyll-a was under T6(MF,125mA for 5 min) (0.0793) followed by T13(EC,125mA for 30 sec) (0.079) and the minimum was found in T7(EC,75 mA for 30 sec) (0.072). Maximum chlorophyll- b was under T6(MF,125mA for 5min) (0.138) followed by T8(EC,75mT for 60sec) (0.132) and the minimum was found in T13(EC,125mA for 30 sec) (0.037).

4.2 Seedling Parameters

Germination percentage (%): It was found that maximum germination per-cent was under seed treatment T6(MF, 125mT for 5min) (99.5%) [25] followed by T13(EC, 125mA for 30 sec) (99 %) and minimum germination per-cent was under seed treatment T8(EC, 75 mA for 60sec) (93.5 %). Due to electromagnetic exposure, on the surface of seed minute cracks was formed. These minute hair cracks make it permissible for the exchange of gases and water from the environment to the seeds. Enzymes and biochemical get triggered due to the exchange of these vital factors and the process of germination inside the seeds gets activated (Singh et al., 2021).

Root length: From the data represented in the Table-5 the mean values of the root length were ranged between 76 cm to11.13 cm with the mean value of 9.72 cm. It was found that maximum root length (cm) was under T4(MF, 100 mT for 5 min) (11.13 cm) followed by control (10.77cm) and minimum root length (cm) was under T14(EC, 125mA for 60 sec) (8.76 cm). There was enhancement in seedling root length when seeds were treated with MF,100mT for 5min may be due to an increased rate of cell division in the root tips and earlier start of emergence (Afzal et al., 2021).

Shoot length: From the data represented in the Table-5 the mean values of shoot length (cm) were ranged between 8.46 cm to 11.3 cm with the mean performance of 9.12 cm. It was found that maximum shoot length (cm) was under T4 (EC,125mA for 60 sec) (11.3 cm) followed by T13(EC,125mA for 30 sec) (9.52 cm) and minimum shoot length was under T3(MF,100mT

Table 3. Effect of treatments on mean performance of buckwheat on growth and yield parameters

Treatment	Field Emergence (%)	Plant height(cm)	Leaf area(cm^2)	Days to first flowering	Seed yield per plant(g)	Biological Yield(g)	Harvest Index (%)
T0	90.00	60.26	25.75	51.00	5.20	474.00	15.32
T1	96.67	61.81	27.31	47.67	6.73	310.33	28.25
T2	95.00	61.11	29.95	47.00	7.07	311.67	26.10
T3	93.33	57.78	30.77	46.33	6.27	282.33	27.37
T4	96.67	67.30	31.35	46.33	7.00	325.33	30.53
T5	96.67	65.87	31.03	47.00	6.53	206.00	39.56
T6	100.00	67.98	39.23	46.00	8.80	277.33	37.55
T7	95.00	59.39	30.65	47.33	6.73	348.33	25.52
T8	96.67	61.18	30.40	49.33	6.53	190.00	40.56
T9	95.00	69.65	29.31	49.67	6.87	351.00	23.20
T10	96.67	72.25	29.73	49.00	6.87	248.67	30.34
T11	96.67	79.47	29.88	48.00	7.20	212.33	40.69
T12	96.67	80.20	29.51	48.67	6.93	325.33	24.28
T13	96.67	85.19	30.03	48.33	7.20	223.33	36.48
T14	98.33	84.97	37.96	46.67	8.67	175.33	42.46
T15	96.67	98.94	31.08	48.33	6.73	256.00	30.35
Mean	96.04	70.84	30.87	47.92	6.96	282.33	31.16
CV	7.26	15.31	5.72	2.18	1.23	129.76	17.14
CD(0.05 *p)*	0.55	2.95	0.84	0.35	0.21	19.06	1.93
Sem	2.27	16.66	10.83	2.90	12.05	27.00	24.72

Table 4. Analysis of Variance for different seedling parameters of buckwheat

Parameters	SS	MSS	F-Value	Remarks
Germination percentage	135.93	9.06*	1.13	NS
Root length	28.54	1.90*	1.14	NS
Shoot length	26.00	1.73*	0.98	NS
SFW	0.007	0.001*	0.66	NS
SDW	0.001	0.001*	1.14	NS
Vigour index-I	942778.56	62851.90*	1.48	NS
Vigor index-II	8.82	0.58*	1.04	NS
SME	0.79	0.05*	0.99	NS
Chl-a	0.000	0.000*	3.813	S
Chl-b	0.04	0.003*	302.64	S

**indicates 5% level of significance; S – Significant; NS – Non significant*
SFW-shoot fresh weight, SDW-shoot dry weight, SME-seed metabolic efficiency, Chl-a- Chlorophyll-a, Chl-b- chlorophyll-b, S-significant, NS-non-significant.

Table 5. Effect of treatments on mean performance of buckwheat for seedling parameters

Treatment	Germination (%)	Root length (cm)	Shoot length (cm)	Seedling Fresh weight (g)	Dry weight (g)	Vigor index-I	Vigour index- II	Seed metabolic efficiency (%)	Chlorophyll content(mg/g)	
									Chlorophyll a	Chlorophyll b
T0	98.50	10.77	8.65	0.127	0.025	1915	2.46	1.01	0.08	0.076
T1	98.50	9.66	8.86	0.155	0.033	1824	3.20	1.17	0.078	0.081
T2	97.00	10.15	9.19	0.155	0.036	1876	3.15	1.01	0.078	0.08
T3	98.50	9.44	8.46	0.157	0.023	1764	2.22	0.85	0.076	0.08
T4	98.50	11.13	11.3	0.162	0.033	2213	3.21	0.75	0.075	0.136
T5	96.00	9.26	9.34	0.162	0.033	1781	3.14	0.08	0.074	0.128
T6	99.50	9.50	8.69	0.177	0.35	1811	3.49	1.05	0.079	0.139
T7	98.50	10.52	9.3	0.162	0.023	1952	2.21	0.95	0.073	0.134
T8	93.50	9.03	9.06	0.145	0.035	1692	3.25	0.92	0.073	0.132
T9	96.00	9.62	9.08	0.162	0.03	1797	2.88	1.09	0.073	0.137
T10	98.50	9.78	8.93	0.147	0.033	1843	3.21	1.05	0.075	0.112
T11	98.50	8.86	8.63	0.16	0.028	1722	2.72	0.96	0.074	0.056
T12	97.50	9.48	9.17	0.152	0.03	1816	2.94	1.06	0.077	0.094
T13	99.00	9.27	9.53	0.15	0.033	1861	3.22	1.07	0.079	0.037
T14	98.00	8.76	8.57	0.162	0.033	1696	3.19	0.78	0.077	0.095
T15	98.50	10.40	9.23	0.155	0.028	1929	2.72	0.93	0.077	0.082
Mean	97.78	9.73	9.13	0.16	0.03	1843	2.95	0.98	0.08	0.10
CV	2.89	13.27	14.52	17.00	24.98	11.17	25.42	23.46	0.001	0.01
CD(0.05 *p*)	-	-	-	-	-	-	-	-	0.003	0.005
Sem	1.42	0.64	0.66	0.013	0.004	102.95	0.37	0.12	2.49	3.09

for 3 min) (8.46 cm). When seeds were treated with MF,100mT for 5min it increased the rate of cell division in the root tips and earlier start of emergence (Afzal et al., 2021).

Seedling fresh weight: It was concluded from the experiment that maximum fresh weight was under T6(MF,125 mT for 5 min) (0.177 g) followed by T4(MF,100mT for5 min), T5(MF 125 mT-3 min), T7(EC,75 mA for 30 sec), T9(EC,75mA for 90 sec), T14(EC,125mA for 60 sec) (0.1625g) and minimum fresh weight (g) was under seed treatment T0 (0.127 g). Similar results were reported by Katsenios et al. [26].

Seedling dry weight: From the data represented in Table-5 that maximum dry weight (g) was under T6(MF, 125mT for 5 min) (0.035 g) followed by T1(MF,75mT for 3min), T2(MF,75 mT for 5 min), T4(MF,100 mT for 5 min), T5(MF, 125mT for 3min), T10(EC,100mA for 30 sec), T13(EC,125mA for 30 sec) & T14(EC,125mA for 60 sec) (0.0325g) and minimum dry weight (g) was under T0 (0.0225 g). Similar results were reported by Katsenios et al. [26].

Vigor index-I: From the data represented in the Table-5 it was found that maximum vigor index - I was under T4(MF,100mT for 5 min) (2212) followed by T7 (1952) and minimum vigor index - I was under T8(EC 75 mA-60sec) (1692). Similar results were reported by Sharma et al., 2014.

Vigor index-II: From the data represented in the Table-3 it was found that maximum vigor index - II was under T6(MF,125mT for 5 min) (3.48) followed by T8(EC,75mA for 60sec) (3.25) and minimum vigor index- II was under T7(EC,75mA for 30 sec) (2.21). Similar results were reported by Srikanth et al., 2018, Payez et al., 2013, Bilalis et al. [27], Pourakbar and Hatami [28]. Seed metabolic efficiency: From the data represented in the Table-3 the maximum Seed metabolic efficiency was observed in seed treatment T1(MF,75mT for 3min) (1.17%) followed by T9(EC,75mA for 90 sec) (1.089%) and minimum Seed metabolic efficiency was observed in seed treatment T4 (MF, 100mT for 5 min) (0.74%).

Chlorophyll-a: From the data represented in the Table-3 there was enhancement in chlorophyll- a when seeds were exposed to magnetic and electric treatments. Maximum chlorophyll-a(mg/g) was under T6(MF,125mA for 5 min) (0.0793) followed by T13(EC,125mA for 30 sec) (0.079) and the minimum was found in T7(EC,75 mA for 30 sec) (0.072).

Chlorophyll-b: From the data represented in the Table-3 there was enhancement in chlorophyll- b when seeds were exposed to magnetic and electric treatments. Maximum chlorophyll-b(mg/g) was under T6(MF,125mA for 5min) (0.139) followed by T8(EC,75mT for 60sec) (0.132) and the minimum was found in T13(EC,125mA for 30 sec) (0.037). There was enhancement in chlorophyll content, mainly due to the enhanced leaf area from magnetically treated seeds may result in a greater interception of light and might be responsible for higher chlorophyll contents and photosynthetic rate [3].

5. CONCLUSION

It is concluded that the buckwheat seedlings treated with various magnetic and electric treatments showed significant variation, among various treatments T_6 (Magnetic field @ 125mT for 5 minutes) showed better in terms of field emergence (96.04%), days to first flowering(46days), and minimum seed yield per plant (8.80g) was found in control. Maximum biological yield was found in T7(EC,75mA for 30 sec) (348.3 g) and Maximum harvest index was found in T14 (EC 125mA for 60 sec) (42.46 %). Results showed that the seeds treated with magnetic field demonstrated remarkable effects on growth and yield parameters of buckwheat.

Germination per-cent (99%), seedling fresh weight (0.177g), seedling dry weight (0.035) and Chlorophyll (a & b) content was higher in T_6 (Magnetic field @ 125mT for 5 minutes) which performed better than other treatments. T6(MF, 125mT for 5 min) (0.035 g) shows maximum seedling fresh and dry weight in buckwheat. T4(MF,100mT for 5 min) showed maximum vigour index-1 when compared with other treatments. Effect of treatments on seedling parameters were found to be non-significant. T_6 (Magnetic field @ 125mT for 5 minutes) showed better in terms of chlorophyll a (0.0793mg/g) and chlorophyll b(0.1386mg/g).

Both the electric current and magnetic field treatment of seeds were likely played important roles in production of food that was free from toxic and chemical residues and were beneficial for human consumption.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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