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Improvement in Seed Germination and Seedling Growth of Chickpea *(Cicer arietinum* L.*)* under the Influence of Magnetized Water

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Abstract

Three sets of *Cicer arietinum L.* seeds were imbibed in magnetically treated water. Out of them two sets were exposed to magnetic fields – one set exposed to weak magnetic field and the other to strong magnetic field. Percentage of germination, speed of germination, emergence index, mean emergence time, vigour indices, shoot length, root length, fresh weight as well as dry weight of shoots and roots were studied. These three sets were compared with another set of seeds which were imbibed in non-magnetized water and not exposed to magnetic field. This set served as control. The best result in almost all parameters was observed in the set of seeds which were imbibed in magnetically treated water and kept under the constant influence of it but not exposed to magnetic fields. Seeds exposed to strong magnetic field drastically reduced the performance of the seeds in almost all parameters. From the present investigation it is evident that the most suitable measure for cultivation of chickpea under rain fed (unirrigated) conditions is the treatment of seeds with magnetized water before sowing because long roots have been found to be produced due to such treatment which would be suitable to absorb water from the deeper regions of soil, but for its cultivation in irrigated condition seeds should be treated with weak magnetic field for producing profuse lateral roots which would be more adaptive to such situations.

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Abbreviations

MTW	Magnetically treated water
WMF	Weak magnetic field
SMF	Strong magnetic field
EI	Emergence index
MET	Mean emergence time
Gr.	Group
mT	Millitesla
T	Tesla

Introduction

Nowadays treatment of seeds by some physical methods have received great importance. These methods are not only friendlier to the environment but also accelerate sprouting, results in better percentage of germination as well as better root and shoot growth. Magnetic seed treatment is one such physical method that has been reported to enhance the performance of various plants. But the process of treatment of seeds by different authors in this regard varies considerably. Galland and Pazur[1] exposed the seeds to both static and pulsed magnetic fields. Florez *et al*.[2] imbibed seeds in water and then exposed to magnetic fields. Saeed and Mutwali[3] exposed seeds not to magnetic fields but to magnetically treated water. Morejon *et al*.[4] studied the effect of statically and dynamically treated magnetic water. Magnetic water has been applied on various plants such as common bean seeds, cowpea seeds,[3] *Pinus tropicalis* seeds,[4] maize seeds,[5] etc. Maheswari and Grewal[6] found that the effects of magnetic treatment varied with plant type and type of water used.

We selected chickpea (*Cicer arietinum* L.) seeds as our study material and objective of the present investigation was to evaluate the effect of magnetically treated water (MTW), effect of MTW along with weak magnetic field (WMF) and MTW with strong magnetic field (SMF) on chickpea seeds after imbibing them in MTW.

Materials and Methods

Seeds of chickpea (*Cicer arietinum* L.) of uniform size and shape without visible defects and malformation were selected. Block magnets (54×13×9 mm) [intensity 1000G at the surface=0.1T=100mT] were used to create a static magnetic field.

Petri-dishes (90 mm diameter) filled with tap water was placed between a pair of magnets for 40 hours to be magnetized. Seeds were divided into four groups and each group contained 15 seeds. Seeds of the first group (Gr.-I) were imbibed with tap water (non-magnetized water) in petri-dishes (90 mm diameter) containing Whatman no.-1 filter paper soaked with tap water which were taken as control. Seeds in the second group (Gr.-II), third group (Gr.-III) and fourth group (Gr.-IV) were imbibed in the same manner as in the Gr.-I but on filter paper soaked with magnetized water (MTW). Besides, the petri-dishes of Gr.-III and Gr.-IV were placed between one pair and two pairs of bar magnets (of static magnetic field) to provide weak and comparatively strong magnetic fields respectively. All the four sets were kept in the laboratory at 23 ± 2ºC temperature in natural light. The number of seeds germinated was counted on a daily basis in all of the four groups. Germination of seeds was completed within 6 days of imbibition but experiment was continued for another 19 days. Total number of seeds germinated finally were then expressed in percentage basis for each group. Seeds germinated in each day were also counted for each group to note speed of germination of seeds. Emergence Index (EI) was calculated as described by Association of official Seed Analysis[7].

Mean emergence time (MET) was calculated according to the equation of Ellis and Roberts[8].

$$EI = \frac{Number\ of\ emerged\ seeds}{Days\ after\ first\ count} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + \frac{Number\ of\ emerged\ seeds}{Days\ of\ final\ count} \quad \ldots(1)$$

$$MET = \frac{\sum D\, n}{\sum n} \quad ...(2)$$

Where, D = number of days counted from the beginning of emergence, n = number of seeds emerged on day D.

To measure the speed of growth of shoot in length of seedlings of all the four groups, they were measured up to 25th day from the setting of experiment at an interval of 5 days. On the 25th day after the set-up of the experiment the final length of shoot and radicle were measured.

Fresh weight of radicle and shoot of the seedlings of each group was taken separately on the 25th day. Radicles and shoots of the seedlings of each group were dried separately overnight in an oven at 90ºC and the dry weight of the seedlings was measured. Seedling vigour was calculated following Abdul Baki and Anderson[9].

Vigour index I = germination % × seedling length (root + shoot). Vigour index II = germination % × seedling dry weight (root + shoot). Characters of the seedlings of each of the four groups were also noted. The experiment was conducted in the year 2024 in the Department of Microbiology, The University of Burdwan, Golapbag, Burdwan, West Bengal, India

Results

The germination of the seeds started on the third day (after about 72 hours) of setting up of the experiment (Table 1) in all of the four groups of seeds although the number of seeds germinated differed in different groups. When protrusion of radicle became evident then the seeds were regarded as germinated. Total numbers of seeds germinated finally were expressed in percentage basis for each group in Table 1. The speed of germination (Fig. 1) was the fastest under the influence of MTW (Gr. II) in comparison to the control samples. Although the percentage of germination was higher in control set initially i.e. on the third day but on the 4th day onwards a change occurred (Fig. 1) in the germination rate of the control samples which became lower than that of the seeds exposed to WMF (Gr. III). The speed of germination of the seeds (Fig. 1) in Gr.-IV was the slowest in which the seeds were watered with MTW and exposed to SMF. The highest percentage of seeds germinated on the 6th day when it was 100% in the Gr.-II which was much higher than control (86.6%). In Gr.-III it was 93.3% while in Gr.-IV it was 73.3%. The seeds of Gr.-III and Gr.-IV were kept in MTW and exposed to WMF and SMF respectively.

Table 1: Percentage of germination of the Chickpea seeds

Seeds set up (Treated Seeds)	No. and percentage of seeds emerged in Days							
	3rd day		4th day		5th day		6th day	
	Seed count	%	Seed count	%	Seed count	%	Seed count	%
Gr.-I	7	46.6	8	53.3	11	73.3	13	86.6
Gr.-II	9	60	11	73.3	13	86.6	15	100
Gr.-III	6	40	9	60	12	80	14	93.3
Gr.-IV	3	20	6	40	9	60	11	73.3

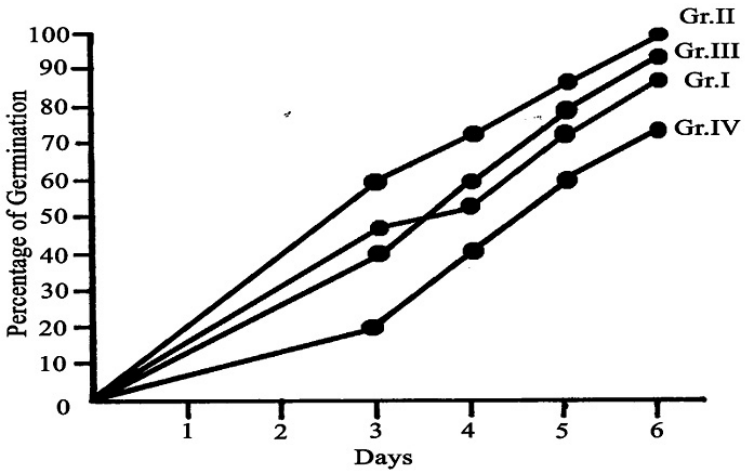


Fig. 1: Speed of germination of seeds in different experiment set ups.

Emergence index (EI) was found (Table 2) to be the best in the seeds influenced by MTW (10.8) followed by Gr.-III (8.9) and control (8.7) and the least in the seeds exposed to SMF (6.1). MET (Table 3) was calculated to be the greatest in Gr.-IV (4.36) which is higher than in control (4.0). In Gr.-III it was almost similar to control (4.07) and the value is least in Gr.-II (3.8).

Table 2: The Emergence-Index (EI) of the Chickpea seeds

Seeds set up (Treated Seeds)	Seedling emergence Percentage (%)	Emergence Index (EI)
Gr.-I	86.6	8.7
Gr.-II	100	10.8
Gr.-III	93.3	8.9
Gr.-IV	73.3	6.1

Table 3: Mean Emergence Time (MET) for germination of Chickpea seeds

Day	Number of first-time germinated seed			
	Gr.-I	Gr.-II	Gr.-III	Gr.-IV
1	0	0	0	0
2	0	0	0	0
3	7	9	6	3
4	1	2	3	3
5	3	2	3	3
6	2	2	2	2
MET (days)	4.0	3.8	4.07	4.36

Speed of growth of shoot was the maximum in control up to the 17th day and then a change occurred and it became lower in relation to Gr.-II and Gr.-III. Speed of growth of shoots of the seedlings of Gr.-II steadily increased from 17th day and these shoots ultimately attained the maximum length (Fig. 2). So, shoot length (Fig. 2) of the seeds of Gr.-IV was the minimum (22.4 cm) and maximum of those of the Gr.-II (28.4 cm). Shoot length of the seeds subjected to MTW with exposure to WMF (28.1 cm) exceeded the performance of those of the control (27.4 cm) in this regard. Radicle length (Fig. 2) was measured on the 25th day and was found to be the maximum in Gr.-II (22.8 cm) which was very much longer in comparison to Gr.-III (18.4 cm), Gr.-I (9.9 cm) and Gr.-IV (2.2 cm). The growth of radicles of the seeds watered with MTW and exposed to SMF became very much retarded with few lateral roots.

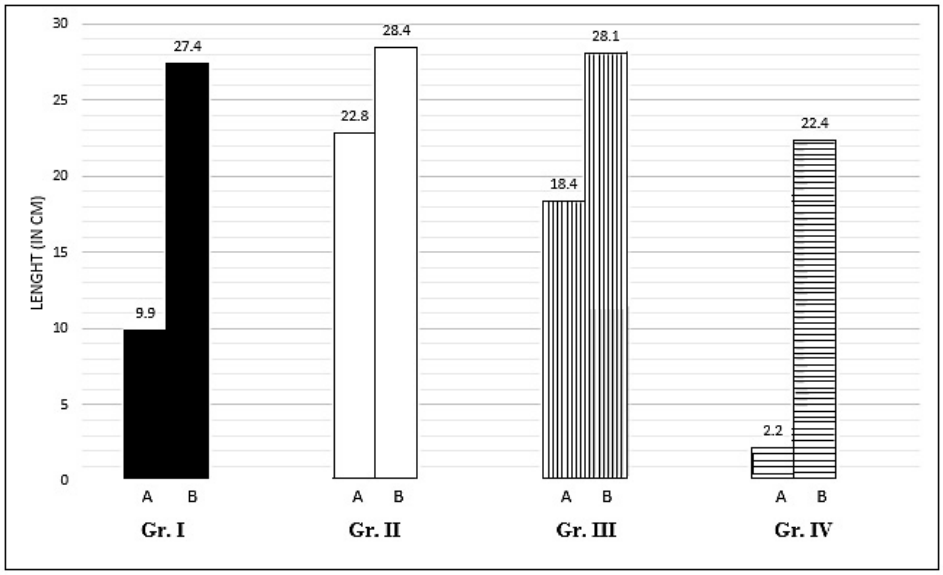


Fig. 2: Length (in cm) of root (A) and shoot (B) of seedlings on 25th day after set up of experiments.

Fresh weight of root and shoot of all the four groups were measured separately. Fresh weight of shoot (Fig. 3) of Gr.-II (5.5 gm) was the greatest. Seeds kept in MTW and exposed to WMF showed higher fresh weight (5.4 gm) than those of control (4.7 gm). The fresh weight of shoot of Gr.-IV was the lowest (3.0 gm). Dry weight of shoot (Fig. 3) of Gr.-II (0.37 gm) was even as Gr.-III but exceeded that of control (0.32 gm). In Gr.-IV it was 0.24 gm. Fresh weight of root (Fig. 4) was the highest in Gr.-II (1.6 gm) followed by Gr.-III (1.5 gm), Gr.-I (1.4 gm) and Gr.-IV (0.9 gm) respectively. Dry weight of the root of the four groups studied followed the same trend as their fresh weight (Fig. 4). It was 0.09gm in control, 0.07 gm in Gr.- IV which were much lower than those of Gr.-II (0.13 gm) and Gr.-III (0.10 gm).

Vigour index I (Table 4) was found to be 5120.0 in Gr.-II, 4338.0 in Gr.-III, 3230.0 in Gr.-I and 1803.1 in Gr.-IV. Vigour index II (Table 4) repeated the same affinity.

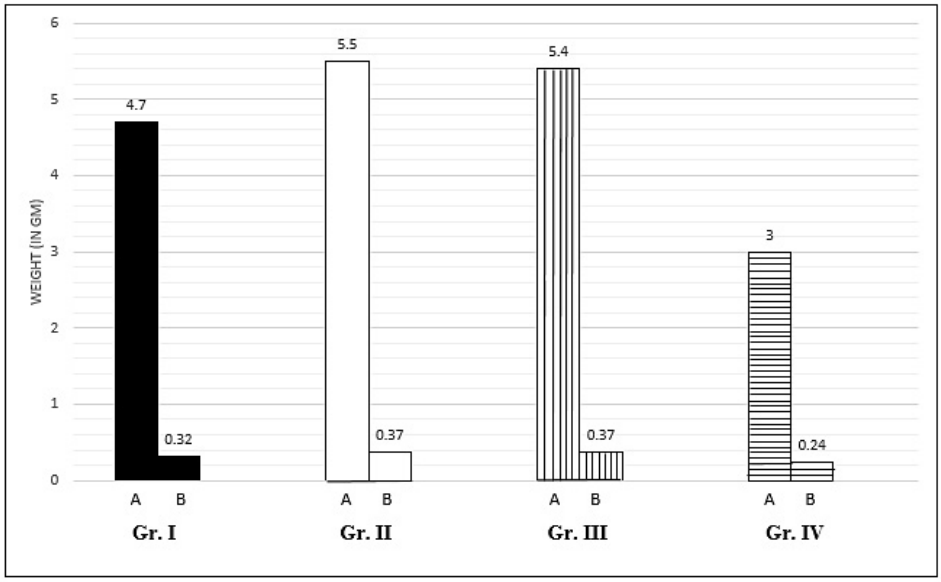


Fig. 3: Fresh weight (A) and dry weight (B) of shoot of seedlings.

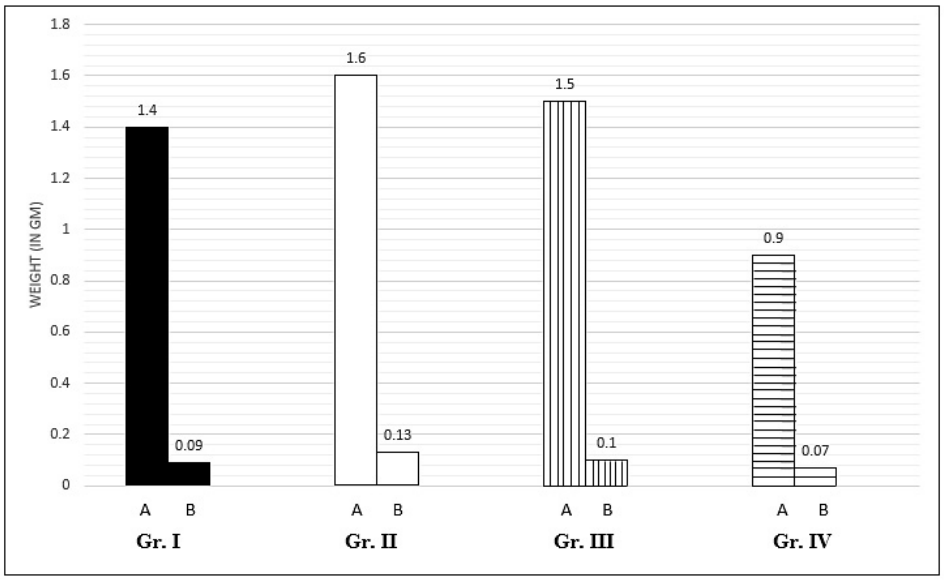
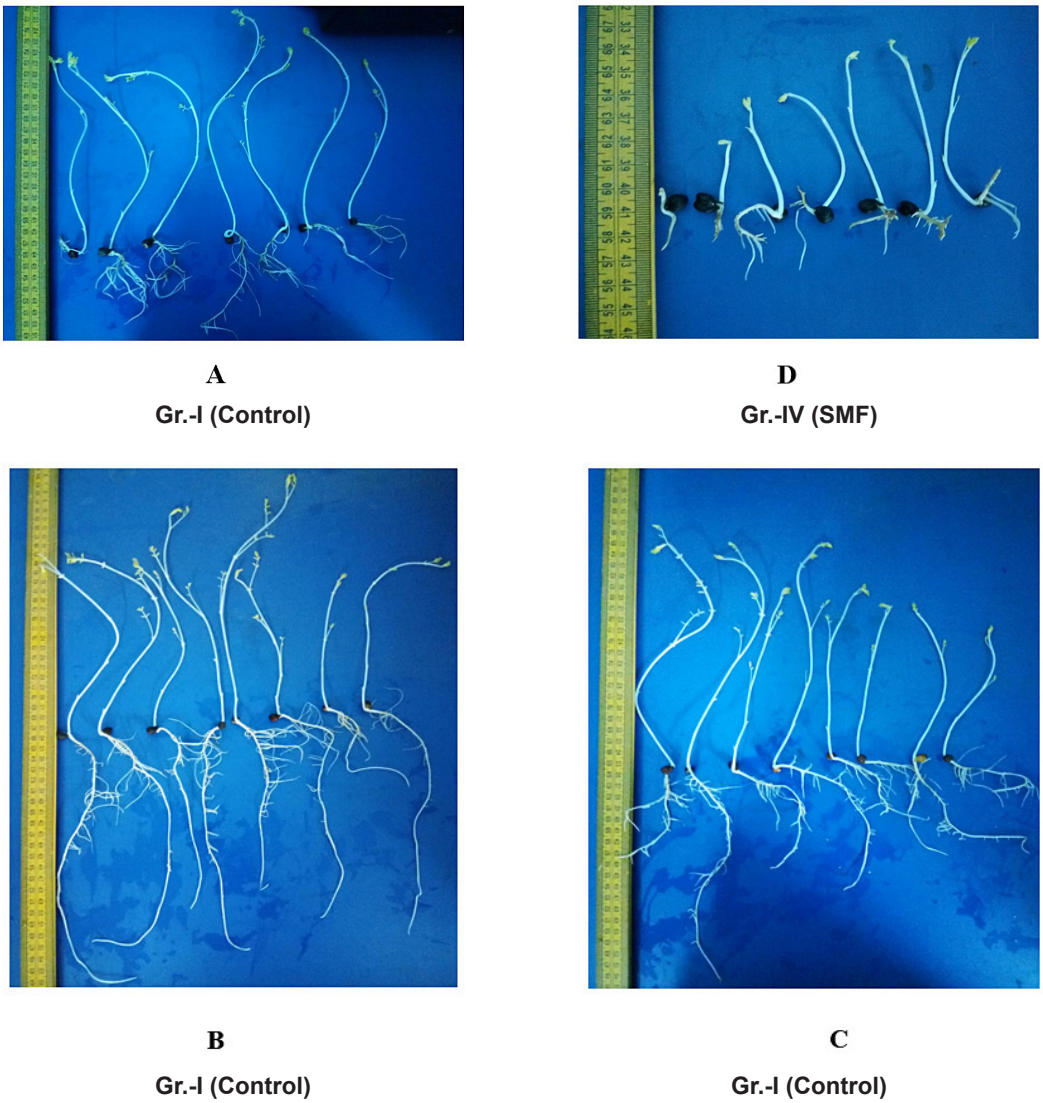


Fig. 4: Fresh weight (A) and dry weight (B) of root of seedlings.

Table 4: The Vigour Indices of the Chickpea seeds

Seeds set up (Treated Seeds)	Germination Percent-age(%)	Seedling Length (cm) (Root + Shoot)	Vigour Index I	Seedling Dry Weight (gm)(Root + Shoot)	Vigour Index II
Gr.-I	86.6	(9.9+27.4) gm = 37.3 gm	3230.02	(0.09+0.32)gm = 0.41gm	35.5
Gr.-II	100	(22.8+28.4) gm = 51.2 gm	5120.0	(0.13+0.37)gm = 0.50gm	50.0
Gr.-III	93.3	(18.4+28.1) gm = 46.5 gm	4338.4	(0.10+0.37)gm =0.47gm	43.8
Gr.-IV	73.3	(2.2+22.4) gm = 24.6 gm	1803.1	(0.07+0.24)gm = 0.31gm	22.7



A
Gr.-I (Control)

D
Gr.-IV (SMF)

B
Gr.-I (Control)

C
Gr.-I (Control)

Fig. 5: Characters produced by the seedlings of (A) Gr.-I (Control); (B) Gr.-II (MTW); (C) Gr.-III (WMF); and (D) Gr.-IV (SMF).

Discussion

From the present investigation (Fig. 4) it is evident that out of the 12 parameters tested (speed of germination of seeds, percentage of germination, EI, MET, length of radicle and shoot, fresh weight and dry weight of radicle and shoot, and vigour indices), in eleven of those the performance was the best in chickpea seeds (Gr.-II) which were imbibed in MTW and also kept under the constant influence of it but not exposed to any magnetic field. In our study the seeds which were imbibed in MTW, watered with MTW and constantly exposed to WMF (Gr.-III) resulted better performance in comparison to control (Gr.-I) while the seeds with similar treatment but exposed to SMF (Gr.-IV), resulted in very poor performance in every parameter except the highest MET value of the seeds in this group. A similar type of result was obtained by Racuciu *et a*l.[10] who also observed inhibitory effect for all measured parameters when the seeds of *Zea mays* were treated with magnets. MET is the parameter that represents the time required for seed emergence. Higher MET value indicates more time required for seed emergence.[5] Beneficial effect of low frequency of magnetic field has been reported by various authors.[11-14] Our result with chickpea shows better performance of the seeds influenced by WMF (Gr.-III) than of control in almost all the recorded parameters. The best result was obtained in all the parameters tested when chickpea seeds were watered with magnetized water (MTW) but not exposed to magnetic fields. Increased performance of seeds due to treatment with magnetized water has been recorded by various workers.[14-16] MTW is more easily absorbed by the seed tissues and in this way it stimulates internal metabolic processes which are conducive to germination.[4] The basic mechanism consisted in the change of physical and chemical properties of water under the influence of magnetic field, allowing MTW to be better incorporated to the inner part of the seeds, thus increasing the ability of germination.[4] Greater incorporation of water may be responsible for the increase in physiological activity which may have resulted in overall increase in seedling length, seedling dry weight and vigour indices in our study. Several authors have reported the stimulatory effect of MTW on growth of seedlings of various plants.[17,18]

No complete and uniform theory exists which can explain how magnetic fields change property of water. There are some hypothetical explanations in this regard. According to Matwijczuk *et.a*l.[19] polarization of external electron shell of water molecules and ions occur under influence of the magnetic fields that change conditions of hydrations of ions. Magnetized water acts on calcium ions and thus increases cell membrane permeability in the seed. Magnetically treated water has been found to change some physical as well as chemical properties of water, such as polarity, hydrogen bonding, surface tension, pH[20] and solubility of salt.[21] These changes of properties of water affect the growth of plants. Irrigation of pea plants with MTW exhibited increased potassium content.[22] Moussa[15] showed that potassium has direct effect upon translocation efficiency as potassium ion is one of the three largest constituents of sap in sieve tube and it plays a role in the synthesis of plant hormones.[23] Sunflower plants treated with magnetized water exhibits increase in GA.[24] According to Hozayn and Qados[25] seeds of wheat when treated with magnetized water cytokinin content is increased which causes mitosis resulting growth of the plants. Influence of magnetic water on roots is pronounced enhancing production of much more lateral roots from radicle in comparison to control. From the present investigation it is evident that roots are more sensitive to the effect of magnetic field than shoot. Strong magnetic field drastically reduced root growth. Growth of radicle as well as lateral root development was very poor in case of the seeds exposed to SMF. But the seeds exposed to MTW produced considerably long radicle. Serraj *et a*l.[26] stated that plants of *Cicer arietinum* having deep and prolific roots are suitable to tolerate drought situations. Therefore, the seeds exposed to MTW producing long radicle in our experiment may perform better under rain fed (unirrigated) conditions because they are much suitable to absorb water from the deeper regions of soil while seeds treated with WMF producing profuse lateral roots would be more adaptive to irrigated areas.

Conclusion

Seeds of *Cicer arietinum* L. imbibed in magnetically treated water (MTW) and also kept under the constant influence of it but not exposed to magnetic

field resulted the best performance in almost all the parameters tested. From the result obtained in the present investigation it can be concluded that for cultivation of chickpea under rain fed (unirrigated) conditions seeds should be treated with magnetized water (but not exposed to magnetic field) before sowing to produce long roots which would be suitable to absorb water from the deeper regions of soil, but for its cultivation in irrigated condition seeds should be treated with WMF for producing profuse lateral roots which would be more adaptive to such situations.

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Conflict of Interest
The authors do not have amy conflict of interest.

Data Availability Statement
All datasets generated or analyzed during this study are included in the manuscript.

Ethics Statement
This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement
This study did not involve human participants, and therefore, informed consent was not required.

Permission to Reproduce Material from other Sources
Not Applicable

Author Contributions
- **Mayukh Bandyopadhyay:** Data Collection, Methodology, Analysis
- **Sushanta Mohan Roy:** Data Collection, Analysis
- **Sayantan Jash:** Data Collection, Analysis, Writing
- **Asit Baran De:** Writing-Review & Editing.

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