Egypt. J. Chem. **Vol. 65,** No. SI13B pp. 1317 - 1331 (2022)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Alleviation salinity stress in germination, seedling vigor, growth, physiochemical, yield and nutritional value of Chickpea (*Cicer arietinum* L) using magnetic technology in sandy soil

[1]Hozayn M.; [2]Abd El-Monem A.A. and [3]El-Mahdy A.A.

*[*1]Field Crops Research Department, Agricultural and Biological Research Institute, National Research Centre, 33 El Behouth St., (Former El-Tahrir St.) 12622, Dokki, Giza, Egypt.*
[2]Botany Department, Agricultural and Biological Research Institute, National Research Centre, 33 El Behouth St., (Former El-Tahrir St.) 12622, Dokki, Giza, Egypt.
[3]Seed Technology Research Department, Field Crops Research Institute, Agricultural Research Centre,109 El-Gama St., Giza, Egypt

Abstract
Most of the field crops (including chickpeas) in the Nubaria region depend on groundwater wells, which may contain different degrees of salinity (2000-2200 ppm), especially in the event of a delay or shortage of water in the Nubariya Canal (the main source of irrigation in that area). To alleviate salinity stress on germination, seedling attributes, growth, pigments, physiochemical, yield and nutritional value of Chickpea; Laboratory and Field Experiments using Chickpea (*Cicer arietinum* L; imported from India by Nahar El-khair Company for Import and Export, 149 Hosh Issa, El-Beheira Governorate) were conducted, respectively, at Laboratory of Field Crops Research Department, National Research Centre, Cairo, Egypt and Experimental Research and Production Station of National Research Centre at El-Emam Malak Village, El-Nuberia District, El-Beheira Governorate, Egypt during winter seasons of 2019/20 and 2020/21. The current study is aiming to evaluate the effect of magneto-priming seeds on Chickpea plants: growth, yield, pigments and physiochemical contents under saline conditions. Results of Laboratory experiment indicated that significant increases were recorded regarding application of different magneto-priming seed treatments (T_1-T_5; 0.05, 0.11, 0.19, 0.27, 0.31 Tesla) compared to untreated (sowing dry seeds) in Seed Germination (G; %), Germination Index (GI), Speed Germination Index (SGI), Germination Energy (GE; %) and Germination Rate (GR; day), seedling length (cm), seedling weight (g), seedling vigor-I and seedling vigor-II of Chickpea. As an average of all magneto-priming treatments (T_1-T_5), the improvement reached 7.31, 7.31, 20.79, 6.91, 5.34, 22.13, 29.41, 34.45, 31.13 and 44.13% in the above-mentioned characters, respectively compared to untreated seed. Similar positive effects were observed in Mean Germination Time (MGT; day) where the seeds were faster germinated by 17.89% compared to untreated treatment. The best magnetized-seeds treatment was applied under field conditions, where irrigation with water passed through magnetic device (2 inch, produced by NRC; 0.20 Tesla) induced positive significant effect in Chickpea growth, pigments and physiochemical at 75 DAS, yield components, yield (ton fed^{-1}) and nutritional value of yielded seeds at harvest under drip irrigation system. The percentage of improvement reached 13.61-26.10% in morphological parameters, 9.64-12.35% in photosynthetic pigment contents, 8.35-23.03% in physiochemical parameters, 8.07-25.54% in yield and its components and 4.00-10.74% in nutritional values of yielded seeds. Under conditions of experiments, could be concluded that application of magnetized water and seed technology alleviate salinity water stress which resulted in improvement of growth and productivity of Chickpea under Nubaria region
Keywords: Chickpea, Magneto-priming seeds, magnetized water, salinity stress, germination, seedling attributes, growth, physiochemical, yield and nutritional value.

1. Introduction

Scarcity of freshwater is a critical problem to sustainable agricultural development worldwide especially in arid and semi-arid areas [1]. The utilization of saline water become an essential way to ameliorate the deficit of freshwater resources [2]. Although, using saline water in irrigation can cause reduction in soil quality, such as accumulation of salt, inhibition in water conductivity, inadequate oxygen content, reduction in organic matter, etc. [3, 4].

In arid and semi-arid regions as Egypt, deficit of water resources is a restricted factor in the irrigation field, which can be rectify via establishing strategies to operatively save water [5, 6]. Also, salinity is one of the most essential criteria for limiting the quality of irrigation water. Salinity is

*Corresponding author e-mail: dr.mahmoud.hozayn@gmail.com
Receive Date: 03 September 2022, Revise Date: 06 December 2022, Accept Date: 22 December 2022
DOI: 10.21608/EJCHEM.2022.160474.6910

known as the concentration of total ions and soluble molecules in any type of water (e.g. drainage water, irrigation water and urban runoff) [7]. Salinity induced variations in all physiological stages of plant growth, germination, seedling, number and size of stomata, physiological processes such as evapotranspiration, photosynthesis, respiration, stomatal conductance, water use efficiency, and ultimately plant growth and yield production. Salinity also changes the endogenous plant structure, especially cell chloroplasts [8]. It alters the absorption of several mineral ions and affects the transfer of them (especially calcium ions) into the plant's growth regions, [3, 9, 10]. Therefore, it must be essential to investigate the new technologies to management the irrigation water, increase its quality and alleviate the salinity stress of brackish water.

In general, magnetized water is one of the promising methods that have been used in saline water management for irrigation. Magnetized water alters the physical and chemical constituents of water. It develops a uniform structure with some alterations in essential characteristics, such as electrostatic polar force or surface adhesion, hardness, specific gravity, viscosity, salinity, water solubility feature and water–surface contact angle [11]. Magnetic treatment of water does not add or remove any substance in the water itself, it is considered a harmless and environmentally friendly technology [12].

In this connection, Abdel Kareem [13] found that significant increases in water productivity for the magnetically treated water when compared with non-magnetically treated water, amounting to 1.65, 1.88, and 1.78 kg m^3 for eggplant, faba beans, and tomato, respectively. It was also observed that the Magnetized water affected the amounts of irrigation water required to be added to different crops during their growing period. The water savings were 11%, 13.5%, and 14.2% for eggplant, faba beans, and tomato, respectively. As a result, net return increased by 1.97, 3.0, and 2.45 kg m^3 for the three crops, respectively.

Moreover, magnetized water is a promising technology had been used to relieve saltiness. It reduces the saltiness degree in irrigation water, lowers soil alkalinity, and it's the high leaching of excess soluble salts [14, 15]. The beneficial effects of applying the magnetic treatment in irrigation water enhanced germination, crop growth and yield [16-18] without any destructive or harmful impact. Magnetic water treatment, as a potential and eco-friendly new technology [19]. Magnetization of water promotes the useful changes to its micro and macro physical and chemical properties. The activity of magnetized water (i.e., the ability of water to interact with other substances, such as solubility, reaction rate, etc.) is obviously enhanced [20], which is very significant in improving water availability and crop stress resistance [21].

Chickpea (*Cicer arietinum*. L) is an earliest cultivated cereal crop. It ranks as the third most important food legume after dry beans and peas [22]. It is salt sensitive crop and its production is severely affected due to salinity [23]. Chickpea is a popular legume grown in arid and semiarid regions all over the world. It is critical for protecting of soil fertility, especially in arid regions. Chickpea seed is a rich protein supplement to cereal based diet, and includes 40- 55% carbohydrate, 13 - 33% protein, and 4-10% oil [24].

Therefore, this study aims to study and evaluate the effects of magneto-priming seeds (0.0, 0.05, 0.11, 0.19, 0.27 and 0.31 mT) under laboratory conditions; and under field conditions, to comparison between magnetized and un-magnetized moderate saline irrigation water treatments on growth, photosynthetic pigment, physiochemical, yield and nutritional value of Chickpea.

2. Materials and methods

Laboratory and Field Experiments using Chickpea (*Cicer arietinum* L; imported from India by Nahar El-khair Company for Import and Export, 149 Hosh Issa, El-Beheira Governorate) were conducted, respectively, at Laboratory of Field Crops Research Department, National Research Centre, Cairo, Egypt and Experimental Research and Production Station of National Research Centre at El-Emam Malak Village, El-Noberia District, El-Beheira Governorate, Egypt during winter seasons of 2019/20 and 2020/21. That to alleviation salinity stress on germination, growth, pigments, physicochemical, yield and nutritional value of *Cicer arietinum* L using magnetized seeds and water treatments. **The laboratory and field experiments were done as following procedure:**

2.1. Laboratory experiments

Laboratory experiment using Chickpea (*Cicer arietinum* L; was conducted at Laboratory of Field Crops Research Department, National Research Centre. The experiments aim to study and evaluate the effects of different magneto-priming treatments on Chickpea germination traits (Table 1). The treatments laid out in Completely Randomized Design (CRD) with four replications.

Table 1. Description of magnetic seed treatments under laboratory conditions.

C_1	**Control-1:** Germinated dry seeds
T_1	Seeds soaking in magnetized water for two hours; Water after path through magnetic unit 0.5 inch; 0.04 - 0.06 T), then dry between with tissue, then the seeds will be ready to sowing.
T_2	Seeds soaking in magnetized water for two hours; Water after path through magnetic unit 0.5 inch; 0.10 - 0.12 T), then dry between with tissue, then the seeds will be ready to sowing.
T_3	Seeds soaking in magnetized water for two hours; Water after path through magnetic unit 0.5 inch; 0.18 - 0.20 T), then dry between with tissue, then the seeds will be ready to sowing.
T_4	Seeds soaking in magnetized water for two hours; Water after path through magnetic unit 0.5 inch; 0.26 - 0.28 T), then dry between with tissue, then the seeds will be ready to sowing.
T_5	Seeds soaking in magnetized water for two hours; Water after path through magnetic unit 0.5 inch; 0.30 - 0.32 T), then dry between with tissue, then the seeds will be ready to sowing.

Germination procedure: Germination test was performed according to ISTA [25], whereas 20 seeds of Chickpea were sown in each replication in sterilized Petri dishes covered at the bottom with two sheets of Whitman filter paper, then placed in an incubator at 20±2°C. Total numbers of seeds germinated were counted daily and percentage was calculated at 12^{th} day. Measurements were made on shoot, root and length (cm) of seedling, fresh and dry weight (g) of seedling. Also, Germination (G; %), Germination Index (GI), Speed Germination Index (SGI), Germination Energy (GE), Germination Rate (GR; day) and Mean Germination Time (MGT; day), Seedling vigore-1 (SV-1) and Seedling vigore-1 (SV-2) were calculated as following:

Seed germination (G; %) = (No. of normal seedling/ number of seeds) × 100; Germination percentage was performed according to International Seed Testing Association (ISTA) [26] and defined as the total number of normal seedlings after 12 days

Germination Energy (GE) = $((N_1+N_2)/M)$ X100; Where N_1, and N_2 = First and second counts; M = Total number of seeds planted (Germination energy defined according Ruan *et al.* [27].

Germination Index (GI) = $(N_1+N_2+N_3+N_4+\ldots..)$ /Ti; Where N_1, N_2, N_3 and N_4 = First, second, third and four counts, etc, respectively and T_i = Count time **(**It calculated as described in the Association of Official Seed Analysis (AOSA) [28]. Seeds were considered germinated when the radical was at least 2 mm. long.

Germination Rate (GR): It was calculated according to the formula of Bartllett [29]; GR= a + (a +b) + (a + b + c) …….. (a + b + c + m) / n (a + b + c + m), where a, b, c are No. of seedlings in the first, second and third count, m is No. of seedlings in final count, n is the number of counts.

Mean Germination Time (MGT; day): It was calculated based on the equation of Ellis and Roberts [30]. MGT= $(N_1 \text{ x } T_1) + (N_2 \text{ x } T_2) + (N_3 \text{ x } T_3) + (N_1 \text{ x } T_4) + (Ni + Ti)/ N_1 + N_2 + N_3 + N_4 + \ldots N_i$; Where N_1,N_2,N_3 and N_4 = First, second, third and four counts, respectively and T_1, T_2, T_3 and T_4 = Time of first, second, third and four counts, respectively

Seedling root and shoot length (cm): It was measured of ten normal seedlings at 12 days after planting.

Seedling fresh and dry weight (g): Ten normal seedlings 12 days after planting were measured to determine fresh weight then the seedlings were dried in hot-air oven at 85^o C for 12 hours to obtain the seedlings dry weight (g).

Seedling Vigore-I (SV-I): It was calculated based on the equation: **SV-I** = Germination percentage X seedling length (cm)

Seedling Vigor-II (SV-II): It was calculated based on the equation: **SV-II =**Germination percentage X seedling dry weight (g)

Statically analysis: Data were statically analyzed by an analysis of variance (ANOVA) of Completely Randomized Design (CRD) using M-Stat program (MSTAT-C v. 3.1.), [31]. Least significant difference (LSD) was applied to compare mean values.

2.2. Field Experiments

Field Experiments using Chickpea (*Cicer arietinum* L) were conducted at Experimental Research and Production Station of National Research Centre at El-Emam Malak Village, El-Noberia District, El-Beheira Governorate, Egypt during winter seasons of 2019/20 and 2020/21. The experiments aim to comparison between irrigation with magnetized and un-magnetized moderate saline irrigation water under drip irrigation systems in Chickpea growth, photosynthetic pigments, physiochemical, and yield and its components and nutritional value. The site of experimental soil and irrigation water were analyzed according to the method described by Chapman and Pratt [32] (Tables 2).

Table 2. Analysis of soil and well irrigation water in the site of field experiments

	Soil depth (0-30 cm)		Irrigation water	
Parameters	**Before**	**After**	**Before**	**After**
Particle size distribution				
Coarse sand	48.20	54.75	--	..
Fine sand	49.11	41.43	--	..
Clay + Silt	2.69	3.82	--	..
Texture	Sandy	Sandy	--	..
pH (1:2.5)	8.93	8.60	8.28	8.43
EC(ds cm^{-1}; 1:5)	3.80	3.10	3.52	3.47
Ca CO_3 (%)	2.75	2.75	--	…
Organic matter (%)	0.02	0.05	--	…
Soluble cations (mq/100g soil)				
Na^+	23.58	16.49	27.22	25.11
K^+	2.52	2.16	0.48	0.59
Ca^{++}	2.63	3.15	3.25	3.35
Mg^{++}	9.28	9.20	4.25	4.46
Soluble anions (mq/100g soil)				
CO^-_3	0.00	0.00	--	…
HCO^-_3	1.17	2.12	5.00	5.50
Cl^-	17.13	14.63	10.00	10.00
SO^{--}_4	19.71	14.26	20.20	20.20

Cultivation method and layout of Experiment: The soil was ploughed twice, ridged at 0.60 meter apart and divided into plots with area (30 m long x 4 m width). During seedbed soil preparation, 150 kg/fed calcium superphosphate (15.5% P_2O_5) and Nitrogen fertilizer (20 kg N Fed^{-1}; 20.60 N% as ammonium sulfate) were applied. Recommended rates of Chickpea (*Cicer arietinum* L) were coated just before sowing with the bacteria inoculants, using Arabic gum (40%) as adhesive agent and were sown in hills 20 cm apart at the first week of November of 2019/20 and 2020/21 winter seasons. Drip irrigation took place immediately after sowing and as plants needed during the period of experiment. Control treatment was irrigated with well water, while the other treatment (magnetized moderate saline well water) was irrigated with water after magnetization through passing into a two-inch magnetic unit (produced by NRC, 0.20 Tesla). Potassium fertilizer (24 kg Fed^{-1}; 48 % K_2O as potassium sulfate) was added during seed bed soil preparation and after one month from sowing. Others recommended agricultural practices for sowing chickpea was done according leaflet Agriculture Research Centre under this province condition. Chickpea was manually harvested on the second of May in both seasons.

Data recorded: Growth parameters at 75 days after sowing: After 75 days from sowing (DAS), ten plants were randomly taken from each plot to record plant height (cm), fresh and dry weight (g Plant^{-1}). Water content was determined using formula: WC = 100× (fresh mass – dry mass)/fresh mass as described by (Henson *et al.* [33].

Physiochemical analysis at 75 DAS: Photosynthetic pigments included Chlorophyll a (Chl a), chlorophyll b (Chl b) and carotenoids were determined using spectrophotometric by method described by [34]**.** Total phenol content measured as described by [35]**.** Indole acetic acid content were extracted and analyzed by the method of [36]**.** Proline and free amino acids were extracted as describes [37] and assayed according to [38]**.** Free amino were estimated according to [39]**.**

Chickpea yield and its component: At harvest, a random sample of 10 plants was taken from each plot to determine plant height (cm), branches, pods and seeds (no. plant^{-1}), pods and seeds weight (g plant^{-1}) and 100-seeds weight (g). Plants in the three inner lines were harvested and their pods were air dried and threshed to calculate seed yield (Ardab fed^{-1}; Fed=4200 m^2).

Nutritional value of yielded seeds: Macro (i.e., N, K, Ca and Mg; in ppm) and microelement (i.e., Zn and Cu in percentage) contents in dried seeds were determined. Total N was determined by using micro-Kjeldahl method as described in **AOAC [40]**. Potassium contents was done using a flame photometer. Mg, Zn and Cu were determined using the Atomic absorption spectrophotometer (Perkin Elemer 100 B).

Statistical analysis: A student test (Independent *t*-test) was also carried out to find the significant differences between magnetic and nonmagnetic water treatments using SPSS program Version 16.

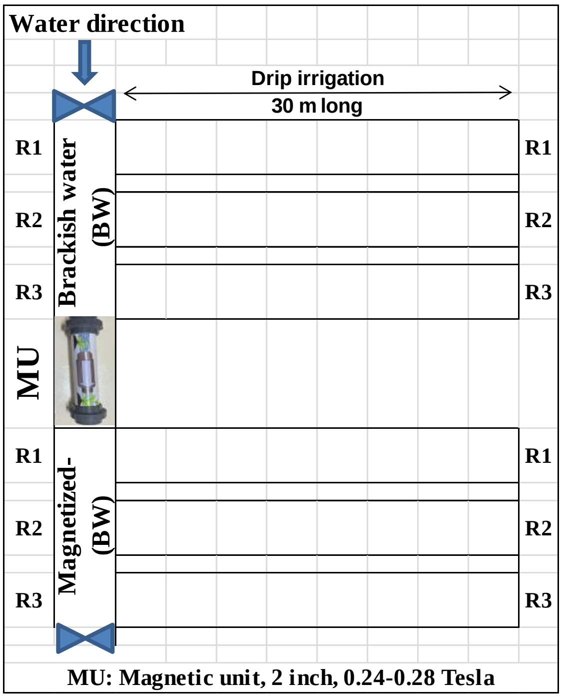

Fig 1. Layout of experiment design under solid set sprinkler system.

3. Results

3.1. Laboratory experiment:

Seed germination and seedling attributes: Table 3 show that significant increases were recorded regarding application of different magneto-priming seed treatments (T_1-T_5) compared to untreated (sowing dry seeds) on Seed Germination (G; %), Germination Index (GI), Speed Germination Index (SGI), Germination Energy (GE; %) and Germination rate (GR; day) of Chick-pea. As an average of all magneto-priming treatments (T_1-T_5), the improvement reached 7.31, 7.31, 20.79, 6.91 and 5.34% in the above-mentioned parameters, respectively compared to untreated seed. Similar positive effect was observed in Mean Germination Time (MGT; day) where the seeds were faster germinated by 17.89% compared to control. Table 4 and Fig 2 show similar positive effects where magneto-priming seed treatments (T_1-T_5) gave more values of seedling length (cm), seedling fresh and dry weight (g), seedling vigor-I and seedling vigor-II compared to untreated seeds. As an average of all magneto-priming treatments (T_1-T_5), the improvement percent reached 22.13, 29.41, 34.45, 31.13 and 44.13% in the above-mentioned characters, respectively compared to untreated seed.

Table 3. Effect of Magneto-priming seed treatments on Seed Germination (G; %), Germination Index (GI), Speed Germination Index (SGI), Germination Energy (GE), Germination rate (GR; day) and Mean Germination Time (MGT; day) of Chick-pea

Character / Treatment	G (%)	GI	SGI	GE (%)	GR (day)	MGT (day)
Control	83.33	3.33	14.19	83.33	0.924	1.38
T_1	91.67	3.67	17.57	90.00	0.976	1.12
T_2	87.50	3.50	16.79	87.50	0.968	1.16
T_3	91.67	3.67	17.72	91.67	0.982	1.09
T_4	86.67	3.47	16.56	86.67	0.977	1.12
T_5	89.63	3.59	17.09	89.63	0.965	1.17
F test	**	**	**	**	**	**
$LSD_{5\%}$	**2.04**	**0.14**	**0.53**	**2.04**	**0.025**	**0.05**
± percentage (average of T_1-T_5) over control	**7.31**	**7.31**	**20.79**	**6.91**	**5.34**	**-17.89**

Table 4. Effect of Magneto-priming seed treatments on seedling length (cm), seedling fresh and dry weight (g), seedling vigor-1 and seedling vigor-2 of Chick-pea at 12 days after planting

Character / Treatment	Seedling length (cm)	Seedling Fresh wt. (g)	Seedling dry wt. (g)	Seedling vigore-1 (SV-I)	Seedling vigore-2 (SV-II)
Control	15.25	0.63	0.072	1270.83	5.96
T_1	19.63	0.75	0.091	1798.96	8.37
T_2	18.13	0.96	0.113	1585.94	9.85
T_3	20.38	0.72	0.090	1867.71	8.25
T_4	19.38	0.77	0.092	1679.17	7.97
T_5	15.63	0.87	0.095	1400.46	8.49
F test	**	**	**	**	**
LSD $_{5\%}$	**1.39**	**0.03**	**0.02**	**52.81**	**1.03**
± percentage (average of T_1-T_5) over control	**22.13**	**29.41**	**34.45**	**31.13**	**44.13**

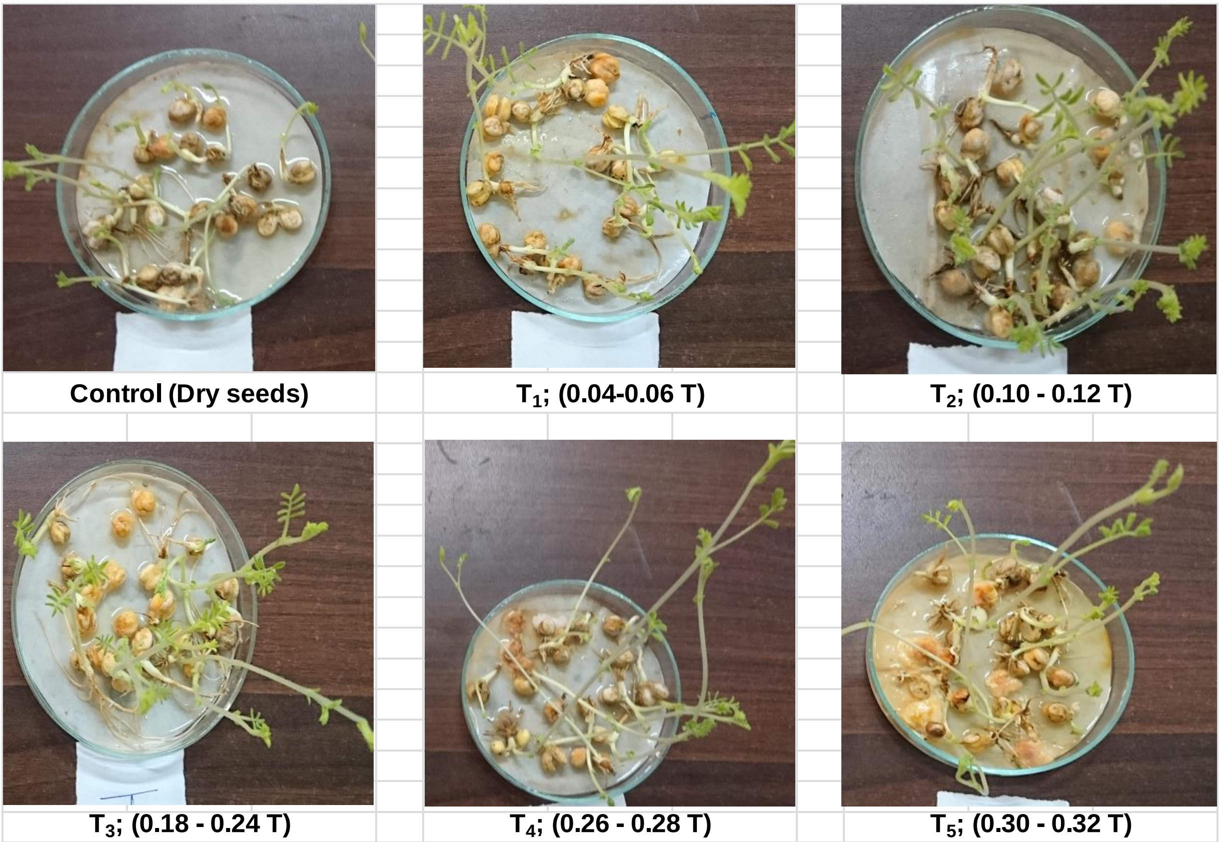

Fig 2. Effect of Magneto-priming seed treatments on Chick-pea seedling growth

3.2. Field experiments

Growth criteria: Data recorded in table 5 and Fig 3 show that irrigation plots with magnetized moderate saline water under drip irrigation system increased significantly Chick-pea growth at 75 days after sowing compared to irrigation with un-magnetized moderate saline water. The percentage of increments reached to 13.61, 26.10, 22.83 and 1.28% in plant height, fresh & dry wt. (g plant^{-1}) and water content (%), respectively.

Table 5. Comparison between magnetized and un-magnetized moderate saline water in chickpea morphological parameters at 75 days after sowing (Average of 2019/20 and 2020/21 winter seasons)

Treatment / Character	Mean ± Se		*p-value*	Increase (%) over control
	Un-magnetized water	Magnetized water		
Plant height (cm)	69.80 ± 0.94	79.30 ± 0.81	0.001	13.61
Fresh weight (g Plant^{-1})	20.31 ± 0.13	25.61 ± 0.68	0.001	26.10
Dry weight (g Plant^{-1})	7.53 ± 0.11	9.25 ± 0.19	0.001	22.83
Water contents (%)	62.92 ± 0.49	63.72 ± 0.96	0.464	1.28

Physiochemical contents at 75 DAS: Data in table 6 shows the stimulatory effects of magnetized irrigation water on photosynthetic pigment contents (chlorophyll a, b, carotenoids, chlorophyll a/b and total pigment contents as compared to un-magnetized moderate saline water. The percent of increments reached to 10.69% at total pigment content and to 12.35% at carotenoid contents. The same trend was observed in chemical constituents (i.e., total soluble sugar, total amino acids, total indole and total phenolic compounds) of chick pea plants at 75 DAS. Proline contents exhibited significant decrease in response to magnetized water treatments as compared with un-magnetized moderate saline water. The percent of increments changed according to the parameter determined. The increase percent reached to 8.35%, 18.57, 23.03 and 9.08 at the total soluble sugar, total amino acids, total indole and total phenolic compounds, respectively. While Proline content decreased by about -24.23% as compared to un-magnetized moderate saline water.

Table 6. Comparison between magnetized and un-magnetized moderate saline water in chickpea photosynthetic pigment and some chemical contents parameters at 75 days after sowing (Average of 2019/20 and 2020/21 winter seasons)

Treatment / Character		Mean ± Se		*p-value*	Increase or decrease (%) over control
		Un-magnetized water	Magnetized water		
Photosynthetic pigments (mg/100 g fresh weight)	**Chlorophyll (a)**	8.88 ± 0.04	9.84 ± 0.03	0.001	10.78
	Chlorophyll (b)	0.92 ± 0.01	1.01 ± .01	0.002	9.64
	Carotenoids	0.083 ± .001	0.094 ± 0.001	0.002	12.35
	Chlorophyll (a+b)	9.81 ± 0.05	10.85 ± 0.02	0.001	10.67
	Total pigments	9.89 ± 0.04	10.95 ± 0.02	0.001	10.69
	Ch a/ch b ratio	9.59 ± 0.06	9.69 ± 1.04	0.461	1.05
Chemical constituents	**Total soluble sugar (mg/g f. wt.)**	234.92 ± 2.23	254.54 ± 4.59	0.018	8.35
	Total amino acids (mg/g f. wt.)	132.18 ± 0.50	156.73 ± 0.67	0.001	18.57
	Indole acetic acids (µf. g/g wt.)	89.80 ± 0.76	110.48 ± 1.11	0.001	23.03
	Phenol (mg/g f. wt.)	674.21 ± 1.02	735.44 ± 0.87	0.001	9.08

Proline (mg/g f. wt.)	55.87 ± 1.14	42.33 ± 0.42	0.001	-24.23

Chickpea yield and its components and nutritional value of yielded seeds: Data tabulated in table 7 show that irrigation plots with magnetized moderate saline water under drip irrigation system increased significantly Chickpea yield and its components at harvest compared to irrigation with un-magnetized moderate saline water. The improvement reached 8.65% in plant height, 20.78, 25.54% and 25.51 in branches, pods and seeds number per plant, respectively, 23.71 and 17.65 % in pods and seed weight (g $plant^{-1}$) and 8.07% in 100-seed weight (g), respectively. These increases reflected in improvement of seed yield (ardab fed^{-1}) by 21.63%. Similar trends were recorded in nutritional value of yielded seeds (i.e., K, Ca and Mg; in percentage) and microelement (i.e., Zn and Cu in ppm) where application of magnetized irrigation water caused an increases by 10.74, 4.23, 4.00, 4.65 and 7.65% in the above-mentioned parameters, respectively compared to irrigation with un-magnetized water. While revers trend were recorded in Na contents, where decreased by 11.64%.

Table 7. Comparison between magnetized and un-magnetized moderate saline water in chickpea yield and its components and nutritional value of yielded seeds at harvest. (Average of 2019/20 and 2020/21 winter seasons)

	Treatment / Character	Mean ± SE		*p-value*	Increase or Decrease (%) over control
		Un-magnetized water	**Magnetized water**		
Chick pea yield and its components	**Plant height (cm)**	78.23 ± 0.51	85.00 ± 1.03	0.001	8.65
	Branches (number $plant^{-1}$)	6.99 ± 0.61	8.45 ± 0.19	0.004	20.78
	Pods (number $plant^{-1}$)	15.40 ± 0.45	19.33 ± 0.47	0.001	25.54
	Seeds (number $plant^{-1}$)	10.88 ± 0.23	13.66 ± 0.39	0.001	25.51
	Pods weight (g $plant^{-1}$)	3.88 ± 0.05	4.80 ± 0.06	0.001	23.71
	Seeds weight (g $plant^{-1}$)	3.40 ± 0.16	4.00 ± 0.26	0.045	17.65
	100-seed weight (g)	27.63 ± 0.21	29.86 ± 0.23	0.001	8.07
	Seed yield (ardab fed^{-1})	5.29 ± 0.10	6.42 ± 0.12	0.002	21.36
Nutritional value of yielded seeds	**K (%)**	2.70 ± .03	2.99 ± 0.03	0.01	10.74
	Ca (%)	0.33 ± 0.02	0.34 ± 0.02	0.56	4.23
	Na(%)	0.071 ± .003	0.064 ± .003	0.11	-11.64
	Mg (%)	0.07 ± .003	0.08 ± .005	0.64	4.00
	Zn (ppm)	43.00 ± 1.15	45.00 ± 0.58	0.19	4.65
	Cu (ppm)	6.00 ± 0.86	6.50 ± 1.15	0.74	7.69

4. Discussion

Seed water absorption during imbibition for germinated seeds was depends on the physical water absorption of the protoplast colloid and also is independent of seed metabolism [41]. The water absorption rate and relative water absorption of cotton seeds to brackish water were lower than fresh water, which may be due to the increase in solute potential by ions in brackish water, and the inhibition of seed water absorption [42]. Magnetic application have significant stimulatory effects on seed germination and seedling growth processes.

The results obtained from laboratory experiment exhibited that all magneto-priming treatments (T_1-T_5) have positive impact on germination and seedling attributes of chick pea plants (Table 3). Their effect depends on many factors and it can also occurs through numerous ways: by enhancing water uptake rate, altering seed surface structure, breakdown of endosperm's food through higher hydrolytic enzyme activity, oxidative stress during priming process which accelerate overall development of seedling. These results are confirmed the findings by **(**Sharma *et al.*, [43] on chickpea seeds. They also added that, according to germination activity, results indicate that, the exposure of seeds to magnetic field 100 mT considerably enhanced final germination count in comparison to untreated seed. These results are lined with the observations of **Florez *et al*.,** [44] in case of maize in which seeds treated with magnetic field emerged quickly than untreated seeds. Higher and quicker germination in magnetically treated seeds was associated with altered hydrolytic enzymes activity inside the seed which leads to uniform germination [43].

The stimulatory effect of magnetic treatments on seed germination and seedling growth may be due to the variation occurs in seed surface properties and more quick water uptake during magnetically treated seeds as compared with untreated control. These results are in good accordance with those obtained by **Sharma *et al*.,** [43] on chick pea seeds. They also added that, magnetic treatments at different doses increased enzyme activities which reflects in rapid germination of treated seeds. Moreover, lower dose of magnetic treatment (100 mT) trigger greater activities, quick reduction in reserve food material and rapid germination of seed while high dose (200 mT) found inadequate to boost physiological and biochemical actions inside the chickpea seed.

In addition, the effect of magnetized water on seedling vigour I and seedling vigour II in our study (Table 4) are accompanied with the effect of different magnetic treatments on water quality. The same results were obtained by Liu *et al*., [45] who suggested that, magnetized brackish water can promote the accumulation of total biomass of cotton seedlings by improving the dry matter ratio of roots to absorb more water and nutrients and it depends on water quality. In this regard, Iderawumi and Friday [46], reported that, application of magnetic treatments (0 -250 mT in steps of 50 mT for 1–4 h) significantly stimulated speed of germination, seedling length and seedling dry weight compared to unexposed control in chickpea (*Cicer arietinum*).

Recently, **Zhang *et al.*** [42], concluded that, magnetized water had the greatest effect on the germination of cotton in the first four days after sowing, and the effect of magnetized brackish water on the germination of cotton seeds was greater than magnetized fresh water. They also added that, magnetized water treatment improved the relative water absorption capacity and water absorption rate of cotton seeds, which indicated that the water absorption of seeds was associated with the physical and chemical properties of irrigation water. After magnetization of the irrigation water, the surface tension and contact angle of water were decreased, and the pH, osmotic pressure, and solubility increased.

Under field conditions, Magnetic treatments used as promising technology to relieve saltiness. Magnetic application reduces the saltiness degree in irrigation water, lowers soil alkalinity, and it's the high leaching of excess soluble salts [14]. Our results exhibited the beneficial effects of applying the magnetic treatment in irrigation water that promoted crop growth and yield (Tables 5-7) of chickpea plant grown under moderate salinity irrigation water. These results are in good accordance with those obtained by Hozayn *et al*., [17, 18] without any destructive or harmful impact on several tested crops. Since magnetic treatment of water does not add or remove any substance in the water itself, it is considered a harmless and environmentally friendly technology [12].

Results (Tables 5) indicated that, application of magnetized water promote growth criteria of chickpea plants grown under moderate saline water irrigation. These results may be attributed to the promotive roles of magnetic technology in all physiological parameters as cell divisions, mitosis, and cell metabolism. It also may be due to their role in increasing photosynthetic pigment contents (Table 6), total IAA content (Table 6) with significant values over un-magnetized moderate saline water (control plants). These results are similar to those obtained by several authors who concluded that, magnetic treatments can be affecting on mitosis of meristematic cells, cell division, protein biosynthesis that reflecting on the change in plant growth and development [15, 47, 49] on chickpea, wheat, and canola plants, respectively. Also, the increasing in growth criteria as a results of magnetic water treatments may be due to their effects on phyto-hormone production, stimulated mobile forms of fertilizers, enhanced water absorption, promoted moisture content, stimulated photosynthetic pigments, promoted endogenous IAA and improved the activity of the bio-enzyme systems consequently growth improvement of orange plant [50]. Moreover, the enhancing and stimulating of overall growth parameters in magnetically treated *Vigna unguiculata* plants than those of treated with tap water may be due to the higher crop growth rate, net assimilation rate of nutrients and higher tissue water contents in those plants treated with magnetized water than the control plants [51].

The significantly increases in the photosynthetic pigment contents in chickpea plants under this study (Table 6) as a result of magnetic water treatments may be attributed to the protective role of magnetic treatment to the chloroplast. These results are in agreement with the previous results on several plants, *Zea mays*, soy bean, moringa and hyssop grown under different stresses conditions, [52-54]. They also added that, the stimulatory effect of magnetic treatment may probably due to reduction of ROS and stabilization of chloroplast ultra-structure. In this regard, **Elkholy et al., [55]** concluded that, magnetic treatments enhanced all photosynthetic pigments contents in leaves at all salinity levels of rosemary plant. They also added that, magnetic water can alleviate (to some extent) the harmful effects occurs during salinity.

The stimulatory effects of magneto-priming treatment on osmoprotectant (total soluble sugar, total amino acids, total phenolic compounds and proline) and total indole molecules in chick pea plants under this study (Table 6) may be attributed to the role of magnetic treatment on change the mineral contents of the soil and also increase the availability of fertilizers consequently increase the mineral up take and increases all above mentioned osmoprotectant and IAA in plant. Moreover, the increment on TSS may be parallel to the increases in photosynthetic pigment contents at this study (Table 6). The same results were recorded by **El-Khayat and Abdellwahd** [56] on orange who reported that, TSS of orange increased as a result of applying magnetized water which caused an increase of nutrients observation from the soil and increases the efficiency of transpiration of these nutrients inside the plants as compared with control. Also, **Dannielly et al., [57]** suggested that, irrigation with this magnetized water had a stimulatory effect on TSS and total carbohydrates that related to the increase of photosynthetic pigments in tomato plant. According to increasing IAA content in response to magnetic water treatment, **Podle´sny et al.,** [58] concluded that, The presowing treatment of pea seed with alternating MFs of 50 Hz (30 and 85 mT) caused a significant increase in the IAA level in the germinating seeds (end-point analysis), as well as in young stems and roots. **Cecchetti et al.** [59] showed that, EMFs caused a strong and significant increase of 36% in the IAA level in the whole big seeds compared to their untreated control. Also, **Liu et al., [60]** concluded that, magnetic treatment could promote nitrogen assimilation and the free amino acids production through enhancing the key enzymes activities.

Phenolic compounds, one from the most important secondary metabolites, naturally aggregate in plants, and as non-enzymatic antioxidants, act a vital role in plants tolerance to stressful conditions, [61]. In this regard, **Azizi *et al.*, [62]** concluded that, application of magnetic treatment on tea plant promoted the production and accumulation of phenolic compounds in cell vacuoles, cell walls and trichomes of epidermal layers of plant, consequently protect other organelles (chloroplasts) under stress condition. Also, Upadyshev et al., [63] recorded that, the pulsed and rotating magnetic fields' complex effect resulted in enhancement of phenolic acid accumulation by about 71%, in Raspberry plants compared to the untreated control.

Proline act as osmoprotectant agent in plants grown under different stress conditions. Magnetic treatment decreased significantly proline contents in chick pea plants grown under moderate salinity water (Table 6). In this regard, Mahmoud *et al*., [50] found that, seedlings with magnetic water treatment (MWT) decreased the proline content significantly of the orange species. They added that, irrigation with magnetized water significantly helped to ameliorate the stress conditions on phenol and proline contents. They added that, decreasing proline content according to M. wt. treatments means the plant were not affected up to 2000 ppm of water salinity to the point of feeling threatened and forced to increase proline. In addition Okba et al., [64] reported that, the increase in leaf chlorophyll, associated with the decrease in proline contents of MW compared with those received no MW, suggested a positive role of MW and proline mitigating the deleterious effects of salinity and drought stress.

Chick pea yield and its attributes were increased in response to irrigation with magnetized water as compared to plant grown under un-magnetized moderate saline water (Table 7). The increment in yield of chick pea and yield attributes may be due to the stimulatory role of magnetic treatment in growth parameters, photosynthetic pigment contents, osmoprotectants and total IAA contents in plants under this study (Tables 5, 6). These results are in accordance with those obtained by of [65-70] on several plants.

In this connection, Abobatta [71] reported that, irrigation with MTW can stimulate the growth and development of plants both quantitatively and qualitatively. It also induce seeds germination, early vegetative development and mineral contents of seeds, plants or fruits. In addition, application of magnetic water treatment improve plant production, promote water use efficiency, reduced soil pH, and increased available nutrient in several plants. Moreover, MTW induced significant stimulatory effect on mobility and uptake of micronutrient concentration and stimulate growth criteria, consequently all these characters reflected in improving biomass and total yield.

Conclusion

Application of different magneto-priming seed treatments (0.05, 0.11, 0.19, 0.27, 0.31 Tesla) improved G; %, GI, SGI, GE; %, GR; day, seedling length (cm), seedling weight (g), seedling vigor-I and vigor-II of Chickpea as compared to the untreated seeds (sowing dry seeds) under laboratory conditions. Under field conditions, irrigation plots with magnetized water induced positive significant effect in Chickpea growth, pigments and physiochemical at 75 DAS, yield components, yield (ton fed^{-1}) and nutritional value of yielded seeds at harvest under drip irrigation system. Under conditions of experiments, could be concluded that application of magnetized water and seed technology could alleviate salinity irrigation water stress which resulted in improvement of growth and productivity of Chickpea under Nubaria region.

Acknowledgement

This work was funded by National Research Centre through Research plan 12nd (2019-2022).

References

[1] M. H. Yang, M. Z. Z. Jahufer, J. He, R. Dong, R. Hofmann, K.H.M. Siddique and F. M. Li, Effect of traditional soybean breeding on water use strategy in arid and semi-arid areas. Eur. J. Agron. 2020, 120, 126-128.

[2] K. S. Sekhon, A. Kaur, S. Thaman, A. S. Sidhu, N. Garg, O. P. Choudhary, G. S. Buttar and N. Chawla, Irrigation water quality and mulching effects on tuber yield and soil properties in potato (Solanum tuberosum L.) under semi-arid conditions of Indian Punjab. F. Crop. Res. 2020, 247, 107544.

[3] M. F. Mohamed, M. M. S. Abdallah, R. K. M. Khalifa, A. G. Ahmed and M. Hozayn, Effect of arginine and GA3 on growth, yield, mineral nutrient content and chemical constituents of faba bean plants grown in sandy soil conditions. *International Journal of ChemTech Research*, 2015, 8 (12), pp. 187-195.

[4] Y. Ren, W. Wang, J. He; L. Zhang, Y. Wei and M. Yang, Nitric oxide alleviates salt stress in seed germination and early seedling growth of pakchoi (Brassica chinensis L.) by enhancing physiological and biochemical parameters. Ecotoxicol. Environ. Saf. 2020, 187, 109785.

[5] H. Z. Abyaneh, M. Jovzi, and M. Albaji, Effect of regulated deficit irrigation, partial root drying and N-fertilizer levels on sugar beet crop (Beta vulgaris L.). Agricultural Water Management. 2017, 194. 10.1016/j.agwat.2017.08.016.

[6] L. Neissi, M. Albaji and B. S. Nasab, Combination of GIS and AHP for site selection of pressurized irrigation systems in the Izeh plain, Iran. Agric. Water Manage. 2020, 231, 106004. https://doi.org/10.1016/j.agwat.2020.106004

[7] M. Albaji, B. S. Nasab, A. A. Naseri and S. Jafari, Comparison of different irrigation methods based on the parametric evaluation approach in Abbas Plain: Iran. J. Irrig. Drainage Eng. 2009, 136 (2) 131-136. https://doi.org/10.1061/(ASCE)IR.1943-4774.0000142

[8] M. Abedi, D. N. Abrahami, N. Nirang, M. Maharrani, E. Khalidi and N. Mehrdadi, Use of saltwater in sustainable farming. Iranian Irrigation and Drainage Committee. 2002.

[9] S. H. Fazelipour, An investigation on the effect of saline water on performance and yield components of a tomato cultivar. Senior dissertation for Irrigation and Drainage, 2002, Ahwaz Shahid Chamran University.

[10] A. M. M. Al-Naggar, S. R. S. Sabry, M. M. M. Atta and O. M. A. El-Aleem, Field screening of wheat (Triticum aestivum L.) genotypes for salinity tolerance at three locations in Egypt. – Journal of Agriculture and Ecology Research International, 2015, 4(3): 88- 104.

[11] P. Ahmadi, Effects of magnetic field on water and agricultural uses of magnetic water.1th International Conference on Modelling Plants, Water, Soil and Air. International Center for Advanced Science and Technology and Environmental Science, 2010, Bahonar Uneversity of Kerman, Iran. (In Farsi).

[12] M. Dastorani, M. Albaji and S.B. A. Nasab, Comparison of the effect of magnetic drip

irrigation and conventional irrigation with different salinity levels on the yield and yield components of sunflower (Helianthus annuus L.). Arab J Geosci, 2022, 15, 1116, https://doi.org/10.1007/s12517-022-10126-1.

[13] N. S. Abdel Kareem, Evaluation of Magnetizing Irrigation Water Impacts on the Enhancement of Yield and Water Productivity for Some Crops. Journal of Agricultural Science and Technology A 8, 2018, 271-283 doi: 10.17265/2161-6256/2018.05.002.

[14] M. H. Hilal, and M. M. Hilal, "Application of Magnetic Technologies in Desert Agriculture: I. Seed Germination and Seedling Emergence of Some Crops in a Saline Calcareous Soil." Egypt Journal of Soil Science, 2000, 40 (3): 413-22.

[15] M. Hozayn, H. M. S. El-Bassiouny, A. A. Abd El-Monem, M.M. Abdallah, Applications of magnetic technology in agriculture, a novel tool for improving water use efficiency and crop productivity: 2. Wheat *International Journal of ChemTech Research*, 2015, 8 (12), pp. 759-771.

[16] H.Ben Hassen, M. Hozayn, A. Elaoud and A. A. Abdd El-monem, Inference of Magnetized Water Impact on Salt-Stressed Wheat. *Arabian Journal for Science and Engineering*, 2020, 45 (6), pp. 4517-4529.

[17] M. Hozayn, A.A. Ramadan, F.M. Elkady and A. A Abd El-Monem, Protective effects of magnetic water technology in alleviating salinity stress on growth, yield and biochemical changes of barleY (Hordeum vulgare, L.). PCBMB; 2020, 21(37-38):149-65. Available from: http://www.ikprress.org/ index. php /PCBMB /article/ view/ 5426.

[18] M. Hozayn, A. Elaoud, , A. A. Abd El-Monem and N. Ben Salah, Effect of magnetic field on growth and yield of barley treated with different salinity levels. Arab J Geosci 14, 701, 2021. https://doi.org/10.1007/s12517-021-07077-4

[19] E. Esmaeilnezhad, H. J. Choi, M. Schaffie, M. Gholizadeh and M. Ranjbar, Characteristics and applications of magnetized water as a green technology. J. Clean. Prod. 2017, 161, 908–921.

[20] F. Moosavi and M. Gholizadeh, Magnetic effects on the solvent properties investigated by molecular dynamics simulation. J. Magn. Magn. Mater. 2014, 354, 239–247.

[21] A. E. S. El-Zawily, M. Meleha, M. El-Sawy, E. H. El-Attar, Y. Bayoumi and T. Alshaal, Application of magnetic field improves growth, yield and fruit quality of tomato irrigated alternatively by fresh and agricultural drainage water. Ecotoxicol. Environ. Saf. 2019, 181, 248–254.

[22] S. Sultana, R. W. Bell and W. H. Vance, Genotypic variation among chickpea and wild Cicer spp. in nutrient uptake with increasing concentration of solution Al at low pH. Plant Physiol. Biochem. 2020, 157, 390–401. 10.1016/j.plaphy.2020.10.034

[23] D. Shanko, G. Jateni, and A. Debela, Effects of Salinity on Chickpea (Cicer arietinum L.) Landraces During Germination Stage. J Biochem Mol Biol, 2017, Vol.3:No.2:9. doi:10.21767/2471-8084.100037

[24] M. G. Dawood, M. A. Khater and M. E. El-Awadi. Physiological Role of Osmoregulators Proline and Glycinebetaine in Increasing Salinity Tolerance of Chickpea. Egyptian Journal of Chemistry, 2021, 79, Volume 64 (12), 7637-7648. DOI: 10.21608/ejchem.2021.85725.4233.

[25] ISTA, International rules for seed testing. International Seed Testing Association (ISTA), Seed Science and Technology, 1999, 27, Supplement.

[26] ISTA, International Rules for Seed Testing. Seed Science and Technology, 1985, 13, 307-520.

[27] S. Ruan, Q. Xue and K. Tylkowska. The influence of priming on germination of rice Oryza sativa L. seeds and seedling emergence and performance in flooded soil. Seed Sci. Technol. 2002, 30: 61-67.

[28] A. O. S. A. Association of Official Seed Analysis, Rules for testing seeds. J. Seed Technol. 1991, 12: 18-19.

[29] M. S. Bartlett, Some samples of statistical methods of research in agricultural and applied biology. J. Roy. Soc., 4. 2, 1937.

[30] R. H. Ellis and E. H. Roberts, The quantification of ageing and survival in orthodox seeds. J Seed Sci Technol1981, 9:377-409

[31] MSTAT-C, a microcomputer program for the design, arrangement and analysis of agronomic research. Michigan State University, East Lansing, 1988.

[32] H. O. Chapman and P.E. Pratt, Methods of

Analysis for Soils, Plants and Water. Univ. of California Agric. Sci. Priced Publication, 4034. pp: 50, 1978.

[33] I. E. Henson, V. Mahalakshmi, F. R. Bidinger and G. Alagarswamy, Genotypic Variation in Pearl Millet (*Pennisetum americanum* (L.) Leeke), in the Ability to Accumulate Abscisic Acid in Response to Water Stress. Journal of Experimental Botany, 1981, 32(130), 899–910. http://www.jstor.org/stable/23690235

[34] H. K. Lichtenthaler and C. Buschmann, Micronutrients foliar application under newly reclaimed sandy soil: Chlorophylls and carotenoids measurement. Australian J. Basic Applied Sci., 2001, characterizationby UV-VISspectroscopy. In: 5: 1328-1334.

[35] A. D. Danil, and C.M. George, Peach seed dormancy in relation to endogenous inhibitors and applied growth substances. J. Amer Society for Hort.Sci., 1972, 17: 621-624.

[36] P. Larsen, , A. Harbo, S. Klungron and T.A. Ashein, On the biosynthesis of some indole compounds in Acetobacter Xylinum. Physiol. Plant., 1962, 15: 552-56

[37] N. Vartainan, P. Hervochon, L. Marcotte and F. Larher, Proline accumulation during Drought rhizogenesis in Brassica napusvar. Oleifera. Plant Physiol., 1992, 140: 623-628.

[38] L. S.Bates, R.P., Waldan and L.D. Teare, Rapid determination of free proline under water stress studies. Plant and Soil. 1973, 39: 205-207

[39] E. W. Yemm and E.C. Cocking, The determination of amino acids with ninhydrin. Analyst., 1955, 80: 209-213

[40] AOAC, Official Methods of Analysis, 17th Ed. Association of Official Analytical Chemists, Washington, 2000, DC, USA.

[41] X. Li, X. Liu, Y. Hua, Y. Chen, X. Kong and C. Zhang, Effects of water absorption of soybean seed on the quality of soymilk and the release of flavor compounds. RSC Adv. 2019, 9, 2906–2918.

[42] J. Zhang, Q. Wang, K. Wei, Y. Guo, W. Mu and Y. Sun, Magnetic Water Treatment: An Eco-Friendly Irrigation Alternative to Alleviate Salt Stress of Brackish Water in Seed Germination and Early Seedling Growth of Cotton (*Gossypium hirsutum* L.). Plants. 2022; 11(11):1397. https://doi.org/10.3390/plants11111397

[43] R. Sharma, S. T. Pandey and O. Verma, Response to pre- sowing seed treatment on germination indices, seedling growth and enzymatic activities of chickpea (*Cicer arietinum* L.) seed. International Journal of Ecology and Environmental Sciences. 2021, 3;(1); 2021; 405-410.

[44] M. Florez, M. V. Carbonell and E. Martinez, Exposure of maize seeds to stationary magnetic field: effect on germination and early growth. Environ Exp Bot. 2007; 59:68-75.

[45] X. Liu, H. Zhu, S. Meng, S. Bi, Y. Zhang, H. Wang, C. Song and F. Ma, The effects of magnetic treatment of irrigation water on seedling growth, photosynthetic capacity and nutrient contents of *Populus euramericana* 'Neva' under NaCl stress. Acta Physiol. Plant 2019, 41, 11.

[46] A. M. Iderawumi and C.E. Friday, "Effects of magnetic field on pre-treament of seedlings and germination", Journal of Agriculture and Research, 2020, no. 6, pp. 1-8.

[47] M. Hozayn, E. M. Abd El-Lateef, F. M. Sharar, A. A. Abd El-Monem, Potential uses of sorghum and sunflower residues for weed control and to improve lentil yields. *Allelopathy Journal*, 27 (1), pp. 15-22, 2011.

[48] M. Hozayn, , M.S.A. Abd El-Wahed, A.A. Abd El-Monem, R.E. Abdelraouf and E.M. Abd Elhamid, Applications of magnetic technology in agriculture, a novel tool for improving water and crop productivity: 3. Faba bean Research Journal of Pharmaceutical, Biological and Chemical Sciences, 2016a, 7(6): pp. 1288-1296.

[49] M. Hozayn, , M.M. Aballha, A.A. Abd El – Monem, A.A. El Saady and M.A. Darwish, Applications of magnetic technology in agriculture :A novel tool for improving crop productivity (1); canola. Afr. J.Agric. Res., 2016b, 11(5): 441- 449

[50] T. A. Mahmoud, E.A. Youssef, S. B. El-harounya and M.A.M. Abo Eida, Effect of irrigation with magnetic water on nitrogen fertilization efficiency of navel orange trees. Plant Archives Journal, 2019, 19(1): pp. 966-975.

[51] E. D. Olowolaju and A. A. Adelusi, Effects of Magnetized Water on Growth Performance,

Photosynthetic Pigments Accumulation and Yield Attributes of Vigna unguiculata (l.) Walp. J Plant Physiol Pathol , 2021, 9:9. 267.

[52] L. Baghel, S. Kataria and M. Jain, Mitigation of adverse effects of salt stress on germination, growth, photosynthetic efficiency and yield in maize (*Zea mays* L.) through magnetopriming. Acta Agrobot. 2019, 72: 1757– 1773.

[54] R. Mohammadi and P. Roshandel, Ameliorative Effects of a Static Magnetic Field on Hyssop (*Hyssopus officinalis* L.) Growth and Phytochemical Traits Under Water Stress. Bioelectromagnetics. 2020, 41:403—412. https://doi.org/10.1002/bem.22278.

[55] S. A. El-Kholy, M. M. Mazrou, M. M. Afify, N. A. M. El-Said and H. M. Z. Zedan, Effect of irrigation with magnetic water on vegetative growth, chemical contents and essential oil in rosemary grown in different levels of salinity. Menoufia J. Plant Prod., 2020, 5: 143 – 157.

[56] H. M. El-Khayat and S. M. Abdellwahd, Effect of some fertigation treatments and magnetized water on Valencia orange trees growing under saline conditions. Middle East Journal of Applied Sciences. 2019, 09: (04) 2019, 1081-1101. DOI: 10.36632/ mejas/ 2019.9.4.23

[57] Z. O. Dannielly, I. A. Elizabeth, R. F. Pedro, F. D. Albys and F. B. Yilan, Water treated with a static magnetic field on photosynthetic pigments and carbohydrates of Solanum lycopersicum L. Revista Cubana de Química, 2022, 34(1),34-48. https://www.redalyc.org/articulo.oa?id=443570155003.

[58] J. Podle´sny, A. Podle´sna, B. Gładyszewska and J. Bojarszczuk, Effect of Pre-Sowing Magnetic Field Treatment on Enzymes and Phytohormones in Pea (*Pisum sativum* L.) Seeds and Seedlings. Agronomy 2021, 11, 494.

[59] D. Cecchetti, A. Pawełek, J. Wyszkowska, M. Antoszewski, A. Szmidt-Jaworska, Treatment of Winter Wheat (*Triticum aestivum* L.) Seeds with Electromagnetic Field Influences Germination and Phytohormone Balance Depending on Seed Size. Agronomy 2022, 12, 1423. https://doi.org/10.3390/ agronomy12061423.

[60] X. Liu, L. Wang, F. Ma, J. Guo, H. Zhu, S. Meng, S. Bi and H. Wang, Magnetic Treatment Improves the Seedling Growth, Nitrogen Metabolism, and Mineral Nutrient Contents in Populus × euramericana ‘Neva’ under Cadmium Stress. Forests. 2022; 13(6):947. https://doi.org/10.3390/f13060947

[61] A. Ghorbani, S. M. Razavi, Ghasemi Omran, V.O., Pirdashti, H. (2018a). Piriformospora indica inoculation alleviates the adverse effect of NaCl stress on growth, gas exchange and chlorophyll fluorescence in tomato (*Solanum lycopersicum* L.). Plant Biol., 20(4), 729–736.

[62] S. M. Y. Azizi, S. H. Sarghein, A. Majd and M. Peyvandi, The effects of the electromagnetic fields on the biochemical components, enzymatic and non-enzymatic antioxidant systems of tea Camellia sinensis L.. Physiol Mol Biol Plants. 2019, 25, 1445–1456 (2019). https://doi.org/10.1007/s12298-019-00702-3.

[63] M. Upadyshev, S. Motyleva, I. Kulikov, V. Donetskih, M. Mertvischeva, K. Metlitskaya and A. Petrova, The effect of magnetic field on phenolic composition and virus sanitation of raspberry plants. Hort. Sci. (Prague), 2020, 48: 166–173.

[64] S. K.Okba, Y.Mazrou, G. B, Mikhael, M.E.H. Farag, S.M. Alam-Eldein, Magnetized Water and Proline to Boost the Growth, Productivity and Fruit Quality of ‘Taifi’ Pomegranate Subjected to Deficit Irrigation in Saline Clay Soils of Semi-Arid Egypt. Horticulturae 2022, 8, 564. https://doi.org/ 10.3390/horticulturae8070564

[65] M. Hozayn and A. M.S. Abd El-Qodos, Magnetic water application for improving wheat (*Triticum aestivum* L.) crop production. Agric. and Biol. J of North America, 2010a, 1(4), 677- 682.

[66] M. Hozayn and A. M.S. Abd El-Qodos, Irrigation with magnetized water enhances growth, chemical constituent and yield of chickpea (*Cicer arietinum* L.). Agric. and Biol. J of North America, 2010b, 1(4), 671 – 676.

[67] A. A. Alderfasi, N. A. Al-Suhaibani, M. M. Selim and B. A. A. Al-Hammad, Using magnetic technologies in management of water irrigation programs under arid and semi-

arid ecosystem. Adv. Plants Agric. 2016, Res. 3: 109–116.

[68] A. F. H. Selim and D. A. Selim, Physio-biochemical behaviour, water use efficiency and productivity of wheat plants exposed to magnetic field. Journal of Plant Production 10 (2), 185–191, 2019.

[69] A. Said, M. Motawea, M. Abdel-rahman and Y. Fawzy, The effect of saline water magnetization on physiological and agronomic traits of bread wheat genotypes. *SVU-International Journal of Agricultural Sciences*, 2(2), 384-400, 2020. doi: 10.21608/svuijas.2020.47495.1049

[70] M. Rahimian and H. Zabihi, Investigation of the Reaction of Potato Plant to Magnetized Saline Water. *Agrotechniques in Industrial Crops*, 1(3), 149-153, 2021. doi: 10.22126/atic.2022.7145.1025.

[71] W. F. Abobatta, Overview of role of magnetizing treated water in agricultural sector development. Adv. Agric. Technol. Plant Sci. 2019, 2, 180023.