SAINS TANAH – Journal of Soil Science and Agroclimatology

Journal homepage: http://jurnal.uns.ac.id/tanah

Effect of pre-sowing magnetic treatment of seeds with bio- and mineral fertilization on the soybean cultivated in a saline calcareous soil

Rama T. Rashad*, Khaled A. H. Shaban, Samia H. Ashmaye, Mona G. Abd El-Kader, Awatef A. Mahmoud

Soils, Water, and Environment Research Institute, Agricultural Research Center, Giza, Egypt

ARTICLE INFO

Keywords:
Bio-fertilizers
Nutrient use efficiency
Seeds magnetization
Seeds soaking
Salinity

Article history
Submitted: 2022-03-05
Accepted: 2022-05-19
Available online: 2022-07-15
Published regularly: December 2022

***** *Corresponding Author*
Email address:
rtalat2005@yahoo.com

ABSTRACT

Bio-farming is an eco-friendly advance that minimizes the required chemical additives for optimizing the quality of crops that their storage is often accompanied by seeds' component degradation. Magnetic treatment of seed was considered a promising tool improves germination and growth. This study aims to evaluate the effect of individual and combined application of bio-fertilizers and the N-P-K mineral fertilizers preceded by magnetic treatment of dry and/or water-soaked seeds before sowing on the yield and quality of soybean cultivated in saline soil. The field experiment was carried out in a split-split plot design with triplicates. The main two factors (F1) were not bio-fertilized and bio-fertilized plots. The sub-factors (F2) were three application rates (A: 50%, B: 75%, and C: 100%) of recommended doses of the three N, P, K fertilizers. The sub-sub factors (F3) were seeds not magnetically treated (NM) and magnetically treated (M). All factors were studied for dry soybean seeds (without soaking) and soaked seeds in magnetically treated water. After harvesting, soil and plant samples were analyzed. The most significant increase in the soybean seed yield (kg ha^{-1}) was by 49.98% for the bio-fertilized magnetized dry seeds at 75% and 100% mineral N-P-K fertilization compared with the NM soaked seeds at 50% N-P-K (A rate) without bio-fertilization. The 75% mineral fertilization significantly increased the protein (%) by 41.69% and decreased the proline (mg g^{-1}dw) by 46.68%. Magnetic treatment of seeds before cultivation and combined bio/mineral N-P-K fertilization reduced the Proline that alleviates the stress conditions.

How to Cite: Rashad, R.T, Shaban, K.A.H., Ashmaye, S.H., Abd El-Kader, M.G., Mahmoud, A.A. (2022). Effect of pre-sowing magnetic treatment of seeds with bio- and mineral fertilization on the soybean cultivated in a saline calcareous soil. Sains Tanah Journal of Soil Science and Agroclimatology, 19(2): 132-144. https://dx.doi.org/10.20961/stjssa.v19i2.59833

1. INTRODUCTION

Agricultural sustainability requires the improvement of conventional agronomic practices as well as innovative ones to obtain good agricultural products both qualitatively and quantitatively. Bio-farming has been introduced as a good agricultural practice (GAP) that restores soil nutritional status, especially under stress conditions (Abbas et al., 2014). Plant growth promoting bacteria (PGPB) has been applied as an eco-friendly approach that minimizes the added chemicals. They are rhizosphere bacteria that enhance plant growth, yield and quality by improving the phyto hormone synthesis and many biological activities (Helaly et al., 2020).

A bio-fertilizer is distinguished by some specific functional microorganisms with organic substances that are organically and microbially beneficial for soil fertility as they can restructure the soil microbial communities associated to the root-zone of different plants. It can partially replace some chemical fertilizers and release macro-and micronutrients in addition to organic substrates that are vital for plant growth (Sayed & Ouis, 2022; Zainuddin et al., 2022). Microbial strains such as *Bacillus* spp., *Trichoderma* spp., and *Streptomyces* spp. can enhance plant growth and be inhibitors for some soil-borne pathogens. Bio-fertilizers may control plant diseases, increase yield, and ameliorate plant tolerance to biotic and abiotic stresses (Nafady et al., 2019). The distribution and function of soil microorganisms are highly dependent on the local environment and plant species (Li et al., 2022).

Bio-fertilizers enriched by N and P nutrients could be extracted from waste recycling (Oliveira et al., 2021). Locally-selected strains of rhizobia formulated into bio-fertilizers significantly enhanced the N- fixation and agronomic N-use efficiency (Yanni et al., 2016). Nitrogen-fixing bacteria provide the N-requirements by slow release during the plant lifecycle. This may be via their slow biological synthesis reactions to produce organic acids in the rhizosphere by crops and bacteria, which in turn stimulates the N-availability (Helaly et al., 2020). Nitrogen is so critical for the synthesis of chlorophyll, amino acids, proteins, nucleic acids, enzymes, and energy-transfer compounds (El-Serafy & El-Sheshtawy, 2020). Different strains of PGPB have enhanced the assimilation of essential nutrients and plant-associated biological nitrogen fixation, i.e., N, P, K, Ca, Mg, Fe, Mn, Zn, and Cu in the plants. This may be due to the stimulated synthesis of organic acids in the rhizosphere by crops and bacteria. They are usually efficient organisms for the phosphate solubilization, iron siderophores complexes production and the proteolyses activity (Hagaggi & Mohamed, 2020; Helaly et al., 2020; Yadav et al., 2021).

Soybean [*Glycine* max L.] is an extremely vital source of edible protein for human nutrition and contains up to 40% protein and a complete set of amino acids. Soaking of soybean seeds enhances the processing of bean products but requires a long soaking time. Soaking efficiency was studied using 60 kHz sweeping frequency ultrasound (SFU). Significant results showed an increase in the soluble protein content by 14.27% after SFU, an enlarged intercellular space and size of soybean, as well as the cell membrane permeability, was enhanced by 4.37%. Unpleasant bean flavour compounds were reduced by 16.37%– 47.6% (Zhang et al., 2021).

Seeds storage is often accompanied by some degradation of their components due to the moisture lipids composition, creation of oxidizing agents, and the reactive oxygen species (ROS). Different physical and chemical seed treatments have been applied including seed priming, thermal treatments, seed coating, and pelleting. Priming of seeds enhances germination via many biochemical changes such as enzyme activation and starch hydrolysis. Physical treatments may include the application of laser irradiation, gamma irradiation, and magnetic field MF (Afzal et al., 2021).

Among the most interesting techniques to enhance agricultural production in an environment friendly way is the application of magnetic fields (MFs) through magnetization of water (MW). It is capable to induce plant growth and development and alter the mineral content of seeds or fruits. Such effect is very strongly species and genotype-dependent. However, MW can lose its magnetism over time and distance (Teixeira da Silva & Dobránszki, 2014).

Magnetic treatment of seeds has been considered as a promising tool to improve germination and seedling growth. The MF affects the electrical charges, ion concentration, and free radicals of seeds leading to a more permeable membrane without change in their chemical profile. Magnetic treatment by 100 mT for 10 min and seed priming with moringa leaf extract (MLE, 3%) in a magnetically treated water (MTW) solution significantly improved the emergence, crop growth rate and sunflower yield (Afzal et al., 2021). The magnetic priming treatment of lentil seeds by 20 mT for 25 min enhanced their growth without a significant lipid per-oxidation. It showed a significant increase in the activity of catalase and superoxide dismutase 0.57 and 1.09 unit mg^{-1} protein compared to 0.15 and 0.40 unit mg^{-1} protein of the control, respectively (Harb et al., 2021).

The global interest for enhancing the soybean production with the best quality requires continuous studies to optimize the most suitable agronomic practices(Abd El-Mohsen et al., 2013). Magnetic treatment of water and/or seeds has been studied as an efficient tool to minimize the salt stress on soybean and soil and accelerate the germination of seeds (Amer et al., 2014; Radhakrishnan, 2019). The present work aims to study the quantitative and qualitative effect of bio-fertilization applied along with the N-P-K mineral fertilization on the yield of soybean in saline soil in case of magnetic treatment (MT) of both dry and water-soaked seeds before sowing. The study tries to find out the optimum combination of the three agricultural practices including bio-fertilization, mineral fertilization, and pre-sowing magnetic treatment of seeds, in order to optimize the soybean productivity under saline calcareous soil conditions.

2. MATERIAL AND METHODS

2.1. The study area

A study in the field was carried out (summer seasons of 2020 and 2021) at a farm in the region named Khaled Ben El-Waled, Sahle El-Hussinia city, El-Sharqia Government, Egypt (between 32° 00' 00" to 32° 15' 00" N latitude - 30° 50' 00" to 31° 15' 00" E longitude). The field is saline soil irrigated by El-Salam Canal (mixed Nile water: daring agriculture water, 1:1). It is a clay texture contains 43.75% clay, 27.05% silt, 22.90% sand, and 6.30% coarse sand [Aridisol] (FAO, 2014). Table 1 presents some physical, chemical and nutritional characteristics of a representative sample of the surface soil (0 – 30 cm) before planting (Piper, 2019).

2.2. Design of the study and Treatments used

The study treatments were distributed in a split-split plot design with three replicates. The main factor (F1) was the bio-fertilization (not bio-fertilized and bio-fertilized plots).

Table 1. Some properties of the soil under study before cultivation

Particle size distribution (%)			
Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)
6.30	22.90	27.05	43.75
Texture		Clay	
O.M. (%)		0.65	
$CaCO_3$ (%)		13.88	
pH (1:2.5)		8.35	
EC (dS m^{-1})		7.55	
Cations (meq/l)			
Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}
13.85	19.33	41.45	0.87
Anions (meq/l)			
HCO_3^{-}	Cl^{-}	SO_4^{-2}	
12.75	35.90	26.85	
Available macronutrients (mg kg^{-1})			
N	P	K	
37.22	4.90	188.00	
Available micronutrients (mg kg^{-1})			
Fe	Mn	Zn	
7.50	2.65	0.52	

The sub-factor (F2) was mineral fertilization (three application rates of the N, P, and K mineral fertilizers). The sub-sub factor (F3) was the magnetic treatment (MT) of seeds (not magnetically treated (NM) and magnetically treated (M)). The three factors were studied for the dry soybean seeds (without soaking) and the soaked seeds in magnetically treated water (MTW).

The bio-fertilizers used in the study were supplied by the Bacteriology Lab, Department of Microbiology, Soils, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt. They were the symbiotic N-Fixing bacteria (*Rhizobium leguminosarum*) (Salt Tolerant PGPR), phosphate dissolving bacteria (*Bacillus megatherium*), and potassium dissolving bacteria (*Bacillus circulans*) to enhance the availability of the N, P, and K nutrients. They were added in the form of solution sprayed on the soil surface after planting in three application times at 21, 50 and 75 days. Each application is 5 L diluted in 400 L water fed^{-1} (11.9 L diluted in 952.4 water ha^{-1}).

Seeds of soybean (*Glycine max L.,* Giza 111 cv) were obtained from the Crops Research Institute Agriculture Research Center, Giza, Egypt. Not magnetically treated seeds (NM) were sown as it is in the dry form. Magnetically treated seeds (M) were prepared by placing about ≈ 200 g seeds inside a metallic magnetic tube consisted of a permanent magnet surrounding an open-ended tube (70 cm Length × 1.5-inch diameter, magnetic field strength 1.4 T) for 30 min.

Soaked seeds were prepared by soaking about ≈ 200 g seeds in a suitable volume of tap water either not magnetically treated water (NM) or magnetically treated water (M) for 30 min. The magnetically treated water was obtained by passing the ordinary tap water through a metallic magnetic tube consisted of a permanent magnet surrounding an open-ended tube (70 cm Length × 1.5-inch diameter, magnetic field strength 1.4 T) connected to the water tank containing tap water.

Mineral fertilization was applied as follows: the area to be planted was divided into three equal regions to receive three application rates: A (50%), B (75%), and C (100%) of the recommended doses (RD) of N, P, and K mineral fertilizers. Doses of the calcium super phosphate (15.5 % P_2O_5 - 100, 150, 200 kg ha^{-1}) were applied for the corresponding region during the soil tillage before sowing. Doses of the nitrogen in the form of urea (46 % N – 45, 67.5, 90 kg ha^{-1}) were applied 31, 45, and 65 days after planting, while the potassium sulphate (48 % K_2O – 37.5, 56.25, 75 kg ha^{-1}) were applied two times 31 and 65 days after planting.

Sowing of seeds was carried out on the 15th of May of the years 2020 and 2021. Four seeds were hand-sown in holes 3 cm deep and 20 cm apart along the ridge. After 30 days, plants were thinned to one plant per hole.

2.3. Soil and plant sampling

At harvesting on the 30th of September 2020 and 2021, representative samples from the plants and the surface soil (0 – 30 cm) were randomly selected from all experimental plots then air-dried to record the following measurements: plant length (cm), weight of pods/plant (g), weight of seeds/plant (g), and 1000 seed weight (g). The yield of seeds and straw (t ha^{-1}) has been calculated based on the seed yield per plot area and the mean of the two seasons was recorded.

2.4. Estimation of N, P, and K content in soil and plant samples

The available concentrations of N, P, and K in soil were extracted by 1% K_2SO_4, 0.5 N $NaHCO_3$, and 1 N NH_4OAc (pH 7.0), respectively. Seeds and/or straw of soybean were dried at 70 °C for 48 h then ground. About 0.5 g of ground seeds was solubilized in 1:1 $H_2SO_4/HClO_4$ acid mixture. Estimation of the total concentrations of N, P and K in the plant and soil extracts was carried out using Kjeldahl, UV-Vis. Spectrophotometer and flame photometer, respectively(Piper, 2019; Rayment & Lyons, 2010). Concentrations of Fe, Mn, and Zn in the seeds' and/or straw extract were measured by the ICP Spectrometry (ICP-*Ultima 2 JY* Plasma).

Total chlorophyll in the fresh leaves, total carbohydrate in the dry seeds, Proline content, total amino acids, and the seeds' oil content were estimated according to the mentioned methods (Piper, 2019). Protein (%) was calculated by multiplying the seeds nitrogen (%) by 6.25.

2.5. Nutrient Use Efficiency Indices

Use efficiency (UE) also expressed as apparent recovery (AR) as well as the agronomic efficiency (AE) for the applied N, P and/or K were calculated by Eq (2) (Roozbeh et al., 2011).

Nutrient Use Efficiency (UE/AR) =

$$\frac{(Pn_f - Pn_0)}{Fertilizer\ rate\ (N, P\ or\ K, kg\ ha{-1})} \times 100 \quad [1]$$

Where P_n = seed nitrogen (N, g kg^{-1}), phosphorus (P, g kg^{-1}) and/or potassium (K, g kg^{-1}); P_{nf} = seed nutrient with bio-fertilization; P_{n0} = seed nutrient without bio-fertilization.

$$\text{Agronomic Efficiency (AE)} = \frac{Y_f - Y_0}{Fertilizer\ rate\ (N, P\ or\ K, kg\ ha\text{-}1)} \quad [2]$$

Where Y = seed yield (kg ha^{-1}).

2.6. Statistical Analysis

The one-way analysis of variance (ANOVA) test was used to calculate the statistical significance (LSD) of the obtained data at a significance level of $P < 0.05$ using the Co-State software Package (Ver. 6.311).

3. RESULTS

3.1. Effect of the studied factors on the soil available nutrients

Varied concentrations of the available nutrients in the experimental soil were recorded due to the studied main factor (bio-fertilizer - F1) and the sub-factor (different rates of mineral N-P-K fertilization - F2) as well as the sub-sub factor (NM and M - F3) in case of the dry and soaked soybean seeds as indicated in Table 2a and 2b, respectively.

Bio- and mineral fertilization as well as the MT have increased the soil available N (mg kg^{-1}) at the significance level of $p < 0.05$. A high significant interaction was found between the bio- and mineral fertilization effect on the soil available N in the case of the dry seeds. Available P (mg kg^{-1}) in soil was increased significantly only due to the mineral N-P-K fertilization for both dry and soaked seeds.

Table 2a. Available macro-micronutrients content in soil after harvest (average values of the two seasons)

Treatment	N-P-K (kg ha^{-1})	Available macronutrients (mg kg^{-1})											
		N				P				K			
		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds	
		NM	M	NM	M	NM	M	NM	M	NM	M	NM	M
Without bio-fertilizers	A	40.9	43.2	39.6	41.3	5.5	5.9	5.1	5.6	195.0	197.0	192.0	193.0
	B	45.3	47.9	44.3	46.3	5.9	6.1	5.9	5.9	203.0	208.0	196.0	198.0
	C	47.6	49.3	45.2	48.9	6.1	6.2	6.0	6.1	198.0	202.0	193.0	195.0
With bio-fertilizers	A	43.6	48.3	42.9	46.8	5.9	6.1	5.4	5.8	204.0	210.0	195.0	199.0
	B	52.3	57.4	48.2	53.5	6.9	7.8	6.3	6.6	215.0	220.0	209.0	215.0
	C	48.2	54.6	47.5	50.2	6.4	6.9	5.9	5.9	220.0	225.0	201.0	210.0
F1	LSD	0.06		1.43		4.14		1.66		16.56		24.84	
	SL	***		**		ns		ns		ns		ns	
F2	LSD	1.54		1.54		0.54		0.54		5.44		7.69	
	SL	***		***		*		*		**		ns	
F3	LSD	1.68		1.51		0.42		0.59		8.39		7.26	
	SL	***		***		ns		ns		ns		ns	
F1*F2		**		ns		ns		ns		ns		ns	
F1*F3		ns		ns		ns		ns		ns		ns	
F2*F3		ns		ns		ns		ns		ns		ns	
F1*F2*F3		ns		ns		ns		ns		ns		ns	

Remarks: A: 50% of the recommended dose (RD), B: 75% of the RD, C: 100% of the RD, NM: not magnetically treated, M: magnetically treated, F1: main factor (bio-fertilizer), F2: sub-factor (mineral fertilizer), F3: sub-sub factor (magnetic treatment), LSD: limit of standard deviation at $p < 0.05$, SL: Significance of Level, ns: non-significant.

Table 2b. Available micro-micronutrients content in soil after harvest (average values of the two seasons)

Treatment	N-P-K (kg ha^{-1})	Available micronutrients (mg kg^{-1})											
		Fe				Mn				Zn			
		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds	
		NM	M	NM	M	NM	M	NM	M	NM	M	NM	M
Without bio-fertilizers	A	8.09	8.33	7.95	8.04	2.98	3.02	2.88	2.90	0.62	0.64	0.55	0.59
	B	8.77	8.85	8.03	8.55	3.08	3.08	2.94	3.04	0.65	0.68	0.59	0.63
	C	8.90	8.97	8.12	8.80	3.12	3.16	2.96	3.09	0.68	0.74	0.62	0.65
With bio-fertilizers	A	8.75	8.88	8.20	8.66	3.17	3.26	2.99	3.10	0.69	0.73	0.62	0.65
	B	9.05	9.13	8.75	8.95	3.40	3.60	3.08	3.33	0.77	0.80	0.66	0.74
	C	9.12	9.30	8.90	9.05	3.88	3.95	3.15	3.75	0.79	0.84	0.74	0.78
F1	LSD	0.03		3.27		1.66		1.66		0.08		0.17	
	SL	***		ns		ns		ns		*		ns	
F2	LSD	0.77		0.76		0.77		0.77		0.11		0.11	
	SL	ns		ns		ns		ns		ns		ns	
F3	LSD	0.84		0.59		0.84		0.84		0.07		0.06	
	SL	ns		ns		ns		ns		ns		ns	
F1*F2		ns		ns		ns		ns		ns		ns	
F1*F3		ns		ns		ns		ns		ns		ns	
F2*F3		ns		ns		ns		ns		ns		ns	
F1*F2*F3		ns		ns		ns		ns		ns		ns	

Remarks: A: 50% of the recommended dose (RD), B: 75% of the RD, C: 100% of the RD, NM: not magnetically treated, M: magnetically treated, F1: main factor (bio-fertilizer), F2: sub-factor (mineral fertilizer), F3: sub-sub factor (magnetic treatment), LSD: limit of standard deviation at $p < 0.05$, SL: Significance of Level, ns: non-significant

The same applies for the available K (mg kg^{-1}) in soil only for dry seeds. Variations due to the bio-fertilization and MT were non-significant at *$p < 0.05$* for both P and K available in soil.

The bio-fertilized magnetized M dry seeds combined with the 75% (B rate) mineral fertilization showed the highest significant relative increase in the available N (by 45.13%) and P (by 51.96%) compared to the minimum recorded value for the NM soaked seeds at the 50% N-P-K (A rate) without bio-fertilization. The available K (mg kg^{-1}) was increased significantly by 17.91% for the bio-fertilized M dry seeds combined with the 100% (C rate) mineral fertilization relative to the minimum value.

The available micronutrient concentrations in soil were also increased due to the studied factors but their increase was non-significant at $p < 0.05$ except for the Fe and Zn under the bio-fertilization of the dry seeds as shown in Table 2b.A significant increase was observed for the soil available Fe and Zn (mg kg^{-1}) in case of the bio-fertilized M dry seeds at 100% mineral N-P-K fertilization by 16.98 and 52.73%, respectively, relative to the minimum-recorded value of the NM soaked seeds at 50% N-P-K without bio-fertilization.

3.2. Effect of the studied factors on the soybean yield

The yield of soybean seeds (kg ha^{-1}) increased significantly for the M dry and soaked seeds under the combined bio- and mineral fertilization at $p < 0.05$ as presented in Table 3a. The most significant relative increase was by 49.98% for the bio-fertilized M dry seeds at 75% and 100% mineral N-P-K fertilization compared with the NM soaked seeds at 50% N-P-K (A rate) without bio-fertilization. The M soaked seeds showed a significant relative increase by 39.98% under the combined bio- and mineral fertilization at the 75% compared to the minimum observed value for the NM soaked seeds without bio-fertilization. The combination between the bio- and mineral fertilization along with the MT was more significant for the dry seeds than for the soaked seeds that are only significantly affected by the combined bio/mineral or mineral/magnetic treatment MT.

The straw yield (kg ha^{-1}) was also significantly increased under the effect of the studied factors with the most significant increase by 30.44% for the bio-fertilized magnetically treated M dry seeds at the 75% N-P-K fertilization relative to the minimum observed value. The combined effect due to the interaction of different factors was generally non-significant.

Table 3b indicates the variation in some yield components of the soybean crop as affected by different treatments. The most significant relative increase in the plant length (cm), weight of pods/plant (g), weight of seeds/plant (g), and 1000 seed weight (g) was found for the bio-fertilized M dry seeds at the 75% N-P-K fertilization by 29.78%, 84.05%, 127.71%, and 60.96%, respectively. The effect of each factor was generally independent of the other factors since the interaction between different factors was almost non-significant for the estimated yield components listed in Table 3b.

3.3. Effect of the studied factors on the nutrients' content in soybean seeds

Total N (g kg^{-1}) in the soybean seeds showed a non-significant increase under the effect of different treatments at $p < 0.05$, while the total P (g kg^{-1}) in seeds was increased significantly due to the bio-fertilization for the dry and soaked seeds and due to soaking of seeds in the magnetized water MTW. The total K (g kg^{-1}) was increased significantly due to both the bio- and mineral N-P-K fertilization as well as due to the MT of the dry seeds as presented in Table 4a. The bio-fertilized M dry seeds at 75% mineral N-P-K fertilization contained the most significant increased concentration of the total N and K by 41.67% and 44.59%, respectively, and the 2nd most for P by 81.25% relative to the minimum value observed for the NM soaked seeds.

Table 3a. Yield (kg ha^{-1}) of soybean seeds and straw under the effect of different treatments after harvest (average values of the two seasons)

Treatment	N-P-K (kg ha^{-1})	Seed yield (kg ha^{-1})				Straw yield (kg ha^{-1})			
		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds	
		NM	M	NM	M	NM	M	NM	M
Without bio-fertilizers	A	2619	2857	2381	2619	5476	5952	5476	5714
	B	2857	3095	2619	2857	5952	6190	5714	5952
	C	3095	3333	2857	2857	5952	6190	5714	5952
With bio-fertilizers	A	3095	3333	2857	3095	6190	6905	5952	6190
	B	3095	3571	3095	3333	6429	7143	6429	6905
	C	3095	3571	3095	3095	6190	6905	6190	6429
F1	LSD	82.80		166.23		646.72		165.61	
	SL	**		**		*		**	
F2	LSD	121.54		54.36		453.12		108.71	
	SL	**		***		ns		***	
F3	LSD	41.93		59.30		370.33		-[1]	
	SL	***		***		**		ns	
F1*F2		*		**		ns		**	
F1*F3		**		ns		ns		ns	
F2*F3		*		**		ns		ns	
F1*F2*F3		*		ns		ns		ns	

Remarks: A: 50% of the recommended dose (RD), B: 75% of the RD, C: 100% of the RD, NM: not magnetically treated, M: magnetically treated, F1: main factor (bio-fertilizer), F2: sub-factor (mineral fertilizer), F3: sub-sub factor (magnetic treatment), LSD: limit of standard deviation at p < 0.05, SL: Significance of Level, ns: non-significant, [1] Variance < 0 (negative value)

Table 3b. Some yield components of soybean plant under the effect of different treatments after harvest (average values of the two seasons)

Treatment	NPK (kg ha^{-1})	Plant length (cm)				Wt. of pods/ Plant (g)				Wt. of seeds/ Plant (g)				1000 seeds Wt. (g)			
		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds	
		NM	M	NM	M	NM	M	NM	M	NM	M	NM	M	NM	M	NM	M
Without bio-fertilizers	A	78.4	83.9	75.9	80.4	32.8	35.7	30.1	33.7	26.1	32.6	23.6	28.1	38.3	42.2	35.6	39.3
	B	82.1	86.3	77.5	85.3	38.0	42.6	32.7	38.3	30.9	36.5	27.6	33.7	41.3	47.6	38.1	43.2
	C	84.3	88.3	79.4	88.2	39.3	45.7	32.9	42.2	35.0	41.0	30.1	37.1	45.7	53.1	44.2	48.4
With bio-fertilizers	A	83.2	87.4	82.1	84.3	35.5	39.3	37.0	38.5	34.7	40.2	33.7	36.0	42.4	47.0	40.5	43.6
	B	88.7	98.5	85.3	94.5	47.0	55.4	46.6	49.3	46.2	53.1	45.1	49.3	52.7	57.3	48.3	54.3
	C	85.2	94.6	84.0	87.4	43.1	52.2	42.0	44.1	45.0	50.2	37.4	44.2	48.2	52.1	44.6	49.5
F1	LSD	2.40		0.03		4.14		16.56		4.14		12.42		0.03		0.06	
	SL	*		***		*		ns		**		ns		***		***	
F2	LSD	8.31		12.15		3.84		2.72		6.08		4.71		4.71		3.84	
	SL	ns		ns		***		***		*		**		*		**	
F3	LSD	8.97		5.93		3.63		2.96		2.10		2.10		4.19		4.19	
	SL	ns		*		**		*		***		***		*		*	
F1*F2		ns		ns		ns		*		ns		ns		ns		*	
F1*F3		ns		ns		ns		ns		ns		ns		ns		ns	
F2*F3		ns		ns		ns		ns		ns		ns		ns		ns	
F1*F2*F3		ns		ns		ns		ns		ns		ns		ns		ns	

Remarks: A: 50% of the recommended dose (RD), B: 75% of the RD, C: 100% of the RD, NM: not magnetically treated, M: magnetically treated, F1: main factor (bio-fertilizer), F2: sub-factor (mineral fertilizer), F3: sub-sub factor (magnetic treatment), LSD: limit of standard deviation at $p < 0.05$, SL: Significance of Level, ns: non-significant.

Table 4a. Concentrations of macro-micro nutrients content in seeds soybean after harvest (average values of the two seasons)

Treatments	N-P-K (kg ha^{-1})	Total concentration (g kg^{-1})											
		N				P				K			
		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds	
		NM	M	NM	M	NM	M	NM	M	NM	M	NM	M
Without bio-fertilizers	A	31.4	32.2	31.2	31.8	4.3	4.6	3.2	3.8	16.3	17.0	15.7	16.2
	B	32.5	33.6	32.0	33.4	5.2	5.7	3.7	4.6	17.5	18.7	16.9	17.3
	C	31.9	32.9	31.7	32.5	4.8	5.4	3.4	4.3	16.9	19.5	16.3	16.6
With bio-fertilizers	A	40.7	42.2	40.8	41.5	4.7	5.3	4.0	4.5	18.4	20.6	18.5	19.8
	B	43.5	44.2	41.5	43.7	5.5	5.8	5.3	5.9	21.0	22.7	21.5	21.3
	C	42.3	43.5	40.9	42.8	5.2	5.4	4.3	4.8	20.8	21.5	20.7	20.9
F1	LSD	24.8		16.6		0.1		0.8		0.2		0.8	
	SL	ns		ns		***		*		***		**	
F2	LSD	7.7		5.4		1.5		1.1		0.8		1.2	
	SL	ns		ns		ns		ns		***		*	
F3	LSD	7.3		5.9		-[1]		0.5		0.8		0.4	
	SL	ns		ns		ns		*		**		ns	
F1*F2		ns		ns		ns		ns		ns		ns	
F1*F3		ns		ns		-		ns		ns		ns	
F2*F3		ns		ns		-		ns		ns		ns	
F1*F2*F3		ns		ns		-		ns		ns		ns	

Remarks: A: 50% of the recommended dose (RD), B: 75% of the RD, C: 100% of the RD, NM: not magnetically treated, M: magnetically treated, F1: main factor (bio-fertilizer), F2: sub-factor (mineral fertilizer), F3: sub-sub factor (magnetic treatment), LSD: limit of standard deviation at $p < 0.05$, SL: Significance of Level, ns: non-significant, [1] Variance < 0 (negative value)

The interactive effect of the different factors was non-significant referring to that each studied factor is independent from the other in its effect on the seeds' N, P, or K content. Table 4b exhibits a significant increase in the total concentration (g kg^{-1}) of the Fe, Mn, and Zn in seeds resulted from the bio- and mineral fertilization as well as the MT of the dry and soaked seeds. Also, the bio-fertilized M dry seeds at the B level of mineral fertilization (75% of the recommended) contained the most significant relative increase in the Fe, Mn, and Zn in seeds by 43.91%, 47.06%, and 63.64%, respectively. The interactive effect between the bio- (F1) and mineral (F2) fertilization was significant for the estimated micronutrients in the dry and soaked seeds, which indicates that each of them completes the other and/or enhances its effect. The significant effect for the dry seeds was higher than for the soaked seeds. The interaction between the bio-fertilization and MT was significant only for the Mn (mg kg^{-1}) in the case of soaked seeds.

Table 4b. Concentrations of micronutrients content in seeds soybean after harvest (average values of the two seasons)

Treatments	N-P-K (kg ha^{-1})	Total concentration (mg kg^{-1})											
		Fe				Mn				Zn			
		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds	
		NM	M	NM	M	NM	M	NM	M	NM	M	NM	M
Without bio-fertilizers	A	53.29	56.96	52.40	54.23	42.31	45.96	39.52	44.63	32.56	37.12	30.14	33.52
	B	56.32	63.45	55.69	57.63	45.66	51.32	42.13	48.95	35.21	39.25	33.25	37.62
	C	59.85	68.23	58.00	62.14	47.32	56.32	44.25	51.32	38.62	42.16	34.69	41.36
With bio-fertilizers	A	59.55	65.21	57.63	62.54	47.99	49.32	47.63	49.32	37.52	39.21	35.20	39.21
	B	70.36	75.41	66.95	73.12	54.23	58.12	52.13	55.69	43.23	49.32	38.52	44.23
	C	65.32	69.87	62.14	68.39	51.32	54.39	49.32	53.12	40.55	46.23	36.21	42.31
F1	LSD	2.48		4.97		0.02		2.69		2.43		2.48	
	SL	**		*		***		*		*		*	
F2	LSD	1.63		3.26		0.04		1.77		1.59		1.63	
	SL	***		**		***		***		***		***	
F3	LSD	2.81		1.78		-[1]		1.36		1.23		1.26	
	SL	***		***		-		***		***		***	
F1*F2		***		*		***		*		**		*	
F1*F3		ns		ns		-		*		ns		ns	
F2*F3		ns		ns		-		ns		ns		ns	
F1*F2*F3		ns		ns		-		ns		ns		ns	

Remarks: A: 50% of the recommended dose (RD), B: 75% of the RD, C: 100% of the RD, NM: not magnetically treated, M: magnetically treated, F1: main factor (bio-fertilizer), F2: sub-factor (mineral fertilizer), F3: sub-sub factor (magnetic treatment), LSD: limit of standard deviation at $p < 0.05$, SL: Significance of Level, ns: non-significant, [1] Variance < 0 (negative value).

3.4. Effect of the studied factors on the nutrients' content in soybean straw

The macronutrient content (g kg^{-1}) in the soybean straw was increased but almost non-significantly and the only significant increase was due to the bio-fertilization effect on the straw N (g kg^{-1}) of the dry seeds and the straw P (g kg^{-1}) of the soaked seeds at the $p < 0.05$ level. Table 5a indicates that the highest relative increase was also for the bio-fertilized M dry seeds by 50.19%, 95.24%, and 28.5% for N, P, and K, respectively compared to the minimum observed value. The interaction between different factors was non-significant for the N, P, and K content in the straw.

The effect of the bio-fertilization on the total concentration (mg kg^{-1}) of micronutrients in the soybean straw was non-significant except for the Fe in the soaked seeds and the Mn in the dry seeds that was significant. The effect of the mineral fertilization was significant except for the concentration of the Mn and Zn (mg kg^{-1}) in the soaked seeds that was non-significant. The effect of the MT and the interactive effect of the studied factors were non-significant as shown in Table 5b. The highest relative increase was by 24.71%, 31.47%, and 88.51% for the Fe, Mn, and Zn, respectively, observed for the bio-fertilized M dry seeds at the 100% mineral fertilization rate.

3.5. Content of the protein (%), proline (mg g^{-1} dw), and chlorophyll (mg g^{-1} f.w) in the soybean plant under the effect of the studied treatments

The bio-fertilization (F1) has increased the seeds' protein (%) and leaves' chlorophyll (mg g^{-1}f.w) significantly while decreased the proline (mg g^{-1} dw) but non-significantly at the $p < 0.05$ for both the dry and soaked seeds. Mineral fertilization (F2) and MT (F3) have decreased the proline significantly while increased the seeds' protein non-significantly for both the dry and soaked seeds. Mineral fertilization has increased the chlorophyll content significantly in the case of dry seeds. The bio-fertilized M dry seeds showed the most significant relative increase in the protein (%) by 41.69% at the 75% mineral fertilization and in the chlorophyll (mg g^{-1} f.w) by 72.33% at the 100% mineral fertilization. The later rate showed also the most significant decrease in the proline (mg g^{-1}dw) by 57.33% relative to the maximum value observed for the NM soaked seeds. The combined effect of the bio-/mineral fertilization (F1 × F2) was significant for the proline content in case of the dry seeds.

3.6. Content of the amino acids (%), carbohydrates (%), and oil (%) in the soybean seeds under the effect of the studied treatments

Table 7 indicates that the amino acids (%) content in the soybean seeds was increased significantly for the dry and soaked seeds due to the individual factors F1, F2, and/or F3 at the significance level of $p < 0.05$. The carbohydrate (%) content was increased significantly for the soaked seeds due to bio-fertilization (F1) and dry seeds due to mineral fertilization (F2). The oil (%) content was increased significantly for the soaked seeds due to the individual and combined effect of the bio- and mineral fertilization. Almost the maximum increase in the amino acids, carbohydrates, and oil was 65.11%, 18.26%, and 18.49%, respectively, observed for the bio-fertilized M dry seeds at the 100% mineral fertilization relative to the minimum value observed for the NM soaked seeds.

Table 5a. Concentrations of macronutrients content in straw soybean after harvest (average values of the two seasons)

Treatment	N-P-K (kg ha^{-1})	Total concentration (g kg^{-1})											
		N				P				K			
		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds	
		NM	M	NM	M	NM	M	NM	M	NM	M	NM	M
Without bio-fertilizers	A	27.5	30.5	26.5	28.8	2.4	3.2	2.1	2.5	23.2	24.4	21.4	22.6
	B	29.5	32.5	29.6	31.2	2.7	3.7	2.4	2.9	24.1	26.3	22.4	24.3
	C	28.7	31.4	28.6	30.6	2.5	3.5	2.2	2.7	23.7	25.5	21.9	23.5
With bio-fertilizers	A	29.8	32.9	28.5	30.7	3.2	3.6	3.0	3.4	24.1	24.5	22.0	23.7
	B	31.5	39.8	30.9	32.7	3.5	4.1	3.5	3.7	26.7	27.5	23.6	25.6
	C	37.5	38.7	29.7	35.5	3.4	3.9	3.3	3.5	25.8	26.6	23.2	24.5
F1	LSD	0.5		8.3		0.8		0.7		33.1		11.0	
	SL	***		ns		ns		***		ns		ns	
F2	LSD	9.4		10.9		1.1		0.9		5.4		7.2	
	SL	ns		ns		ns		ns		ns		ns	
F3	LSD	8.4		7.3		0.7		0.8		5.9		7.6	
	SL	ns		ns		ns		ns		ns		ns	
F1*F2		ns		ns		ns		ns		ns		ns	
F1*F3		ns		ns		ns		ns		ns		ns	
F2*F3		ns		ns		ns		ns		ns		ns	
F1*F2*F3		ns		ns		ns		ns		ns		ns	

Remarks: A: 50% of the recommended dose (RD), B: 75% of the RD, C: 100% of the RD, NM: not magnetically treated, M: magnetically treated, F1: main factor (bio-fertilizer), F2: sub-factor (mineral fertilizer), F3: sub-sub factor (magnetic treatment), LSD: limit of standard deviation at $p < 0.05$, SL: Significance of Level, ns: non-significant.

Table 5b. Concentrations of micronutrients content in straw soybean after harvest (average values of the two seasons)

Treatment	N-P-K (kg ha^{-1})	Total concentrations (mg kg^{-1})											
		Fe				Mn				Zn			
		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds	
		NM	M	NM	M	NM	M	NM	M	NM	M	NM	M
Without bio-fertilizers	A	116.20	123.89	115.20	118.30	76.40	80.34	75.30	77.40	23.88	26.19	22.10	24.67
	B	125.77	131.00	120.30	128.30	83.20	87.55	78.40	79.50	29.00	32.88	28.90	29.70
	C	130.20	138.55	122.19	132.00	87.30	89.10	82.40	85.30	31.00	37.00	29.77	32.15
With bio-fertilizers	A	124.29	128.77	122.49	125.50	86.90	88.90	79.60	84.00	27.45	28.60	26.80	28.77
	B	130.54	140.00	128.30	135.90	94.60	96.90	83.85	87.60	35.76	37.90	34.80	36.75
	C	137.66	143.67	138.20	140.11	98.90	99.00	86.00	89.00	38.44	41.66	38.60	39.20
F1	LSD	8.28		8.28		7.67		8.28		8.28		8.28	
	SL	ns		*		*		ns		ns		ns	
F2	LSD	10.87		5.44		5.66		7.69		7.69		12.15	
	SL	*		**		**		ns		*		ns	
F3	LSD	7.26		9.38		9.24		7.26		7.26		4.19	
	SL	ns		ns		ns		ns		ns		ns	
F1*F2		ns		ns		ns		ns		ns		ns	
F1*F3		ns		ns		ns		ns		ns		ns	
F2*F3		ns		ns		ns		ns		ns		ns	
F1*F2*F3		ns		ns		ns		ns		ns		ns	

Remarks: A: 50% of the recommended dose (RD), B: 75% of the RD, C: 100% of the RD, NM: not magnetically treated, M: magnetically treated, F1: main factor (bio-fertilizer), F2: sub-factor (mineral fertilizer), F3: sub-sub factor (magnetic treatment), LSD: limit of standard deviation at $p < 0.05$, SL: Significance of Level, ns: non-significant.

4. DISCUSSION

Optimized agricultural practices are mandatory to maximize the crop productivity of reclaimed soils such as that under the present study being saline clay soil with a high $CaCO_3$ content (13.88%). Bio-fertilization, mineral N-P-K fertilization, MT of seeds as well as soaking the seeds before cultivation are practices that have been studied and used efficiently to improve plant productivity (Afzal et al., 2021; El-Serafy & El-Sheshtawy, 2020; Fouda, 2021; Harb et al., 2021; Zainuddin et al., 2022).

The nutrients' status of the studied soil in Table 2a and 2b reveals that the available N was significantly increased by the bio-fertilization (F1), mineral fertilization (F2), and the MT (F3) in both cases of the dry and soaked seeds. Magnetic treatment of seeds affects their behavior towards the nutrient uptake due to some bio-chemical changes that activate the germination and growth and consequently affect the remained available nutrients in the soil (Harb et al., 2021; Teixeira da Silva & Dobránszki, 2014). The available P was significantly increased by the mineral fertilization in both cases of seeds for P and in the case of dry seeds alone for K. This can be attributed to the added concentration of the N, P, and K salt being more soluble forms obtained from the mineral fertilization. The bioorganic forms of nutrients may be less soluble, slowly released and completely consumed during the cultivation season. The residual concentration of the minerals N, P, and K may be greater than the residual of the biocompatible bio-fertilizer that is easily absorbed by the plant leaving less remaining due to a higher uptake of nutrients by the plant. Another reason may be the presence of N-fixing bacteria, P-and K-dissolving bacteria in the bio-fertilizer that can increase their soluble forms to the extent that they are either highly uptake by plants or lost by leaching from soil giving a non-significant residual available concentration after harvesting (Zainuddin et al., 2022).

The increasing of available concentration of the Fe, Mn, and Zn in soil due to the factors F1, F2, and F3 was non-significant except for the effect of the bio-fertilization on the Fe and Zn in the case of the dry seeds. Either this behaviour can be attributed to a high uptake by plant or loss by leaching from soil giving non-significant residual available concentration after harvesting in addition that the applied mineral N-P-K fertilization is free from micronutrients.

The response of the dry and soaked seeds to the MT may be more reflected in the plant-related parameters than the soil-related ones. The yield of soybean seeds significantly increased by the bio-, mineral fertilization, and the MT in both cases of the dry and soaked seeds as indicated in Table 3a. Additionally, the doubled and tripled combination between the studied factors also affected the seed yield significantly at $p < 0.05$ in case of the dry seeds. Only the combined bio-/mineral or the mineral/magnetic effect was significant in the case of the soaked seeds.

When seeds are soaked, they absorb water and then expand with the formation of large deep pores. The intercellular space increases and the water diffusion increases with some gradual swelling of the cells. Furthermore, the separation between cells and the formation of channels increases that may lead to a larger area of tissue rupture. The soluble protein content of seeds may permeate into the soaking solution. Large-scale destruction of the cell structure and some loss of nutrients may be caused by cell damage and ion leakage. Seeds germination and the nutrients uptake during the plant growth are affected by the intercellular changes to some degree. Because of this reason, the MT of dry seeds in the present study showed a more significant relative increase in some of the estimated parameters in comparison to the soaking seeds in the MTW (Zhang et al., 2021).

Table 6. Content of protein (%), proline (mg g^{-1}dw), and chlorophyll (mg g^{-1}f.w) in the soybean plant under the effect of the studied treatments (average values of the two seasons)

Treatments	N-P-K (kg ha^{-1})	Protein (%)				Proline (mg g^{-1} dw)				Chlorophyll (mg g^{-1} f.w)			
		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds	
		NM	M	NM	M	NM	M	NM	M	NM	M	NM	M
Without bio-fertilizers	A	19.63	20.13	19.50	19.88	44.25	40.10	47.32	43.25	4.73	4.85	4.12	4.58
	B	20.31	21.00	20.00	20.88	38.25	30.52	42.03	34.23	4.88	4.97	4.65	4.85
	C	19.94	20.56	19.81	20.31	33.14	24.12	37.23	30.14	5.13	5.12	4.88	5.06
With bio-fertilizers	A	25.44	26.38	25.50	25.94	39.58	30.14	45.32	37.23	5.92	6.01	5.45	5.77
	B	27.19	27.63	25.94	27.31	31.56	25.23	40.19	33.25	6.18	6.38	5.75	6.03
	C	26.44	27.19	25.56	26.75	29.12	20.19	35.21	28.10	6.97	7.10	5.89	6.22
F1	LSD	0.09		3.31		7.45		2.48		0.83		0.83	
	SL	***		*		ns		ns		*		*	
F2	LSD	1.54		1.54		0.04		1.63		0.54		0.77	
	SL	ns		ns		***		***		*		ns	
F3	LSD	1.68		1.68		2.18		1.26		0.42		0.73	
	SL	ns		ns		***		***		ns		ns	
F1*F2		ns		ns		***		ns		ns		ns	
F1*F3		ns		ns		ns		ns		ns		ns	
F2*F3		ns		ns		ns		ns		ns		ns	
F1*F2*F3		ns		ns		ns		ns		ns		ns	

Remarks: A: 50% of the recommended dose (RD), B: 75% of the RD, C: 100% of the RD, NM: not magnetically treated, M: magnetically treated, F1: main factor (bio-fertilizer), F2: sub-factor (mineral fertilizer), F3: sub-sub factor (magnetic treatment), LSD: limit of standard deviation at p < 0.05, SL: Significance of Level, ns: non-significant.

Table 7. Content of amino acids (%), carbohydrates (%), and oil (%) in the soybean seeds under the effect of the studied treatments (average values of the two seasons)

Treatments	N-P-K (kg ha^{-1})	Amino acids (%)				Carbohydrate (%)				Oil (%)			
		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds		Dry seeds		Soaked seeds	
		NM	M	NM	M	NM	M	NM	M	NM	M	NM	M
Without bio-fertilizers	A	24.95	29.52	24.36	27.65	66.32	68.32	65.32	68.32	17.95	18.99	17.20	18.55
	B	26.48	32.46	25.69	29.41	70.45	74.65	69.23	72.13	18.66	19.68	17.89	18.96
	C	30.41	35.74	27.32	31.56	71.85	76.32	70.12	73.23	18.85	19.94	18.32	19.35
With bio-fertilizers	A	31.85	34.65	28.95	32.75	71.65	72.96	70.32	72.85	18.95	19.23	18.10	18.55
	B	34.65	38.65	31.56	36.42	73.41	75.61	72.63	75.54	19.85	19.97	18.75	19.35
	C	36.52	40.22	33.41	38.95	75.66	77.25	74.32	77.52	20.13	20.38	18.96	19.88
F1	LSD	2.49		0.03		12.4		0.03		1.66		0.01	
	SL	**		***		ns		***		ns		***	
F2	LSD	2.31		2.31		3.84		6.08		1.09		0.01	
	SL	**		**		*		ns		ns		***	
F3	LSD	2.18		2.52		3.63		2.96		0.84		-[1]	
	SL	**		**		ns		ns		ns		-	
F1*F2		ns		ns		ns		ns		ns		***	
F1*F3		ns		ns		ns		ns		ns		-	
F2*F3		ns		ns		ns		ns		ns		-	
F1*F2*F3		ns		ns		ns		ns		ns		-	

Remarks: A: 50% of the recommended dose (RD), B: 75% of the RD, C: 100% of the RD, NM: not magnetically treated, M: magnetically treated, F1: main factor (bio-fertilizer), F2: sub-factor (mineral fertilizer), F3: sub-sub factor (magnetic treatment), LSD: limit of standard deviation at $p < 0.05$, SL: Significance of Level, ns: non-significant, [1] Variance < 0 (negative value).

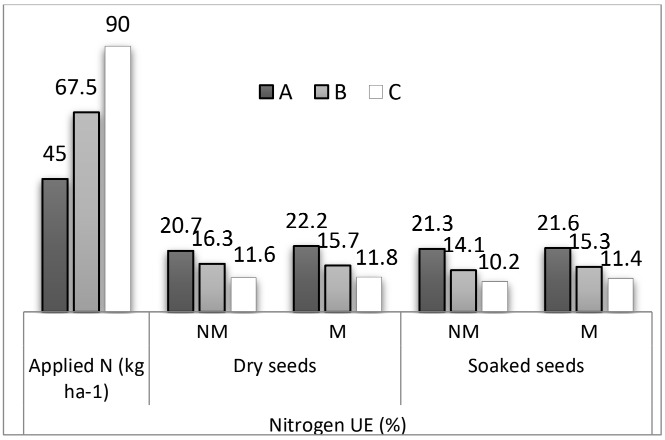

Figure 1a. Nitrogen use efficiency (NUE) at A, B, and C application rates of mineral N-P-K fertilization with biofertilization

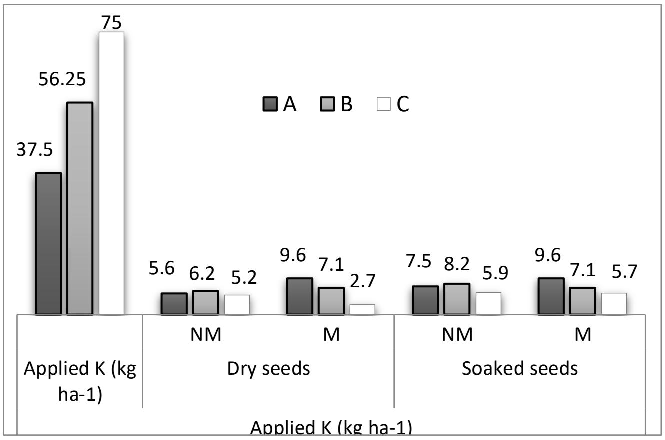

Figure 1c. Potassium use efficiency (KUE) at A, B, and C application rates of mineral N-P-K fertilization with biofertilization

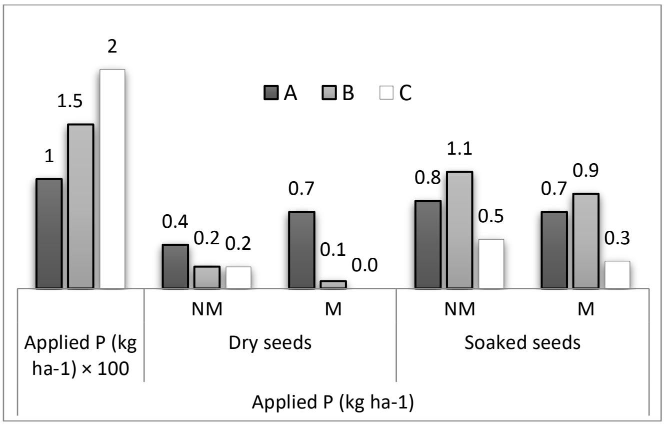

Figure 1b. Phosphorus use efficiency (PUE) at A, B, and C application rates of mineral N-P-K fertilization with biofertilization

Significant increases were observed in the concentrations of Fe, Mn, and Zn in seeds due to the individual F1, F2, and F3 and the combined bio-/mineral fertilization. This may refer to the efficiency of the studied factors in the enhancement of micronutrient uptake by the soybean seeds under the studied calcareous soil conditions commonly deficient in micronutrients. Sparingly soluble Fe (III) forms not available for root uptake under some conditions can be reduced by a Fe-reductase or via the acidification of the rhizosphere by the proton flux via a plasmalemma H-ATPase (Gonzalo et al., 2013).

This mechanism of the Fe availability in soil may occur under the effect of the bio- and/or mineral fertilization as well as the MT that enhances the Fe uptake by the plant. Salinity leads to the proline accumulation in the plant upon the osmotic stress. The chlorophyll content is much sensitive to salinity which causes a reduction in the photosynthesis and transpiration rates (Nazar et al., 2011). In the present study, the mineral fertilization (F2) and the MT (F3) as well as the combination between the bio- and mineral fertilization significantly decreased the accumulation of the proline in the soybean plant for both the dry and soaked seeds as indicated in Table 6.

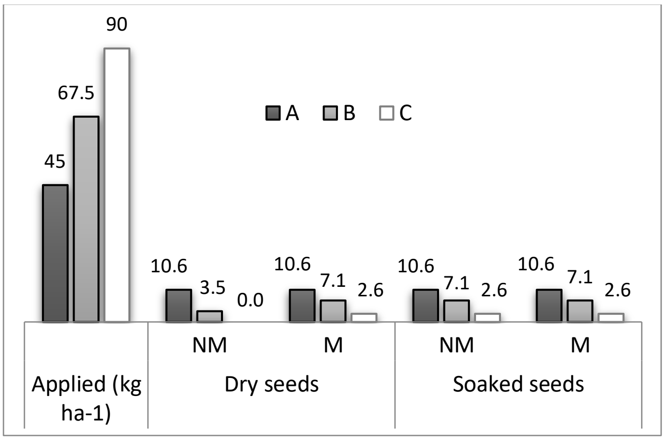

Figure 2a. Nitrogen agronomic efficiency (NAE) at A, B, and C application rates of mineral N-P-K fertilization with biofertilization

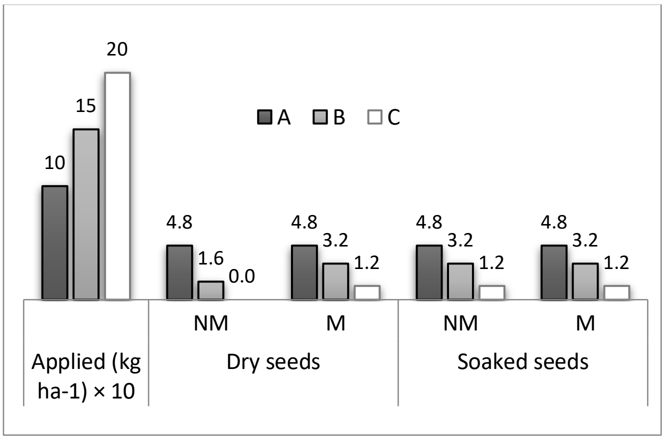

Figure 2b. Phosphorus agronomic efficiency (PAE) at A, B, and C application rates of mineral N-P-K fertilization with biofertilization

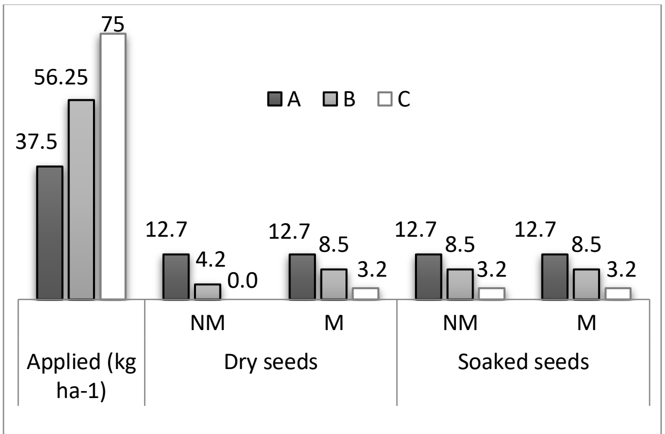

Figure 2c. Potassium agronomic efficiency (KAE) at A, B, and C application rates of mineral N-P-K fertilization with biofertilization

This can be a key factor behind the improved soybean yield and quality parameters. The studied factors F1, F2, and F3 may alleviate the effect of the $CaCO_3$ content and the stress of soil salinity, which increased the content of protein, chlorophyll, and amino acids.

According to Figures 1a and 1c, the maximum relative increase in the NUE and KUE were by 117.65% and 255.56%, respectively, obtained for the M dry seeds at a mineral fertilization rat A compared to the minimum calculated value. On the other hand, the maximum PUE was obtained for the NM soaked seeds at the mineral rate B. The intercellular bio-chemical changes that accompany soaking the seeds before cultivation may facilitate the uptake of phosphorus available in soil solution by plant which improves its use efficiency (Harb et al., 2021; Teixeira da Silva & Dobránszki, 2014).

At rates B and C, the AE values of the M dry seeds were equivalent to those of the M and NM soaked seeds, which were greater than the NM dry seeds. At rate A, the AE value was the same for all the NM and M dry and soaked seeds. Therefore, economically; the bio-fertilization applied in the present study is capable to optimize the AE of the application rate at 50% of the mineral N-P-K recommended dose regardless the seeds pre-sowing treatment either magnetic or by soaking. More yield and quality optimization can be attained by the magnetic pre-treatment and/or soaking of seeds before cultivation.

5. CONCLUSION

Magnetic treatment of the dry soybean seeds before cultivation along with the utilization of the bio-fertilizers combined with 75% of the recommended dose of the mineral N-P-K fertilizers was significantly efficient in improving the soybean yield and quality under saline calcareous soil conditions. These recommended agronomic practices produced the most significant increase in the soil available N (mg kg^{-1}), seeds yield (kg ha^{-1}), seeds' content of Fe, Mn, and Zn (mg kg^{-1}), and the amino acids (%). The proline (mg g^{-1}dw) was also significantly reduced that indicating an alleviation of the stress conditions.

Declaration of Competing Interest

The authors declare that no competing financial or personal interests that may appear and influence the work reported in this paper.

References

Abbas, M. T., Hamza, M. A., Youssef, H. H., Youssef, G. H., Fayez, M., Monib, M., & Hegazi, N. A. (2014). Bio-preparates support the productivity of potato plants grown under desert farming conditions of north Sinai: Five years of field trials. *Journal of Advanced Research*, *5*(1), 41-48. https://doi.org/10.1016/j.jare.2012.11.004

Abd El-Mohsen, A. A., Mahmoud, G. O., & Safina, S. A. (2013). Agronomical evaluation of six soybean cultivars using correlation and regression analysis under different irrigation regime conditions. *Journal of plant breeding and crop science*, *5*(5), 91-102. https://academicjournals.org/journal/JPBCS/article-full-text-pdf/7DCB9802359

Afzal, I., Saleem, S., Skalicky, M., Javed, T., Bakhtavar, M. A., Haq, Z., Kamran, M., Shahid, M., Saddiq, M. S., Afzal, A., Shafqat, N., Dessoky, E. S., Gupta, A., Korczyk-Szabo, J., Brestic, M., & Sabagh, A. E. L. (2021). Magnetic Field Treatments Improves Sunflower Yield by Inducing Physiological and Biochemical Modulations in Seeds. *Molecules 26*, 1-14.

Amer, M., El Sanat, A., & Rashed, S. H. (2014). Effects of Magnetized Low Quality Irrigation Water on Some Soil Properties and Soybean Yield (Glycine max L.) Under Salt Affected Soils Conditions. *Journal of Soil Sciences and Agricultural Engineering*, *5*(10), 1377-1388. https://doi.org/10.21608/JSSAE.2014.49755

El-Serafy, R. S., & El-Sheshtawy, A. A. (2020). Effect of nitrogen fixing bacteria and moringa leaf extract on fruit yield, estragole content and total phenols of organic fennel. *Scientia Horticulturae*, *265*, 109209. https://doi.org/10.1016/j.scienta.2020.109209

FAO. (2014). *World reference base for soil resources 2014: International soil classification system for naming soils and creating legends for soil maps*. Food and Agriculture Organization of The United Nations. https://www.fao.org/3/i3794en/I3794en.pdf

Fouda, S. E. E. (2021). Cyanobacteria and N-Fertilization Enhance the Efficiency of Rice Plants Grown Under Saline Soil Conditions. *Egyptian Journal of Soil Science*, *61*(1), 63-77. https://doi.org/10.21608/ejss.2021.56333.1420

Gonzalo, M. J., Lucena, J. J., & Hernández-Apaolaza, L. (2013). Effect of silicon addition on soybean (Glycine max) and cucumber (Cucumis sativus) plants grown under iron deficiency. *Plant Physiology and Biochemistry*, *70*, 455-461. https://doi.org/10.1016/j.plaphy.2013.06.007

Hagaggi, N. S. A., & Mohamed, A. A. A. (2020). Enhancement of Zea mays (L.) growth performance using indole acetic acid producing endophyte Mixta theicola isolated from Solenostemma argel (Hayne). *South African Journal of Botany*, *134*, 64-71. https://doi.org/10.1016/j.sajb.2020.02.034

Harb, A. M., Alnawateer, B. a. M., & Abu-Aljarayesh, I. (2021). Influence of Static Magnetic Field Seed Treatments on the Morphological and the Biochemical Changes in Lentil Seedlings (Lens Culinaris Medik). *Jordan Journal of Biological Sciences*, *14*(1), 179-186. https://jjbs.hu.edu.jo/files/vol14/n1/Binder14n1.pdf

Helaly, A. A., Hassan, S. M., Craker, L. E., & Mady, E. (2020). Effects of growth-promoting bacteria on growth, yield and nutritional value of collard plants. *Annals of Agricultural Sciences*, *65*(1), 77-82. https://doi.org/10.1016/j.aoas.2020.01.001

Li, Y., Li, H., Han, X., Han, G., Xi, J., Liu, Y., Zhang, Y., Xue, Q., Guo, Q., & Lai, H. (2022). Actinobacterial biofertilizer improves the yields of different plants and alters the assembly processes of rhizosphere microbial communities. *Applied Soil Ecology*, *171*, 104345. https://doi.org/10.1016/j.apsoil.2021.104345

Nafady, N. A., Hashem, M., Hassan, E. A., Ahmed, H. A. M., & Alamri, S. A. (2019). The combined effect of arbuscular mycorrhizae and plant-growth-promoting yeast improves sunflower defense against Macrophomina phaseolina diseases. *Biological Control*, *138*, 104049. https://doi.org/10.1016/j.biocontrol.2019.104049

Nazar, R., Iqbal, N., Syeed, S., & Khan, N. A. (2011). Salicylic acid alleviates decreases in photosynthesis under salt stress by enhancing nitrogen and sulfur assimilation and antioxidant metabolism differentially in two mungbean cultivars. *Journal of Plant Physiology*, *168*(8), 807-815. https://doi.org/10.1016/j.jplph.2010.11.001

Oliveira, V., Dias-Ferreira, C., González-García, I., Labrincha, J., Horta, C., & García-González, M. C. (2021). A novel approach for nutrients recovery from municipal waste as biofertilizers by combining electrodialytic and gas permeable membrane technologies. *Waste Management*, *125*, 293-302. https://doi.org/10.1016/j.wasman.2021.02.055

Piper, C. S. (2019). *Soil and plant analysis*. Scientific Publishers. https://www.scientificpubonline.com/bookdetail/soil-plant-analysis/9788172336202/0

Radhakrishnan, R. (2019). Exposure of magnetic waves stimulates rapid germination of soybean seeds by enzymatic regulation in cotyledons and embryonic axis. *Biocatalysis and Agricultural Biotechnology*, *20*, 101273. https://doi.org/10.1016/j.bcab.2019.101273

Rayment, G. E., & Lyons, D. J. (2010). *Soil Chemical Methods - Australasia*. CSIRO publishing. https://doi.org/10.1071/9780643101364

Roozbeh, M., Sheikhdavoodi, M., Almassi, M., & Bahrami, H. (2011). Effects of tillage intensity and anionic polyacrylamide on sediment and nitrogen losses in irrigated wheat field. *African Journal of Agricultural Research*, *6*(23), 5320-5327. https://academicjournals.org/journal/AJAR/cited-by-article/C7A4C8237926

Sayed, E. G., & Ouis, M. A. (2022). Improvement of pea plants growth, yield, and seed quality using glass fertilizers and biofertilizers. *Environmental Technology & Innovation*, *26*, 102356. https://doi.org/10.1016/j.eti.2022.102356

Teixeira da Silva, J. A., & Dobránszki, J. (2014). Impact of magnetic water on plant growth. *Environmental and Experimental Biology*, *12*, 137-142. http://eeb.lu.lv/EEB/201412/EEB_XII_4_Teixeira_da_Silva_1.shtml

Yadav, A. N., Kour, D., Kaur, T., Devi, R., Yadav, A., Dikilitas, M., Abdel -Azeem, A. M., Ahluwalia, A. S., & Saxena, A. K. (2021). Biodiversity, and biotechnological contribution of beneficial soil microbiomes for nutrient cycling, plant growth improvement and nutrient uptake. *Biocatalysis and Agricultural Biotechnology*, *33*, 102009.

Yanni, Y., Zidan, M., Dazzo, F., Rizk, R., Mehesen, A., Abdelfattah, F., & Elsadany, A. (2016). Enhanced symbiotic performance and productivity of drought stressed common bean after inoculation with tolerant native rhizobia in extensive fields. *Agriculture,* *Ecosystems & Environment*, *232*, 119-128. https://doi.org/10.1016/j.agee.2016.07.006

Zainuddin, N., Keni, M. F., Ibrahim, S. A. S., & Masri, M. M. M. (2022). Effect of integrated biofertilizers with chemical fertilizers on the oil palm growth and soil microbial diversity. *Biocatalysis and Agricultural Biotechnology*, *39*, 102237. https://doi.org/10.1016/j.bcab.2021.102237

Zhang, L., Hu, Y., Wang, X., Abiola Fakayode, O., Ma, H., Zhou, C., Xia, A., & Li, Q. (2021). Improving soaking efficiency of soybeans through sweeping frequency ultrasound assisted by parameters optimization. *Ultrasonics Sonochemistry*, *79*, 105794. https://doi.org/10.1016/j.ultsonch.2021.105794