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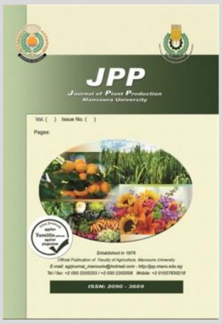
Effect of Biological, Chemical and Physical Agents on Common Bean Plant under Saline Conditions

Abeer I. Shabana[1*]; Doaa M. Mostafa[1] and M. A. M. Abd El-Hady[2]

[1] Vegetable Res. Dept., Hort. Res. Institute (HRI), Agric. Res. Center (ARC), Giza, Egypt
[2] Veget. and Flori. Dept., Fac. Agric., Damietta Univ., Egypt



ABSTRACT

Phaseolus vulgaris L. are salt-sensitive plants in all growth phases. Hence, this study aimed to investigate the benefit impacts of magnetized water (MW) alone or combined with soil amendment by agricultural gypsum and plant inoculation with vesicular arbuscular micorrhyzal fungi (AMF) on growth (plant height, dry weight and leaf area), relative water content (RWC%), water retention capacity (WRC), salt tolerance index (STI%), foliage mineral contents (N, P, K, Ca and Na), (K$^+$+Ca^{2+})/Na$^+$ ratio and yield components (number of pods/plant, number of seeds/pod, 100seeds weight, seed yield/feddan and harvest index%) of dry bean cv. Nebraska grown under salinity conditions. The study was conducted in Dakahlia Governorate at the northeastern of the Delta Egypt during summer seasons of 2019 and 2020. A split plot design with three replicates was used. Salinity significantly reduced all traits, particularly seed yield (around 53.9% losses), except Na%. Magnetized water (MW) and soil amendments sole or in combination had a tendency to increase all studied parameters, except Na%. Moreover, a negative relationship was observed between foliage Na content and seed yield, whereas a positive one was observed between salt tolerance index% and (K$^+$+Ca^{2+})/Na$^+$ ratio which were more reliable in selection criterion in bean plant. Overall, the treatment of magnetized water + gypsum + micorrhyzae is a very important management tool in common bean production in the clay and intermediate salinity soils of northern Delta of Egypt.

Keywords: *Plaseolus valgaris*, Mycorrhiza, magnetized water, Gypsum, salinity, yield

INTRODUCTION

Overcoming salt stress is a main issue to secure crop productivity. On a global scale, more than 33% of cultivated lands are estimated to be salt-affected (FAO, 2008) which mostly exist in arid and semi-arid climates, where annual rainfall less than 500 mm coupled with high evaporation due to the forecasted effects of climate change. Finally, the result is the accumulation of large amount of salts in the lands. Egypt is characterized as arid zone that has high evaporation rates (1500-2400 mm/year) and very low rainfall (5-200 mm/year), besides the relatively high air temperature in summer seasons (more than 31.6ºC in 2019 and 2020). Soil and water salinity stresses were magnified after the interruption of the Nile flood, particularly in north Delta, near the Nile estuary. Officially, Egypt is classified as salt-affected land two decades ago according to Executive Authority for Land Improvement Projects (EALIP), Egyptian Ministry of Agriculture (60% of the cultivated soil in the north Delta, 20% in the South and Middle Delta and 20% in Upper Egypt).

Phaseolus valgaris is considered as the most favorable legumes valued for its nutritional value, especially protein and energy rich dry seeds as well as its ability to maintain soil fertility through its excellent capacity to fix atmospheric nitrogen. The total area devoted to such important crop was 396665 and 27255 hectares for dry and green bean, respectively in 2017 according to FAO. The threshold level varies within species and their varieties. Unfortunately, bean is a glycophyte, salt-sensitive crop, with threshold value of 1.0 dSm^{-1} and a linearly and asymptotically decline in yield of 19.0% per dSm^{-1} (Maas, 1990). The main effect of salinity on plants is osmotic stress. Osmotically, plants growing in saline conditions appear wilting i.e., water stressed because of the difficulty in water absorption by roots. Physiological unavailability of water condition is known as wet drought conditions. Therefore, plants uptake salt in order to adjust their osmotic pressure in an attempt to cope with salinity stress. The low water potential and high potentially toxic ions (Na$^+$ and Cl$^-$) in the soil lead to water deficit and nutritional imbalance (Levitt, 1980) which directly or in directly inhibit plant growth by disturbing the physiological processes, i.e., germination, growth, photosynthesis, respiration and metabolite accumulation (Ebrahim and Saleem, 2017 and Zayed *et al.*, 2017), in addition to the overproduction of reactive oxygen species (ROS) that limits several enzymes activity. Therefore, DNA mutation, protein denaturation, reduction of ATP generation and redox metabolites, essential for cellular defense and repair, are occurred (Li, 2009 and Belew *et al.*, 2010). These detrimental effects decrease plant tolerance to salinity and cause growth retardation and early senescence (Hashem *et al.*, 2015). The basic salt tolerance to counteract cellular dehydration and ion toxicity involves ion homeostasis, maintenance of cellular osmotic balance and water transport into the cell, compartmentalization of toxic ions in the vacuole and synthesis and accumulation of osmolytes or compatible solutes in the cytoplasm (Al Hassan *et al.*, 2016).

On the other hand, salinity affects the soil physical properties i.e., disperses soil aggregates and therefore plugs soil pores and impedes water movement and soil drainage. For reclamation, replacement of excess Na ions from the exchange

[*] Corresponding author.
E-mail address: abeershabana1@gmail.com
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complex, leaching out the salts below the rhizosphere and provision of adequate drainage are to be accomplished and to overcome the cementing effect of saline soil and therefore improve permeability and air water relations. Sodium (Na^+) is a much poorer aggregator than calcium (Ca^{+2}) because of its less charge and larger ion size. Therefore, gypsum ($CaSO_4.2H_2O$), soluble sources of calcium, is the most commonly used chemical amendment because of its low cost and abundant availability. According to Sharma and Minhas (2005), chemical reclamation of gypsum could be clarified by the exchange reaction given in the following equation:

$2Na\text{- clay} + Ca^{+2}\ (\text{solution}) \longrightarrow Ca\text{-clay} + 2Na^+\ (\text{solution}) \downarrow$ (leachable). Also, the effect of sulfur as a component of gypsum on reducing soil pH and hence increasing minerals availability cannot be ignored.

However, biological reclamation by beneficial microorganisms e.g., vesicular arbuscular mycchorhizal fungi (AMF) is now a well-recognized requirement. It could be a cost effective and sustainable approach to enhance the salt tolerance of economically important crops such as beans. Under saline condition, AMF symbiosis improves host plant growth by increasing water uptake, availability of several essential elements and photosynthetic rate (Abeer, 2004; Selvakumar *et al.*, 2018 and Garcia *et al.*, 2019) as well as reduce oxidative damage through strengthening of the antioxidant defense system (Hashem *et al.*, 2015). Additionally, AMF increase soil moisture retention (Ruiz-Lozano, 2003) and production of glycoprotein known as glomalin-related soil protein (GRSP). GRSP, an extracellular secretion of AMF, has been shown to increase soil aggregate stability, soil water potential and overall increase in crop yield (Lˇü *et al.*, 2019)

Moreover, irrigation with magnetized water (MW) is another special aspect of using magnetic fields as a physical treatment for improving crop production, especially under salinity stress. Magnetization changes water solidifying and boiling point, viscosity and dielectric constant and the formation of clustering structures which increase polarization and decrease surface tension force without molecular changes (Pang and Deng, 2008). Consequently, many growth traits are positively affected due to induction of some biochemical and physiological processes in the plant. Snow pea irrigated with 1000 ppm saline water exhibited increases in yield and dry weight of pods by 6% and 8.2%, respectively (Maheshawari and Grewal, 2009). External exposure to magnetic fields has significantly improved the growth and productivity of horticultural crops.

Over the next decades, effective approaches to increase bean yield could be based on raising plant salt tolerance from one side and improving water and land quality to another side. Therefore, the present investigation aimed to study the individual and combined effects of agricultural gypsum additive as a traditional method for soil salinity treating, AMF inoculation for avoidance of salt absorption and irrigation with magnetized water for improving saline water quality on common bean grown in north Nile Delta conditions.

MATERIALS AND METHODS

The Experiments were conducted in private farm located near Sherbeen district, at the northeastern of the Delta Egypt, (31°.20′N, 31°.53′E with an elevation of 11 meters above sea level), Dakahlia Governorate, where salinity level of irrigation water at the ends of the canal, near the outlet of the River Nile, exceeds the critical limit of beans, as shown in Table (1). Besides, the moderate salinity of the experimental soil as shown in Table (2) which was formed mainly by the accumulation of salts from the succession of irrigation with saline water for long periods. Bean seeds cv. Nebraska were sown on 25th February in both seasons of 2019 and 2020 in 7cm apart on two sides of the ridge. The experimental unit area was 10.5 m^2 and it contains three ridges with 5m in length and 70cm in width.

Table 1. Chemical analysis of the irrigation water in the seasons of 2019 and 2020.

Properties	EC (dSm^{-1})	pH	Soluble cations ($meq.l^{-1}$)				Soluble anions ($meq.l^{-1}$)		
			Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	SO_4^{--}	HCO_3^-
1st season	1.55	7.7	13.6	0.41	5.08	5.38	10.03	2.33	6.20
2nd season	1.62	7.8	13.9	0.32	4.73	5.23	9.67	2.58	5.71

Table 2. Physical and chemical analysis of the experimental soil.

Properties	1st season	2nd season
Physical analysis		
Clay %	43.2	41.9
Silt %	30.1	31.2
Sand %	26.7	26.9
Texture class	loam Clay	loam Clay
Chemical analysis		
PH (1:2.5)	8.1	8.3
EC(dSm^{-1}) (1:5)	3.17	3.51
SAR%	15.03	15.29
ESP	25.6	26.0
OM%	1.86	1.93
$CaCO_3$ (g/kg)	2.81	2.65
Soluble cations (meq/L)		
Ca^{++}	16.47	15.82
Na^+	41.25	44.70
K^+	0.82	0.67
Soluble anions (meq/L)		
HCO_3^-	7.33	5.12
Cl^-	32.73	40.55
SO_4^{--}	31.65	36.12

The applied treatments:

1- Gypsum Treatment:

The dose of gypsum needed for reducing exchangeable sodium percentage (ESP) of the experimental soil from 26% to 20% was 4 tons/fed. according to USDA (1954). Agricultural gypsum was added two weeks before sowing by thoroughly flipping with the upper 30cm layer of the soil followed by heavy irrigation.

2- AMF treatment:

The AMF inoculum was provided from Agricultural Research Center, Cairo. An inoculum consisting of 20 g of rhizosphere soil, approx. 950 spores of *Glomus spp.* and 0.5 g of infected onion root fragments, was used as a thin layer at 3cm-depth beneath the seeds at the time of sowing before sunrise to avoid the inhibition effect of direct light on mycorrhizal spores. However, the nonmycorrhizal plants were supplied with filtered washings of an equal amount of the rhizosphere soil to provide the same associated microorganisms other than mycorrhizal propagules.

3- Generation and treatment of magnetic field:

Irrigation water was magnetized by an electromagnetic field generator Delta Water (Alexandria based Egypt company), with magnetic induction ranged between 100 and 150 mT and internal diameter of 1 inch (Fig.

1). In the surface irrigation system followed in this experiment, the device is embedded beneath the soil surface in front of the irrigation canal. The plants received magnetized irrigation water throughout the experiment period.

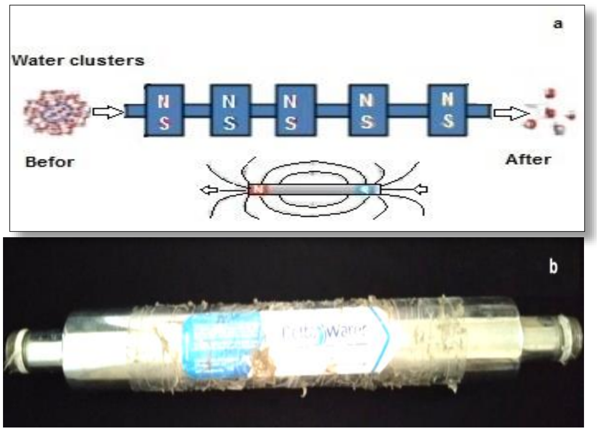

Fig. 1. a: A Schematic diagram of water flow direction in permanent magnets; b: A photo of used magnetic treatment device.

Experimental design:

The experiment was laid out in a split plot design with three replicates. Tow treatments of irrigation water i.e., magnetized water (MW) and plain water (PW) were represented in the main plot, while, 4 soil and plant treatments (control, agricultural gypsum, AMF inoculation and Gypsum + AMF) were represented in the sub plot.

1-Data recorded:

1- a- Vegetative growth traits and total chlorophyll content of leaves:

A sample of three plants was randomly taken from each plot after 50 days from sowing to determine plant height (cm), dry weight/plant (g) and leaf area (cm^2/plant). Moreover, total chlorophyll of leaves was estimated according to Von Wettstein (1957).

1 - b- Water relationship and salt tolerance index:

Water relationship as relative water content (RWC) and water retention capacity (WRC) was estimated. Six leaf slides of each replicate were taken, soaked with distilled water into Petri dish for 24 hr. then dried for 48 hr. to estimate fresh, turgid and dry weights, respectively. RWC and WRC were measured according to Taiz and Zeiger (1998) using the following equations:

$$RWC\% = \frac{Fresh\ weight - Dry\ weight}{Turgid\ weight - Dry\ weight} \times 100$$

$$WRC = \frac{Turgid\ weight}{Dry\ weight}$$

Furthermore, salt tolerance index (STI) of plant dry weight trait was calculated according to Ali *et al.*, (2007) using the formula:

$$STI\% = \frac{Plant\ dry\ weight\ of\ assigned\ treatment}{Plant\ dry\ weight\ of\ salt\ stressed\ treatment} \times 100$$

2- Chemical analysis of the foliage:

Three plants from each plot at 50 days after sowing were taken to determine mineral contents. Nitrogen was estimated using micro-keldahl according to Cottteni *et al.*, (1982). Phosphorus was colorimetrically determined according to Sandell (1950). Also, potassium and Calcium were determined according to Horneck and Hanson (1998) and Chapman and Pratt (1961), respectively, while, sodium was determined spectro-photometrically according to Johanson and Ulrichs (1959). Moreover, (K^++ Ca^{2+})/Na^+ ratio was calculated by dividing the K^++Ca^{2+} (%) on Na^+ (%).

3- Pods and seed yield attributes:

At harvest time, samples of ten plants were taken randomly from each plot to determine the number of pods per plant, number of seeds/pod, 100 seed weight and harvest index. Harvest index was calculated as the following formula:

$$Harvest\ index\% = \frac{Seed\ yield}{Total\ plant\ wieght\ (including\ pods)} \times 100$$

Seed yield of each plot was harvesting, threshing and weighing. Seed yield was then expressed in kg fed^{-1}.

Statistical analysis

Data statistically analyzed using CoSTAT statistical package (Version 6.303, CoHort, USA, 1998-2004). The statistical analysis performed was two-way ANOVA due to the split plot design, and its two factors (irrigation water treatment and soil amendments). Duncan Multiple Range Test (DMRT) was used to test the significant differences between treatment means at 5% level of probability. In addition, correlations between (K^++Ca^{2+})/Na^+ ratio and salt tolerance index and between Na content of foliage and seed yield (kg/fed.) were analyzed.

RESULTS AND DISCUSSION

1-Vegetative growth, total chlorophyll, water relationship and salt tolerance index attributes:

Increasing salinity level above the threshold value (1.0 dSm^{-1}) significantly suppressed all studied traits. Accordingly, Table 3 and Fig. 2 and 3 clear that plant height, dry weight, leaf area, total chlorophyll, relative water content (RWC%), water retention capacity (WRC) and salt tolerance index (STI) adversely affected under salinity condition, whereas they significantly enhanced by magnetized irrigation water (MW). Also, the treatment of gypsum, AMF sole or in combination improved all studied traits and the dual treatment was more pronounced in this respect during both seasons of the experiment. Concerning the interaction between MW, gypsum and AMF, the same table and figures reveal that all treatments could effectively mitigate the adverse impacts of salinity on bean plant, represented by the vegetative growth traits, total chlorophyll content of leaves and water relations, as well as STI. The highest values were obtained by the treatment of MW+ gypsum+AMF followed by those of MW+AMF and MW+ gypsum, alternatively.

Fig. 2. A photograph of common bean plant, Nebraska cv., shows the effect of 1: control (PW); 2: MW; 3: MW+gypsum; 4: MW+AMF; 5: MW+ gypsum+AMF under salinity stress conditions.

The reduction in water uptake as a common effect of salinity stress reflected on cell expansion hence reduction in leaf area and drastic disturbances in normal metabolism resulting in cessation of growth (Khan *et al.*, 2015). Also, leaf area, total chlorophyll content and mineral contents as shown later in Tables 3 and 4 have been reflected on total dry matter production. Restricted water supply conditions results in early stomatal closure which reduces internal CO2 level and the continuous exposure to sunlight causes transfer of electrons to molecular oxygen resulting in generation of superoxide ions, one of the reactive oxygen species (ROS), at photosystem I (PSI) by the process called as Mehler reaction (Asada 2006 and Garcia *et al.*, 2019). ROS generation exceeds the scavenging potential of cellular defense system resulting in oxidative stress that damages cellular components resulting in their dysfunction (Ahanger *et al.*, 2017). The reduction in shoot and root growth due to salinity may be attributed to the significant increase in the content of malondialdehyde, a product of lipid peroxidation, (Taïbi *et al.*, 2016) and to energy expenditure in the synthesis of compatible osmolytes needed to keep root water potential lower than that of the external medium.

Table 3. Effect of magnetized water, gypsum and mycorrhiza on growth traits, total chlorophyll of leaves and water relationship of common bean grown under saline conditions during seasons of 2019 and 2020.

Parameters		**Plant height (cm)**		**Dry Weight (g/ plant)**		**Leaf area (cm^2)**		**Total chlorophyll (mg/g fw)**		**RWC %**		**WRC**	
Treatments		**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**
MW	PW	40.0 b	35.6b	10.25b	8.72b	258.3b	244.7b	2.07b	1.97b	54.55b	43.69b	5.33b	5.15b
	MW	47.2 a	41.4a	12.66a	11.78a	338.2a	326.5a	2.79a	2.69a	70.47a	63.39a	6.65a	5.84a
Soil amends	Without amends	38.8d	34.3d	10.13c	9.07d	264.3d	256.0d	2.11d	2.02d	45.48d	41.11d	5.74c	5.55b
	Gyps	44.3b	39.8b	11.15b	9.92c	304.12b	290.1b	2.36c	2.29c	58.37c	50.9c	5.93b	5.19c
	AMF	41.8c	37.8c	11.50b	10.42b	295.5c	279.8c	2.53b	2.47b	66.51b	55.66b	5.92b	5.18c
	Gyps +AMF.	49.3a	42.2a	13.03a	11.58a	329.4a	316.5a	2.73a	2.55a	79.89a	66.51a	6.38a	6.06a
Interaction													
PW	Without amends	35.0f	30.7f	8.67e	7.27g	226.1g	217.3g	1.58g	1.51h	35.43g	29.42e	5.24f	5.07f
	Gyps	41.3d	39.0cd	10.33cd	8.26f	272.4e	256.5e	2.04f	1.98g	51.07f	41.4d	5.29e	5.06f
	AMF	39.3e	35.3e	9.97d	9.27e	254.9f	235.8f	2.22e	2.16f	60.67d	50.98c	5.26ef	5.13e
	Gyps +AMF	44.3c	37.6d	12.03b	10.07d	279.9d	269.3d	2.43d	2.22e	71.04b	52.97c	5.54d	5.34c
MW	Without amends	42.7c	38.1d	11.60b	10.87c	302.5c	294.7c	2.63c	2.52d	55.52e	52.8c	6.23c	6.04b
	Gyps	47.4b	40.6b	12.67b	11.56b	335.8b	323.6b	2.68c	2.60c	65.67c	60.4b	6.58b	5.33c
	AMF	44.4c	40.3bc	12.33b	11.57b	336.0b	323.7b	2.83b	2.77b	72.35b	60.3b	6.58b	5.23d
	Gyps +AMF	54.3a	46.6a	14.03a	13.10a	378.8a	363.8a	3.03a	2.89a	88.33a	80.0a	7.22a	6.76a

MW: magnetized water; PW: plain water; Gyps: gypsum and AMF: mycorhizal fungi; RWC: relative water content; WRC: water retention capacity. Means followed by the same letters within each column are not significantly differed at 0.05.

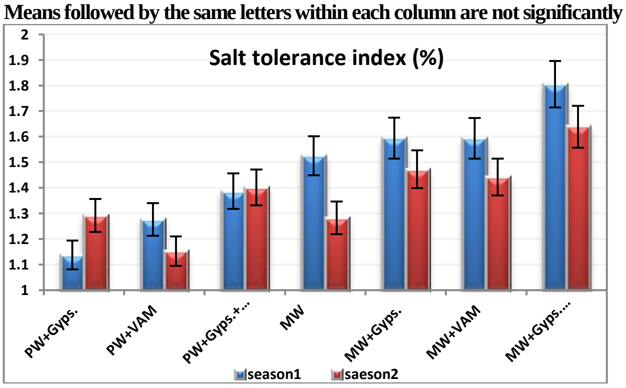

Fig. 3. Effect of magnetized water, gypsum and mycorrhizae on salt tolerance index of bean plant during seasons of 2019 and 2020.

Further, magnetic field could induce biochemical changes that stimulate growth related reactions in normal and salinity conditions, since it was proved as the best application in reducing salt concentration in soil surface and resulting in higher mass production of plants. Positive effects of magnetized water on vegetative growth, water relationship and total chlorophyll content could be referred to the improved capacity of nutrients and water uptake (Sadeghipour and Aghaei, 2013; Hameda, 2014 and Dawa *et al.*, 2019). On the other hand, gypsum additive improves some physio-chemical properties of salt affected soils such as electric conductivity and basic infiltration rates (Amer and Hashem, 2018), pH and particles aggregation which in turn enhance bean plant growth. In addition, gypsum ingredients of 23% calcium and 18% sulfur can reduce the deleterious effects of salinity. Calcium plays essential roles in processes that stabilize cell wall structures (Neves-Piestun and Bernstein, 2001), preserve the structural and functional integrity of cell membranes (Tuna *et al.*, 2007), control ion-exchange behavior and regulate ion transport and selectivity (Hadi and Karimi, 2012). Sulfur, however, plays key roles in the plants metabolism and provides structural components of essential molecules, i.e. cysteine, and as a S-donor in glutathione and abscisic acid (ABA) synthesis that helps in detoxification of ROS (Evelin *et al.*, 2019), in addition to act as signaling molecules for cellular communication with the environment (Nazar *et al.*, 2011).

Moreover, AMF promote root development and alter root architecture by the production of phytohormones such as IAA, cytokinins, and gibberellins (Hashem *et al.*, 2015). The fungus hyphae often penetrate more than 7cm beyond the root into the rhizosphere to absorb water and nutrients far from saline area which enhances the growth of mycorrhizal plants grown in saline environment (Kumar *et al.*, 2010). AMF exudates i.e., GRSP (Lˇü *et al.*, 2019) affect the physical, chemical and biological properties of soils, particularly soil moisture retention properties thus improved stress resistance by facilitating soil water uptake (Garcia *et al.*, 2019 and Lˇü *et al.*, 2019). Finally, AMF protect plants under osmotic stress against the oxidative damage by altering some plant antioxidant enzymes and growth substances, i.e., cytokinin-like substances (Barea and Azcon-Aguilar, 1982) and ABA (Danneberg *et al.*, 1992). Also, it was found that nitrate reductase activity, the first enzyme in the NO3 assimilation pathway, photosynthetic rate and minerals uptake were higher in mycorrhizal plants subjected to water stress. Such enhancement correlates with a higher tolerance of AMF plant to stress in terms of plant biomass production (Ruiz-Lozano, 2003; Evelin *et al.*, 2019 and Garcia *et al.*, 2019). It is of important also to mention that variation in plant sizes could theoretically contribute to differences in the salinity tolerance which could be applied in an initial selection of the most tolerant plants in breeding programs to improve salt tolerance of beans after further analysis at later developmental stages (Al Hassan *et al.*, 2016).

2- Chemical constituents of bean foliage:

Salinity conditions add a new level of complexity to the mineral nutrition of crops. Table 3 and Fig.4 clearly illustrate that under salinity stress conditions, MW increased N, P, K and Ca contents as well as (K++Ca2+)/Na+ ratio in bean foliage compared with plain water (PW).

Table 4. Effect of magnetized water, gypsum and mycorrhizae on chemical analysis of common bean foliage under saline conditions during seasons of 2019 and 2020.

Parameters		N%		P%		K%		Ca%		Na%	
Treatments		**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**
MW	PW	2.87b	2.78b	0.35b	0.31b	2.85b	2.70b	1.12b	1.08b	0.43a	0.53a
	MW	3.14a	3.17a	0.43a	0.42a	3.08a	3.08a	1.22a	1.14a	0.38b	.044b
Soil amends	Without amends	2.78c	2.65b	0.30d	0.30d	2.70d	2.72d	1.10d	1.06c	0.47a	0.56a
	Gyps	2.97b	3.08a	0.35c	0.35c	2.86c	2.83c	1.15c	1.13b	0.40b	0.49b
	AMF	3.14a	3.06a	0.42b	0.39b	3.11b	2.96b	1.20b	1.11b	0.38c	0.48b
	Gyps+ AMF.	3.15a	3.10a	0.50a	0.44a	3.19a	3.04a	1.24a	1.15a	0.38c	0.43c
Interaction											
PW	Without amends	2.50d	2.30e	0.27f	0.23g	2.55g	2.43h	1.03f	0.10d	0.55a	0.64a
	Gyps	2.87c	2.80d	0.30e	0.29f	2.71f	2.60g	1.17d	1.11cd	0.41b	0.52b
	AMF	3.05b	2.97c	0.35d	0.32e	3.00d	2.81f	1.10e	1.09d	0.38cd	0.52b
	Gyps +AMF	3.05b	3.03c	0.48b	0.41c	3.12c	2.93e	1.20c	1.12bc	0.38cd	0.44d
MW	Without amends	3.05b	3.00c	0.32e	0.36d	2.85e	3.01d	1.16d	1.12bc	0.38cd	0.47c
	Gyps	3.07b	3.37a	0.39c	0.41c	3.01d	3.05c	1.24b	1.14b	0.39bc	0.44d
	AMF	3.22a	3.15b	0.49b	0.45b	3.21b	3.11b	1.21c	1.13bc	0.38cd	0.44d
	Gyps +AMF	3.24a	3.17b	0.52a	0.47a	3.26a	3.14a	1.29a	1.17a	0.37d	0.42d

MW: magnetized water; PW: plain water; Gyps: gypsum and AMF: mycorhizal fungi.
Means followed by the same letters within each column are not significantly differed at 0.05.

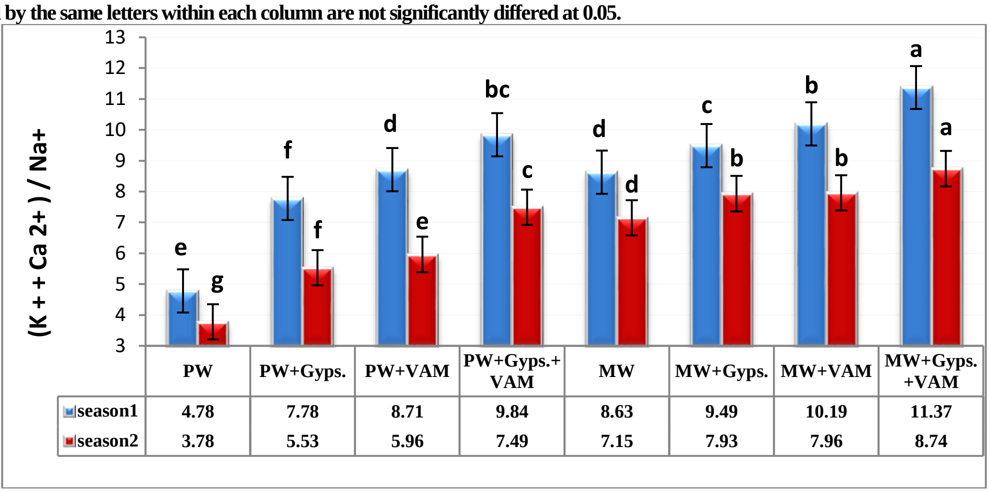

Fig. 4. Effect of magnetized water, gypsum and mycorrhizae on $(K^{+}+Ca^{2+})/Na^{+}$ ratio of bean plant grown under saline conditions during seasons of 2019 and 2020. Same letters indicate no statistical difference ($p > 0.05$).

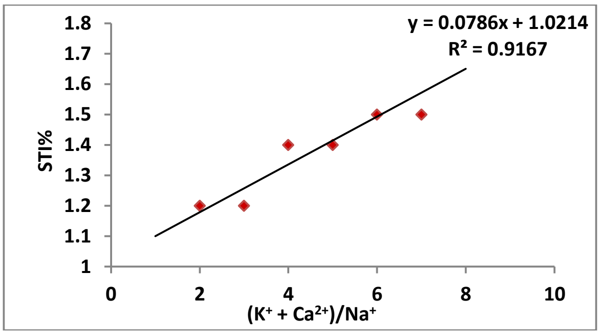

Fig. 5. Linear regression analysis of $(K^{+}+Ca^{2+})/Na^{+}$ ratio and salt tolerance index of bean plant grown under saline conditions (average of the two seasons).

However, Na content was significantly decreased by MW in both seasons. Moreover, the assigned soil amendments increased all minerals contents under study, except Na% and the treatment of gypsum+AMF was more superior in this respect followed by that of AMF only. In regard to the interaction between MW and soil amendments, data in the same table and figure show that all mineral contents under study were significantly increased in bean grown under saline conditions, except for Na% which was decreased. The more effective treatment was MW+gypsum+AMF followed by that of MW+AMF. In addition, a positive correlation between STI% and $(K^{+}+Ca^{2+})/Na^{+}$ is shown in Fig. 5. The obtained result was significant at a confidence level of 95%, with determination coefficients (R^2) of 0.917.

Salinity exceedingly affects ionic balance and reduces the solubility and mobility of micronutrients which decrease plant uptake of the essential elements. Under salt stress, a high NaCl concentration in the rhizosphere hampers the absorption of Ca^{2+} by replacing it in cell wall and plasma membrane thereby reducing Ca^{2+}/Na^{+} ratio in salt stressed plants. The final results are decreases in hydraulic conductivity and plant cell turgor and disturb Ca^{2+} signaling (Läuchli and Lüttge, 2002). One of the main reasons related to salt tolerance in *Phaseolus spp*. is the presence of mechanisms that restrict the transport of Na^{+} to the aerial part of plants. Na^{+} can compete with K^{+} for the same transporters (Munns and Termaat, 1986), thus mechanisms able to maintain relatively low Na^{+}/K^{+} ratios would therefore contribute to salt tolerance.

Irrigation with magnetically treated water lead to an increase in all elements content (Ahmed, 2011), except sodium (Al-Khazan *et al.*, 2011) because the elements are diamagnetic which are repelled by a magnetic field (Nave, 2008). AMF also have the ability to improve plant nutrients uptake by spreading their hyphae in the soil beyond rhizosphere (Hashem *et al.*, 2015 and Selvakumar *et al.*, 2018) that shortens the path of nutrients' entry into plant, in addition to induce changes in pH of the rhizosphere, which modulates nutrient solubility and their availability (Li and Christie, 2001). In micorrhizal plants, Evelin *et al.* (2019) found that Ca^{2+}/Na^{+} ratio increased by improving Ca^{2+} uptake under salt stress conditions. On the other hand, gypsum mainly improved plant tolerance to salinity by enhancing physical and chemical properties of the soil (Amer and Hashem, 2018 and Evelin *et al.*, 2019).

3- Pod and seed yield attributes:

Data in table 5 show that irrigation of bean plants with magnetized water (MW) increased yield and its components expressed as number of pods/plant, number of seeds/pod, weight of 100seeds and total seed yield/ feddan, as well as harvest index compared with irrigation with plain water (PW) under salinity conditions. Data also indicate that soil amendments studied enhanced yield attributes, particularly the dual treatment i.e., gypsum+ AMF then the individual treatments without significant differences between them (P> 5%). Concerning the interaction between MW and soil amendments, the same table and Figure 6 show that all assigned treatments considerably alleviated the harmful effects of salinity on bean yield. Generally, the combined treatments of soil amendments with MW outperformed those with PW. The treatment of MW+ gypsum+AMF was more superior in this respect. In addition, Figure 7 clears that there was a negative correlation between Na content of bean foliage and seed yield (kg/fed). The obtained result was significant at a confidence level of 95%, with determination coefficients (R^2) of 0.640.

Table 5. Effect of magnetized water, gypsum and mycorrhizae on yield characteristics of common bean grown under saline conditions during 2019 and 2020 seasons.

Parameters		**No. of pods/plant**		**No. of seeds/pod**		**Weight of 100 seeds (g)**		**Harvest index%**		**Total seed yield (kg/fed)**	
Treatments		**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**
MW	PW	12.4b	10.3b	3.8b	3.5b	47.9b	43.7b	47.4b	44.7b	550.3b	529.8b
	MW	17.1a	14.7a	4.4a	4.1a	51.5a	49.3a	50.7a	48.3a	719.3a	707.0a
Soil amends	Without amends	11.1d	9.5c	3.8b	3.6b	47.7c	45.1c	47.0c	44.5c	540.1d	514.4d
	Gyps	14.7b	12.4b	4.0b	3.8b	49.7b	46.0b	49.1b	46.5b	626.7c	618.7c
	AMF	14.4b	12.3b	4.1b	3.8b	49.8b	46.3b	48.9b	46.4b	636.6b	624.1b
	Gyps.+AMF.	18.8a	16.0a	4.5a	4.2a	51.6a	48.7a	51.3a	48.6a	736.0a	716.5a
Interaction											
PW	Without amends	8.5e	7.3f	3.5d	3.2d	44.9e	41.2e	45.6f	42.2g	470.2g	430.7g
	Gyps.	13.0d	10.6e	3.8cd	3.5cd	48.2d	43.1d	47.3e	45.3e	550.3f	533.8f
	AMF	12.9d	10.5e	3.8cd	3.4d	48.6d	43.4d	47.4e	44.6f	555.2f	543.7e
	Gyps.+AMF	15.3c	12.8c	4.0bc	3.9bc	49.8c	47.2c	49.3c	46.7d	625.5d	611.0c
MW	Without amends	13.6d	11.6d	4.1bc	3.9bc	50.5b	48.9b	48.4d	46.8d	610.0e	598.0d
	Gyps	16.4b	14.2b	4.2bc	4.0ab	51.1b	48.9b	50.8b	47.6c	703.0c	703.5b
	AMF	15.9bc	14.0b	4.3b	4.1ab	53.3a	49.1b	50.3b	48.2b	717.9b	704.5b
	Gyps.+AMF	22.3a	19.1a	4.9a	4.4a	53.8a	50.2a	53.2a	50.5a	846.4a	822.0a

MW: magnetized water; PW: plain water; Gyps: gypsum and AMF: mycorhizal fungi; feddan ($4200m^2$).
Means followed by the same letters within each column are not significantly differed at 0.05.

Fig. 6. A photograph of common bean pods, Nebraska cv., shows the effect of 1: control (plain water); 2: gypsum; 3: AMF; 4: gypsum+AMF; 5: MW; 6: MW+gypsum; 7: MW+AMF; 8: MW+gypsum+ AMF under salinity stress condition.

The reduction in dry matter production, water content and nutrients uptake as well as the increase in Na content (Tales 3and 4) must have been reflected on yield and its component. Maas (1990) mentioned that beans yield was reduced by about 20% and 47% at salinity levels of 2 and 3 dS/m, respectively. The ameliorative effect of assigned treatments on vegetative growth, water relationship and minerals uptake as shown previously clearly reflected on bean yield grown under saline stress conditions. Additionally, the superiority of MW+ gypsum+ AMF may be due to the solidarity of the positive effect of both gypsum and MW on AMF colonization, which increases the plant's tolerance to salinity. Eventually, the results of this study are consistent with many studies that confirm the mitigating effects on crop growth and overall relief from salt stress by MW (Nave, 2008; Ahmed, 2011 and Al-Khazan *et al.*, 2011), gypsum (Amer and Hashem, 2018) and AMF (Bothe, 2012; Evelin *et al.*, 2019 and Garcia *et al.*, 2019).

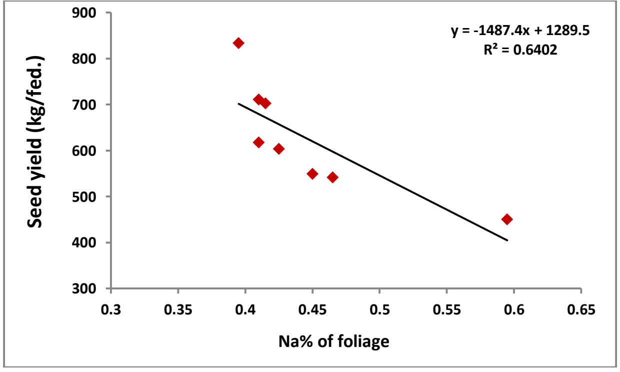

Fig. 7. Linear regression analysis of foliage Na content and seed yield (kg/fed.) of bean plant grown under saline conditions (average of the two seasons).

CONCLUSION

To raise the efficiency of agricultural production in Egypt at the level of local consumption and export, the optimal use of available resources i.e., low quality soil and irrigation water must be taken into account as one of the most important necessities at the present time. Therefore, The present study concluded that the possibility of obtaining satisfactory yield with acceptable quality of common bean cv. Nebraska could be achieved under salinity stress conditions of irrigation water (about 1.6 dSm^{-1}) and soil (about 3.5 dSm^{-1}) by means of combined treatments of magnetized irrigation water, agricultural gypsum additive (4 ton/fed.) and myccorhizal inoculation under the conditions of this study.

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تأثير بعض المعاملات الحيويه والكيميائيه والفيزيائيه على نباتات الفاصوليا الناميه تحت ظروف الملوحة

عبير ابراهيم عبد الغفار شبانه[1]*، دعاء محمد مصطفي أحمد[1] ومحمود أحمد محمد عبد الهادى[2]
[1] قسم بحوث الخضر- معهد بحوث البساتين- مركز البحوث الزراعيه- الجيزة - مصر
[2] قسم الخضر والزينة – كلية الزراعة – جامعة دمياط – مصر

تعتبر الفاصوليا الجافة من النباتات الحساسة للملوحة فى كل مراحل النمو. لذا تهدف الدراسة الحالية الى معرفة التأثيرات النافعة للرى بالماء الممغنط بمفرده أو مع الإمداد الأرضى بالجبس الزراعى و تلقيح النباتات بفطر الميكورهيزاعلى الفاصوليا صنف نبراسكا تحت ظروف الملوحة من حيث صفات النمو الخضرى (إرتفاع النبات ، الوزن الجاف ، المساحة الورقية) ، المحتوى النسبى للماء ، قدرة النبات على الإحتفاظ بالماء ، دليل تحمل الملح ، المحتوى المعدنى للنبات من كل من النيتروجين ، الفوسفور ، البوتاسيوم ، الكالسيوم ، الصوديوم ، نسبة مجموع أيونات البوتاسيوم والكالسيوم الى أيون الصوديوم و صفات المحصول البذرى (عدد القرون/ النبات ، عدد البذور/ القرن ، وزن الـ 100 بذرة ، المحصول الكلى للبذور/الفدان ، دليل الحصاد). أجريت التجربة بمزرعة خاصة شمال شرق مصر بمحافظة الدقهلية خلال الموسم الصيفى للعامين 2019 و2020م. أستخدم لذلك تصميم القطع المنشقة. أعطت معاملة الملوحة أقل القيم لكل الصفات المدروسة خاصة المحصول البذرى بنسبة فقد تصل لـ53.9% فيما عدا عنصر الصوديوم. أدت المعاملة بكل من الماء الممغنط أو المعاملات الأرضية منفردة أو مجتمعة الى زيادة جميع الصفات المدروسة فيما عدا محتوى النبات من الصوديوم. لوحظ أيضا وجود علاقة عكسية بين محصول البذور/الفدان و محتوى النبات من الصوديوم ، بينما كانت العلاقة طردية بين دليل تحمل النبات للملح و نسبة مجموع أيونات البوتاسيوم والكالسيوم الى أيون الصوديوم والتى تعد الأكثر أهمية كمعيار للإنتخاب فى الفاصوليا. بصفة عامة، تعد المعاملة بماء رى ممغنط + الإمدادالأرضى بالجبس الزراعى+ تلقيح النباتات بالميكورهيزا من التطبيقات المهمة للغاية لإنتاج الفاصوليا الجافة فى شمال الدلتا حيث الأراضى الطينية متوسطة الملوحة.