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Evaluation of bio-fertilization and pre-sowing seeds' magnetization on the quality and productivity of roselle (*Hibiscus sabdariffa* L.) cultivars and on the soil fertility

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ABSTRACT

The aim of this study is to assess the effect of seeds' magnetization time before sowing combined with the bio-fertilization at different rates of mineral N fertilization on the quality and productivity of roselle (*Hibiscus sabdariffa* L.) cultivars and on the soil fertility. Bright and dark red calyces of Roselle cultivars were cultivated in two split-plot field experiments during the successive summers of the years 2022 and 2023. The main plots were the applied mineral N fertilization rates (0, 35, 50, and 70 kg N fed^{-1}), while the times of pre-sowing seeds' magnetization (0, 15, 30 and 60 min) were the sub-plots. All treatments were triplicated. A bacterium culture contains two types of bacteria (1st type: Mw 879336, 2nd type: Pseudomonas Sp.) plus liquid vinasse as a carrier were used as the bio-fertilizer that was foliar-applied (30 L fed^{-1}) before transplanting, on soil before planting and at 25, 45 and 65 days after sowing on soil and plant. The results indicated that the 50 kg N fed^{-1} application combined with 30 min magnetization time of seeds before cultivation and bio-fertilization has significantly decreased the soil EC by 38.5% (from 4.88 to 3.0 dS m^{-1}) and increased the soil organic matter OM by 26.2% relative to the same treatment without bio-fertilizer or without magnetization (from 0.65% to 0.82%). The soil available N, P, Fe, Mn and Zn were significantly increased by 49.4%, 22.5%, 29.2%, 87.7%, and 26.9%, respectively, with the same treatment. The plant growth components, protein, carbohydrate, Anthocyanin, and chlorophyll were improved.

Keywords: Bio-fertilizer, soil fertility, mineral nitrogen fertilizer, magnetic field times, Roselle

INTRODUCTION

Bio-fertilization can optimize calcareous soil fertility because it minimizes the impact of some nutrient deficiencies by fixing them in soil. The microbial strains as bio-fertilizers decrease the chemical fertilization application and produce high quality harvests free of harmful agrochemicals (El-Naim *et al.,* 2017). Bio-fertilizers can increase the available phosphorus (P) and nitrogen (N) under the calcareous soil conditions that commonly reduce the nutrients' availability (El-Zemrany *et al.,* 2016; Ganzour *et al.,* 2020). The bio-fertilizers may play the role of plant growth-promoter PGP, which enhances the plant growth and inhibits the activity of plant pathogens' and harmful rhizosphere microorganisms. Such an effect may take place during the biotransformation and antibiotics production (Akinrinlola *et al.,* 2018). The plant growth promotion and development by bio-fertilizers depends on their nature, content, and mode of action, application timing, and growing circumstances, from seed germination to plant maturity. For instance, the bacteria *Sporosarcina pasteurii* was used with calcium chloride solution and microbial led to calcite precipitation in soils (Cardoso *et al.,* 2018). Bio-fertilizer (consortium bacteria) + liquid vinasse as a carrier before transplanting (30 L fed^{-1}) has improved the soil status as it decreased the soil pH and EC (dS m^{-1}) and increased the available nutrients in soil (Sadek *et al.,* 2022).

Magnetization by exposure to a magnetic field (MF) enhances plant growth, accelerates the vegetative growth, and improves the mineral content of seeds and fruits (Morimitsu *et al.,* 2000). The physical treatment of seeds by magnetic priming is promising as it improves germination and seedling through stimulating the electrical charges, ion concentration, and free radicals of seeds leading to a more permeable membrane without change in their chemical profile. The magnetic induction does not change the atomic/molecular constitution of a matter but may affect its' polarization or dipole moment. The magnetic stimulation of seeds may cause biochemical changes and variations in the enzymes' activities that affect the plant processes like photosynthesis, nutrients uptake, growth, ionic balance, and transportation across the cell membranes, which become more permeable. The seed quality is kept against the oxidizing agents causing the degradation upon storage, which inhibits their germination. Such stimulation effect of seeds' magnetization can be optimized when combined with the bio-fertilization. The MF may affect the seeds physiologically via penetrating the plasma membrane, inducing transferring water and energy signals into the cell. Variations in the ionic fluxes across the cell membrane may induce the water uptake mechanism. The treated seeds can absorb water faster. The ion mobility across plasma membranes may be improved, which enhances the amino acid uptake, and biosynthesis of the chlorophyll and carotenes nutritive for seedlings (Rashad *et al.,* 2022; Ahmed *et al.,* 2023; Abd El-Rahman *et al.,* 2025)

Aladjadjiyan, (2002) mentioned that a 10 min exposure time to MF was the most effective time for maize seed germination. The MF affects the crop plants growth and yield, root and stem growth, protein and chlorophyll content, rhizosphere organisms community (Stanislaw and Martine, 2015). The exposure of the callus to the MF increased the oil compounds more than the callus not exposed to the MF (Abdul Hussian and Jawad, 2019). Pre-sowing seeds' magnetization for 45 min has increased available macro-micronutrients in soil and produced the highest mean values of plant length (cm), grains weight(g) /plant, straw weight(g)/plant, 1000-grains weight (g), grains' and straw yield (ton fed^{-1}) (Shaban *et al.,* 2023).

The Roselle plant in Egypt was cultivated on 7730 fed area during the year 2012 distributed in the governorates: Assuit, Qena, Luxor, Aswan, New Valley, Red Sea, Nubaryia, 6-October, Middle Egypt and Matruh with an average seed yield 850 kg fed^{-1} and seeds' production may exceed 6570.5 tons per year. Roselle tea aids the digestion process, works as an anti-rotten stomach and is an antiseptic for microbes. It is a drink that reduces the high temperatures in the body and includes candy making (Louis *et al.,* 2013). Egyptian Roselle seeds' powder contained high protein content (≈31.02% -28.67%), crude fat (≈21.6% -16.94%) and total ash (6.89% ± 0.11% and 5.60% ± 0.10%), respectively (Matter, 2009).

The objective of this research is to evaluate the effect of seeds' magnetization time before sowing combined with the bio-fertilization at different rates of mineral N fertilization on the quality and productivity of roselle (*Hibiscus sabdariffa* L.) cultivars under saline calcareous soil conditions.

MATERIALS AND METHODS

Field experiments were carried out at El-Bossily Protected Cultivation Experimental farm (Central Laboratory-Agricultural Research Center, 3 m above sea level, 31.40° N, 30.40° E), El-Beheira Governorate-Egypt. The main physical and chemical properties of soil were determined before planting (Page *et al.,* 1982; Piper, 2019) and listed in *(*Table 1*)*.

Table 1. Mean values of physical and chemical properties in the study soil before planting

<table>
<tr><th>Coarse sand (%)</th><th>Fine sand (%)</th><th>Silt (%)</th><th colspan="2">Clay (%)</th><th colspan="2">Texture</th><th>O.M. (%)</th><th>$CaCO_3$ (%)</th></tr>
<tr><td>5.12</td><td>77.30</td><td>9.75</td><td colspan="2">7.83</td><td colspan="2">Loamy sand</td><td>0.59</td><td>14.40</td></tr>
<tr><th rowspan="2">pH (1:2.5)</th><th rowspan="2">EC (dS m^{-1})</th><th colspan="4">Cations (meq L^{-1})</th><th colspan="3">Anions (meq L^{-1})</th></tr>
<tr><th>Ca^{++}</th><th>Mg^{++}</th><th>Na^{+}</th><th>K^{+}</th><th>HCO^{-}_3</th><th>Cl^{-}</th><th>SO^{--}_4</th></tr>
<tr><td>8.00</td><td>7.85</td><td>14.50</td><td>9.50</td><td>53.62</td><td>0.88</td><td>12.63</td><td>46.30</td><td>19.57</td></tr>
<tr><th colspan="4">Available macronutrients (mg kg^{-1})</th><th colspan="5">Available micronutrients (mg kg^{-1})</th></tr>
<tr><th>N</th><th>P</th><th colspan="2">K</th><th colspan="2">Fe</th><th colspan="2">Mn</th><th>Zn</th></tr>
<tr><td>35.66</td><td>7.88</td><td colspan="2">180.65</td><td colspan="2">3.20</td><td colspan="2">1.88</td><td>0.60</td></tr>
</table>

In both seasons 2021/2022 and 2022/2023 each experiment was carried out in a split-plot design with three replicates. Treatments of the mineral N fertilization rates are the main plots and the pre-swing seeds' magnetization times are the sub-main plots .

Roselle cultivars: bright and dark red calyces were obtained from the Medicinal and Aromatic Plants Section, Horticultural Research Institute, Agricultural Research Center, Giza, Egypt. The experimental area (one fed = 4200 m^2) was divided into two parts for the bright and dark red cultivars. The required number of seeds was placed in a MF (1.4 Tesla) inside a magnetic tube (70 cm Length × 2 inch diameter, (Fig. 1) for times (0, 15, 30, and 60 min) (the authors suggested the treatment times).

Fig. 1. Magnetic device used for seeds' magnetization

Foliar application of the bio-fertilizer was by a bacterium culture containing two types of bacteria: 1st type (FMw879336) and 2nd type is (*Pseudomonas* Sp.) plus liquid vinasse as a carrier before transplanting (30 L fed^{-1}.), on soil before planting and after 25, 45 and 65 days after sowing on soil and plant. Prof. Dr. Faten M. Mohamed developed this bio-fertilizer strain supplement from the Microbiology Department (Soils, Water and Environment, Research Institute, Agricultural Research Centre, Giza, Egypt). Table (2) shows the used bio-fertilizer composition:

Table 2. Chemical and biochemical properties of the consortium bacteria

Treatment	Lipid	Total amino acid	Total carbohydrate	Organic acid	Ag (ppm)	IAA (ppm)	Total phenol (ppm)
Vinasse	0.01	0.61	9.1	1.6	108	69	12610
Vinasse + compounded	00.0.16	0.88	11.3	2.10	161	80	131500

The super phosphate (15.5% P_2O_5, 100 kg fed^{-1}) fertilizer was applied during soil tillage before planting. Mineral N fertilization was by urea (46% N) applied at the rates (0, 35, 50 and 70 kg N fed^{-1}) after 25, 45 and 65 days from planting. Potassium sulphate (48% K_2O, 75 kg fed^{-1}) was applied 25 and 45 days after planting. Sowing seeds was carried out on the 25th of May 2022 and 2023 in holes (2 cm depth, and 20 cm distance between holes). After 25 days, the plants were thinned to one plant per hole. Three replicates of plant samples were taken after 75 days from sowing to estimate some physiological and vegetative growth parameters.

Representative samples from all plots were picked up after harvesting for testing and analysis. The growth parameters were measured including the plant height (cm), number of branches/plant, No. of calyxes/plant, weight of calyxes (g/plant), weight of dry plant (g/plant), and weight of calyxes (kg fed^{-1}) based on the plot area data, and the two seasons' mean was obtained. The available N-P-K macro-micronutrient contents in soil were extracted by 1% K_2SO_4, 0.5 N $NaHCO_3$, and 1 N NH_4OAc (pH 7.0), respectively (Jackson, 1973). Total concentrations of the N, P, and K in the soil extracts were measured (by distillation: Kjeldahl apparatus, colorimetric: the UV-Vis Spectrophotometer, and by flame photometer, respectively) (Piper, 2019). Soluble concentrations of the Fe, Mn, and Zn micro-micronutrient were measured by the ICP Spectrometry (ICP-Ultima 2 JY Plasma).

Photosynthetic pigments (total chlorophyll was estimated in fresh leaves. Total anthocyanin percentage powder of dried calices was used for determination according to (Du and Francis, 1973). Total protein content was calculated by multiplying the N value by 6.25. The acidity (pH) was determined according to (Diab, 1968).

Statistical analysis:

The data was subjected to the two-way analysis of variance (ANOVA) test using the COSTAT statistic program to find out the significance of data variation using the Least Significant Difference (LSD) between treatments at $P \leq 0.05$ according to (Gomez and Gomez, 1984).

RESULTS

Soil properties:

Soil pH:

Data presented in (Table 3) indicated that the bio-fertilizer alone or combined with mineral N fertilizer decreased the soil pH compared to the control at 30 min magnetization time combined with 50 kg N fed^{-1} combined with bio-fertilizer compared with other treatments. The soil of the experiment is slightly to moderately alkaline of pH value 7.98 - 7.79. The applied bio-fertilizers may activate microorganisms in soil and dehydrogenase enzyme production, which decreases the soil pH compared with the control. The mineral N showed on no significant effect on soil pH, while the bio-fertilizer significantly decreased the soil pH. The seeds' magnetization time combined with mineral N fertilizer showed no significant impact, while magnetization time combined with bio-fertilizer application significantly decreased the soil pH. The interaction between all treatments was not significant for soil pH.

Soil salinity (EC, dS m^{-1}):

Table (3) shows that the minimum mean value of soil EC is 3.56 dS m^{-1} at 30 min magnetization treatment with the bio-fertilizer combined with mineral N mineral fertilizer at different rates. At a rate of 50 kg N fed^{-1}, the soil EC was decreased to 3.0 dS m^{-1} at 30 min magnetic time. The interaction between the effects of all treatments was not significant of soil salinity.

Table 3. Soil pH, EC (dS m^{-1}), OM (%) and $CaCO_3$ (%) contents in soil studied after harvest

Magnetic time (min)	N rates (kg fed^{-1})	Mineral	Bio-fertilizer	Mineral	Bio-fertilizer	Mineral	Bio-fertilizer	Mineral	Bio-fertilizer
		pH (1:2.5)		**EC (dSm^{-1})**		**OM (%)**		**$CaCO_3$ (%)**	
0	0	7.98	7.96	5.53	5.13	0.60	0.63	14.23	13.84
	35	7.96	7.94	5.10	4.98	0.62	0.66	13.88	13.50
	50	7.95	7.90	4.88	4.35	0.65	0.68	13.55	12.45
	70	7.92	7.89	4.30	4.10	0.68	0.72	13.28	12.48
Mean		---	---	**4.95**	**4.64**	**0.64**	**0.67**	**13.74**	**13.07**
15	0	7.97	7.87	5.02	5.05	0.63	0.66	13.90	13.75
	35	7.93	7.84	4.83	4.88	0.65	0.72	13.45	12.65
	50	7.92	7.82	4.10	4.10	0.68	0.78	13.10	12.22
	70	7.90	7.83	4.35	3.85	0.71	0.73	13.02	12.35
Mean		---	---	**4.58**	**4.47**	**0.67**	**0.72**	**13.37**	**12.74**
30	0	7.95	7.85	4.75	4.35	0.66	0.68	13.85	12.85
	35	7.92	7.82	4.12	3.72	0.70	0.76	13.33	12.35
	50	7.89	7.79	3.25	3.00	0.77	0.82	13.09	11.53
	70	7.91	7.80	3.75	3.25	0.73	0.75	12.96	11.55
Mean		---	---	**3.97**	**3.58**	**0.72**	**0.75**	**13.31**	**12.07**
60	0	7.96	7.88	4.80	4.56	0.64	0.67	13.88	12.88
	35	7.94	7.84	4.57	3.80	0.67	0.74	13.44	12.43
	50	7.90	7.81	3.90	3.25	0.75	0.80	13.12	11.75
	70	7.92	7.82	3.94	3.39	0.72	0.74	13.01	12.20
Mean		----	---	**4.30**	**3.75**	**0.70**	**0.74**	**13.36**	**12.32**
$LSD_{5\%}$ N rates		**ns**	**0.04**	**ns**	**0.25**	**0.02**	**0.015**	**ns**	**ns**
$LSD_{5\%}$ magnetic time		**ns**	**0.02**	**0.59**	**0.39**	**0.20**	**0.016**	**ns**	**ns**
Interaction		**ns**	**ns**	**ns**	**ns**	**ns**	******	**ns**	**ns**

Organic matter (OM, %) content in soil:

The maximum OM content in soil shown in (Table 3) was obtained by bio-fertilizer combined with 50 kg N fed^{-1} at 30 min magnetization time compared with other treatments. The relative increases of mean values of soil OM% affected by N mineral and bio-fertilizer were 8.33 and 9.52% respectively, compared to treatment without N mineral fertilizer and without magnetization times. The relative increases of mean values were 7.94 and 12.12, 10.61% and 14.71 and 10.94% and 13.43% for soil treated with mineral N fertilizer all different rates and bio-fertilizer for MF at 15, 30 and 60 min, respectively than compared to untreated mineral N fertilizer. This can be attributed to the microorganisms' activity in soil, which caused an increase of the OM content in soil.

Calcium carbonate ($CaCO_3$%) content in soil:

Table (3) shows that the $CaCO_3$ % in soil was decreased although not significantly by 30 min magnetization time and bio-fertilization combined with 70 kg N fed^{-1} compared with other treatments. The relative decreases of mean values of $CaCO_3$ content in soil were between 6.68 and 7.44% for soil treated with mineral N at different rates and bio-fertilizer combined with mineral N fertilizer to varying rates without MF compared with the control. The corresponding relative decreases of mean values were between 5.11% and 9.75% for $CaCO_3$ content in soil treated with mineral N fertilizer at different rates combined with 15 min magnetization time and bio-fertilizer combined with magnetization at 15 min compared with MF at 15min without mineral N fertilizer. T. The relative decreases of mean values were between 4.97% and 5.82% for soil treated with mineral N fertilizer at different rates and bio-fertilizer combined with magnetization at 60 min compared to the treatment without mineral fertilizer. The efficiency of magnetization is determined by the two seasons of study which reduces $CaCO_3$ formation and separation processes, due to the ionic mechanism effect on ion hydration. Using the bio-fertilizer treatments decreased $CaCO_3$ and soil pH, which may be due to the microbial activity resulting in the OM formation and the production of organic acids.

Macronutrient contents in soil of the study:

Table (4) indicates that there are increases in available macronutrients (N, P and K) contents in soil as affected by bio-fertilizer combined with mineral N fertilization rate 50 kg N fed^{-1} plus 60 min magnetization time compared to other treatments. There is a significant increase in the available N content in soil was observed after treatment with N fertilizer and P as a result of bio-fertilizer combined with mineral fertilizer at different rates. In contrast, variation of the available K content in soil was not significant. The pre-sowing magnetization at different times significantly increased the available N and P contents in soil, while the K increase was not significant. The interaction between the application of N mineral fertilizer at different rates and at different times of magnetization resulted in a significant increase in N content in the soil while K showed no significant change. The relative increases of mean values were 23.61%, 8.52 % and 1.02 % for N, P and K respectively contents in soil treated with mineral N fertilizer different rates, while the available N, P and K contents in soil treated with bio-fertilizer combined with mineral N fertilizer different rates were 23.04, 5.70% and 0.43% respectively, compared to treatments without mineral fertilizer. The relative increases of mean values macronutrients (N, P and K) contents in soil treated with mineral N fertilizer combined with 15 min magnetization were 28.49% for N, 9.68% for P and 1.29% for K, while the relative increases resulted from the combination between the bio-fertilization with 15 min magnetization and mineral N fertilizer were 29.36 % for N, 10.74 for P and 4.40% for K. Also, the highest mean values percentage were 35.94% for N, 14.49 % for P and 3.04 % for K in soil treated with mineral N different rates combined with MF at 30 min time, while the soil treated with bio-fertilizer combined with mineral N different rates and at 30 min magnetization time were 44.97 % for N, 16.37% for P and 4.94% for K than with 30 min magnetization alone. .

Table 4. Available macro- and micronutrient contents in the soil of the study after harvest

Magnetic time (min)	N rates (kg fed^{-1})	Mineral	Bio-fertilizer	Mineral	Bio-fertilizer	Mineral	Bio-fertilizer	Mineral	Bio-fertilizer	Mineral	Bio-fertilizer	Mineral	Bio-fertilizer
		N (mg kg^{-1})		P (mg kg^{-1})		K (mg kg^{-1})		Fe (mg kg^{-1})		Mn (mg kg^{-1})		Zn (mg kg^{-1})	
0	0	32.40	35.80	8.22	8.60	183.29	185.40	3.75	3.88	1.90	1.96	0.62	0.65
	35	35.70	38.55	8.65	8.95	184.00	185.59	3.89	4.08	1.98	1.99	0.64	0.68
	50	39.75	49.20	8.95	9.34	184.77	187.89	4.21	4. 95	2.12	2.50	0.67	0.72
	70	44.70	44.40	9.15	8.98	186.70	185.10	4.02	4.77	2.45	2.23	0.69	0.69
Mean		**38.14**	**41.74**	**8.74**	**8.97**	**184.69**	**186.00**	**3.97**	**4.24**	**2.11**	**2.17**	**0.66**	**0.69**
15	0	35.66	37.40	8.68	8.75	185.77	186.00	4.70	4.03	2.10	2.19	0.64	0.68
	35	42.80	45.20	9.13	9.05	187.30	188.77	5.06	4.55	2.77	2.80	0.68	0.73
	50	45.35	52.60	9.55	10.23	188.30	198.40	5.77	5.05	2.90	3.25	0.69	0.79
	70	49.30	47.33	9.88	9.80	188.90	195.40	5.95	4.80	3.12	3.08	0.73	0.77
Mean		**43.28**	**45.63**	**9.31**	**9.46**	**187.57**	**192.14**	**5.37**	**4.61**	**2.72**	**2.83**	**0.69**	**0.74**
30	0	38.40	39.40	8.97	9.04	187.40	190.30	4.95	4.75	2.35	2.45	0.66	0.71
	35	48.40	55.85	9.88	9.95	190.21	197.40	5.14	4.90	2.99	3.18	0.73	0.78
	50	55.30	59.22	10.07	10.96	194.20	203.22	5.90	5.44	3.15	3.98	0.75	0.85
	70	52.90	56.30	10.87	10.66	194.90	198.50	6.10	5.10	3.19	3.88	0.78	0.82
Mean		**48.75**	**52.69**	**9.95**	**10.15**	**191.68**	**197.36**	**5.52**	**5.05**	**2.92**	**3.37**	**0.73**	**0.79**
60	0	40.32	42.10	9.03	9.66	188.30	193.90	5.06	4.86	2.88	2.96	0.69	0.74
	35	54.60	59.80	10.23	10.33	191.78	205.80	5.55	5.09	3.35	3.85	0.76	0.79
	50	57.21	63.10	10.35	11.75	196.30	212.00	6.12	5.55	3.50	4.33	0.79	0.88
	70	59.60	60.33	10.88	11.54	198.40	209.30	6.35	5.33	3.88	4.07	0.82	0.85
Mean		**52.93**	**56.33**	**10.12**	**10.82**	**193.70**	**205.25**	**5.77**	**5.21**	**3.40**	**3.80**	**0.77**	**0.80**
$LSD_{5\%}$ N rates		**0.63**	**3.26**	**ns**	**0.49**	**ns**	**ns**	**0.54**	**0.32**	**0.49**	**0.67**	**0.04**	**0.011**
$LSD_{5\%}$ magnetic time		**1.09**	**2.51**	**1.00**	**0.24**	**ns**	**ns**	**0.28**	**0.24**	**0.36**	**0.32**	**0.03**	**0.010**
Interaction		*******	******	**ns**	*******	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	*******

Micronutrient available contents in soil:

The mean values in (Table 4) were increased 5.77 mg kg^{-1} for Fe, 3.40 mg kg^{-1} for Mn, and 0.77 for Zn mg kg^{-1} in soil treated with mineral fertilizer rates combined with magnetization for 60 min time, while the increase was 5.21 mg kg^{-1} for Fe, 3.80 mg kg^{-1} for Mn, and 0.8 mg kg^{-1} for Zn for soil treated with bio-fertilizer combined with magnetization at 60 min time and mineral N fertilizer compared with other treatments. Also, the significant increase in Fe, Mn and Zn contents in soil treated with mineral N rate or bio-fertilizer combined with different magnetization times. The interaction the mineral fertilizer and bio-fertilizer combined with magnetization time was not significant for Fe and Mn while the interaction between Zn and magnetization time was significant.

Plant growth:

Results in (Table 5) indicated that the increase of plant height (cm) and No. of calyxes /plant for plants treated with bio-fertilizer combined with mineral N fertilizer at a rate of 50 kg N fed^{-1} and magnetization at 30 min in dark calyxes /plant, while the increase of No. breaches / plant for calyxes bright compared with other treatments.

Table 5. Effect of pre-sowing magnetic time of treatment of seeds, N-fertilizer rates and bio-fertilizer on some plant features (values of two seasons)

Magnetic time (min)	N rates (kg fed^{-1})	Bright	Dark	Bright	Dark	Bright	Dark	Bright	Dark	Bright	Dark	Bright	Dark
		Plant height (cm)				No. of branches /plant				No. of calyxes /plant			
		Mineral		Bio-fertilizer		Mineral		Bio-fertilizer		Mineral		Bio-fertilizer	
0	0	77.30	91.67	88.60	127.65	6.88	4.66	8.30	6.40	11.33	25.33	13.67	35.90
	35	127.67	125.33	94.30	160.33	8.44	7.40	10.66	8.30	17.66	36.77	18.76	45.77
	50	155.30	154.33	115.70	171.33	9.30	8.30	14.66	10.40	22.67	50.66	25.33	60.60
	70	108.30	127.67	97.66	133.67	11.30	5.88	11.76	7.40	11.66	65.30	15.30	58.90
Mean		**117.14**	**124.75**	**99.07**	**148.25**	**8.98**	**6.56**	**11.35**	**8.13**	**15.83**	**44.52**	**18.27**	**50.29**
15	0	106.30	130.45	115.33	134.70	8.33	6.67	10.33	8.30	16.33	32.12	22.33	42.66
	35	137.70	184.33	145.40	189.30	10.67	8.30	13.40	10.33	24.33	50.67	28.67	62.33
	50	175.70	197.77	184.33	202.70	12.30	10.30	15.77	12.77	43.66	56.99	49.30	79.70
	70	129.30	166.30	135.00	178.30	9.77	7.50	12.33	9.77	26.60	53.23	35.66	69.87
		137.25	**169.71**	**145.02**	**176.25**	**10.27**	**8.19**	**12.96**	**10.29**	**27.73**	**48.25**	**33.99**	**63.64**
30	0	128.30	189.00	136.70	198.30	9.77	7.60	12.30	9.50	18.33	36.33	25.66	45.77
	35	140.77	212.24	155.70	222.80	13.35	10.30	15.60	11.20	34.33	60.66	34.30	72.10
	50	177.10	228.10	189.33	237.40	15.33	13.30	16.66	13.80	45.60	68.54	55.33	87.90
	70	174.77	197.77	149.30	209.30	11.67	9.66	13.33	10.30	31.00	65.43	41.66	85.44
Mean		**155.24**	**306.78**	**157.76**	**216.95**	**12.53**	**10.22**	**14.47**	**11.20**	**32.32**	**57.74**	**39.24**	**72.80**
60	0	119.30	152.66	122.33	162.30	8.33	5.30	11.76	7.40	16.90	29.65	20.66	40.33
	35	147.33	186.66	158.77	186.40	11.66	8.70	13.80	10.30	30.56	45.80	30.76	68.50
	50	171.30	201.67	180.33	205.30	13.33	10.40	14.89	11.70	39.66	53.90	45.66	80.55
	70	135.76	178.33	153.77	195.30	10.66	8.30	12.30	9.77	35.20	50.77	37.33	74.90
Mean		**143.43**	**179.83**	**153.80**	**187.33**	**11.00**	**8.18**	**13.19**	**9.79**	**30.58**	**45.03**	**33.60**	**66.07**
$LSD_{5\%}$ N rates		**4.73**	**2.53**	**7.61**	**1.42**	**0.40**	**0.82**	**1.10**	**1.03**	**1.77**	**4.82**	**0.64**	**1.37**
$LSD_{5\%}$ magnetic time		**4.15**	**2.58**	**6.05**	**2.02**	**1.21**	**0.64**	**1.31**	**1.33**	**1.41**	**3.89**	**1.25**	**1.05**
Interaction		***	***	***	***	ns	ns	ns	ns	***	***	***	***

Yield and yield components:

Data presented in (Table 6) show that the increase of weight of calyxes (g/plant), weight of dry plant (g/plant) and weight of calyxes (kg fed^{-1}) for Roselle dark was affected by bio-fertilizer combined with mineral nitrogen at a rate of 50 kg N fed^{-1} and magnetic treatment of seeds at 30 min compared to other treatments. The treatment with mineral N rates resulted in a significant increase of weight of calyxes (g/plant), weight of dry plant (g/plant) and weight of calyxes (kg fed^{-1}) for bright and dark Roselle. Also, the application of bio-fertilizer significantly increased the weight of calyxes' (g/plant), weight of dry plant (g/plant) and weight of calyxes (kg fed^{-1}) for bright and dark Roselle.

Table 6. Effect of pre-sowing magnetic time of treatment of seeds, N-fertilizer rates and bio-fertilizer on some yield components (values of two seasons)

Magnetic time (min)	N rates (kg fed^{-1})	Bright	Dark	Bright	Dark	Bright	Dark	Bright	Dark	Bright	Dark	Bright	Dark
		Weight of calyxes (g/plant)				Weight of dry plant (g/plant)				Weight of calyxes (kg fed^{-1})			
		Mineral		Bio-fertilizer		Mineral		Bio-fertilizer		Mineral		Bio-fertilizer	
0	0	10.78	13.66	13.20	15.30	136.40	145.90	140.50	153.20	180.33	195.40	199.44	220.49
	35	17.40	21.33	25.44	29.40	146.30	165.40	158.90	166.70	197.67	210.59	228.30	280.50
	50	25.40	29.76	36.40	40.66	155.90	188.10	179.70	195.40	216.55	230.48	295.40	335.90
	70	30.55	35.55	40.66	45.20	152.30	180.40	173.33	188.54	222.90	254.30	327.33	348.99
Mean		**21.03**	**25.08**	**28.93**	**32.64**	**147.73**	**169.95**	**163.11**	**175.96**	**204.36**	**222.69**	**262.62**	**296.47**
15	0	13.20	15.88	18.40	20.55	145.30	148.30	150.30	157.30	195.45	210.33	225.66	245.66
	35	26.40	30.76	30.66	35.20	152.55	179.60	160.40	188.60	230.55	231.66	280.50	340.50
	50	40.40	43.33	47.30	50.49	160.20	197.30	197.30	208.60	261.90	248.50	358.67	385.60
	70	35.50	37.90	40.88	45.77	159.30	192.30	184.67	197.66	266.70	265.44	330.33	378.30
		28.88	**31.97**	**34.31**	**38.00**	**154.34**	**179.38**	**173.17**	**188.04**	**238.65**	**238.98**	**298.79**	**337.52**
30	0	18.50	25.56	25.40	30.49	149.00	153.90	153.90	160.55	220.75	240.30	235.30	265.50
	35	30.40	35.88	40.50	48.20	155.30	193.20	177.50	212.00	270.40	309.33	355.40	380.50
	50	50.44	55.43	55.78	60.48	173.90	214.00	207.00	255.30	292.88	341.22	375.44	420.50
	70	45.40	48.85	52.40	56.66	167.40	206.20	197.50	225.11	285.44	416.66	368.50	410.30
Mean		**36.19**	**41.43**	**43.52**	**48.96**	**161.40**	**191.83**	**183.98**	**213.24**	**267.37**	**326.88**	**333.66**	**369.20**
60	0	15.30	20.65	23.50	25.90	146.40	151.90	150.88	159.40	215.40	223.90	230.66	275.90
	35	30.48	33.65	42.30	45.10	153.40	189.75	174.30	195.40	265.40	281.30	325.80	366.33
	50	42.30	46.90	50.55	55.30	170.30	205.80	195.60	209.40	290.65	306.40	350.80	375.80
	70	44.30	45.80	50.95	52.40	162.00	199.50	189.66	202.98	280.55	292.30	345.90	350.66
Mean		**33.10**	**36.75**	**41.83**	**44.68**	**158.03**	**186.74**	**177.61**	**191.80**	**263.00**	**275.98**	**313.29**	**342.17**
$LSD_{5\%}$ N rates		**0.64**	**1.38**	**0.45**	**0.62**	**4.93**	**2.06**	**0.82**	**13.32**	**2.33**	**2.54**	**4.18**	**1.49**
$LSD_{5\%}$ magnetic time		**1.10**	**1.17**	**1.41**	**0.85**	**4.30**	**1.35**	**1.25**	**11.31**	**1.87**	**2.59**	**3.36**	**1.57**
Interaction		***	***	***	***	ns	***	***	**	***	***	ns	***

The times of magnetic treatment of seeds significantly increased weight of calyxes' (g/plant), weight of dry plant (g/plant) and weight of calyxes (kg fed^{-1}) for bright and dark Roselle. The interaction between all studied treatments resulted in a significant increase in the weight of calyxes (g/plant), weight of dry plant (g/plant) and weight of calyxes (kg fed^{-1}) for bright and dark Roselle, while weight of dry plant (g/plant) as mineral N rates and weight of calyxes (kg fed^{-1}) as bio-fertilizer for bright calyxes.

Roselle quality as affected by all treatments:

Data presented in (Tables 7 and 8) about the effect of bio-fertilizer and mineral N fertilizer at different rates combined with pre-sowing seeds magnetization times on the protein (%), carbohydrate (%), Anthocyanin (mg/gdw), chlorophyll (mg/g.f.w), and pH showed a positive effect.

Table 7. Effect of pre-sowing magnetic time of treatment of seeds, N-fertilizer rates and bio-fertilizer on yield quality (values of two seasons)

Magnetic time (min)	N rates (kg fed^{-1})	Bright	Dark	Bright	Dark	Bright	Dark	Bright	Dark	Bright	Dark	Bright	Dark
		Protein (%)				Carbohydrate (%)				Anthocyanin (mg/g.dw)			
		Mineral		Bio-fertilizer		Mineral		Bio-fertilizer		Mineral		Bio-fertilizer	
0	0	7.69	7.31	11.13	10.00	12.10	12.88	12.88	12.90	14.30	14.75	14.80	14.90
	35	8.88	8.06	12.75	11.56	12.77	12.96	12.95	13.09	14.86	14.89	14.95	15.16
	50	9.38	8.56	13.31	13.13	12.89	13.07	13.19	13.55	14.98	15.05	15.22	15.70
	70	10.88	9.63	13.06	12.81	12.95	13.25	13.05	13.38	15.03	15.13	15.05	15.40
Mean		**9.20**	**8.39**	**12.56**	**11.88**	**12.68**	**13.04**	**13.02**	**13.23**	**14.79**	**14.96**	**15.01**	**15.29**
15	0	8.38	7.94	13.69	13.31	12.55	12.95	12.95	13.06	14.66	14.80	14.88	15.06
	35	9.63	8.88	16.56	14.06	12.88	13.09	13.12	14.14	14.95	15.10	15.20	15.88
	50	10.44	10.25	19.50	16.88	13.12	13.45	13.55	14.88	15.12	15.23	15.52	16.70
	70	11.44	10.81	17.06	15.81	13.38	13.56	13.28	13.77	15.33	15.34	15.39	16.55
		9.60	**9.47**	**14.40**	**15.02**	**12.98**	**13.26**	**13.23**	**13.96**	**15.02**	**15.12**	**15.25**	**16.05**
30	0	8.75	8.50	14.75	13.94	12.85	13.06	13.15	13.23	14.85	14.95	14.98	15.19
	35	10.00	9.50	17.81	15.88	13.09	13.83	13.77	14.78	15.15	15.33	15.44	16.20
	50	11.38	11.13	20.31	19.38	13.55	14.33	13.85	15.85	16.40	16.90	16.75	16.77
	70	11.81	11.50	19.19	18.00	13.65	15.00	13.80	14.70	15.88	15.95	15.98	16.62
Mean		**10.48**	**10.16**	**18.02**	**16.80**	**13.29**	**14.06**	**13.64**	**14.64**	**15.57**	**15.78**	**15.79**	**16.20**
60	0	8.55	8.44	15.00	14.88	12.74	13.00	13.08	13.15	14.79	14.90	14.88	15.13
	35	9.75	9.31	18.06	17.19	12.89	13.80	13.29	13.95	14.98	15.22	15.35	15.98
	50	11.13	10.44	19.50	19.31	13.06	13.88	13.48	14.80	15.09	15.80	15.55	16.50
	70	11.63	10.94	18.63	18.38	13.22	14.05	13.30	14.65	15.21	15.98	15.89	16.44
Mean		**10.27**	**9.78**	**17.80**	**17.44**	**12.98**	**13.68**	**13.29**	**14.14**	**15.02**	**15.48**	**15.42**	**16.01**
$LSD_{5\%}$ N rates		**0.288**	**ns**	**1.41**	**1.50**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
$LSD_{5\%}$ magnetic time		**0.298**	**ns**	**1.22**	**1.22**	**ns**	**0.30**	**ns**	**0.63**	**ns**	**ns**	**ns**	**ns**
Interaction		**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

There was a significant increase in protein content in the dark and bright calyxes as affected by bio-fertilizer combined with mineral N rates, while the affect mineral N rates was not significant for dark calyxes compared to other treatments. Also, the protein (%) content in bright calyxes was increased by at rate 70 kg mineral N fed^{-1} and magnetic at 30 min time. There was an increase in protein (%) content in bright calyxes after treatment with bio-fertilizer combined with 50 kg N fed^{-1} and magnetic seeds at 30 min.

The carbohydrate content was increased in the bright calyxes treated with 70 kg N fed^{-1} combined with magnetic seeds at 30 min, while the increase of carbohydrate content in dark calyxes was affected by bio-fertilizer combined with mineral N at a rate of 50 kg fed^{-1} and magnetic seeds at 30 min. The effect of mineral N at different rates on carbohydrate content in calyxes dark and bright was not significant, while the carbohydrate content in calyxes' dark was significantly increased with the magnetized seeds combined with the bio-fertilizer application. The interaction between all treatments was not significant regarding the effect on the carbohydrate content in dark or bright calyxes.

Anthocyanin (mg/g.dw) content in the dark calyxes treated with mineral N at a rate of 50 kg fed^{-1} and bio-fertilizer combined with the magnetized seeds at 30 min. The effect of mineral N fertilizer rates on the anthocyanin (mg/g.d.w) content in bright and dark calyxes was not significant. The calyxes' created with magnetized seeds combined with bio-fertilizer and mineral N fertilizer rates were not significant. The interaction between all treatments on calyxes (dark and bright) was not significant.

It is clear from the data in Table 8 that the increase in chlorophyll content in dark and bright calyxes treated with bio-fertilizer combined with mineral N fertilizer at a rate of 50 kg fed^{-1} and magnetic seeds at 30 min compared with other treatments. There was a significant increase of chlorophyll content in bright calyxes with increasing the mineral N fertilizer and magnetized seeds, while the magnetized seeds at different times combined with bio-fertilizer were significant for the chlorophyll content in dark calyxes. The highest value of chlorophyll was 4.80 (mg/g.f.w.) for dark calyxes treated with magnetic seeds at 30 min combined with bio-fertilizer and mineral N at 50 kg fed^{-1}.

Data presented in Table 8 shows that the decrease in juice content pH in calyxes' dark Roselle plant treated with bio-fertilizer combined with mineral N at a rate of 50 kg fed^{-1} and magnetic seeds at 30 min time. The effect of magnetic seeds on dark calyxes resulted in a significant decrease in pH content in juice Roselle plant. The different rates of mineral N fertilizer applied were not significantly different for pH content in juice of the dark and bright calyxes. The interaction between all treatments on pH of the juice of the dark and bright calyxes was not significant.

Table 8. Effect of pre-sowing magnetic treatment of seeds, N-fertilizer rates and bio-fertilizer on chlorophyll and pH content in plant (values of two seasons)

Magnetic time (min)	N rates (kg fed^{-1})	Bright	Dark	Bright	Dark	Bright	Dark	Bright	Dark
		Chlorophyll (mg/g f.w)				pH			
		Mineral		Bio-fertilizer		Mineral		Bio-fertilizer	
0		**2.75**	**2.88**	**3.06**	**3.15**	**3.44**	**3.32**	**3.20**	**3.05**
	35	2.94	2.97	3.12	3.30	3.37	3.20	3.09	2.89
	50	3.04	3.12	3.89	3.90	3.21	3.15	3.00	2.70
	70	3.09	3.25	3.55	3.84	3.20	3.08	3.06	2.84
Mean		**2.96**	**3.06**	**3.41**	**3.55**	**3.31**	**3.19**	**3.09**	**2.87**
15	0	2.80	2.98	3.10	3.30	3.37	3.25	3.13	2.88
	35	3.07	3.10	3.55	4.06	3.19	3.17	2.96	2.76
	50	3.13	3.23	4.08	4.35	3.13	3.10	2.65	2.45
	70	3.18	3.40	3.80	3.88	3.05	3.08	2.78	2.68
Mean		**3.05**	**3.18**	**3.63**	**3.90**	**3.19**	**3.15**	**2.88**	**1.69**
30	0	2.99	3.08	3.22	3.40	3.33	3.20	2.85	2.80
	35	3.12	3.22	4.09	4.25	3.02	3.12	2.54	2.50
	50	3.25	3.50	4.65	4.80	2.85	2.98	2.30	2.10
	70	3.34	3.75	4.02	4.77	2. 97	3.06	2.45	2.30
Mean		**3.18**	**3.39**	**4.00**	**4.31**	**3.04**	**3.09**	**2.54**	**2.43**
60	0	2.90	3.02	3.17	3.55	3.18	3.24	3.05	2.85
	35	3.10	3.16	3.89	4.10	3.07	3.15	2.75	2.66
	50	3.21	3.47	4.13	4.45	2.99	3.06	2.45	2.38
	70	3.29	3.69	4.09	4.20	2.90	3.01	2.58	2.40
Mean		**3.13**	**3.34**	**3.82**	**4.08**	**3.04**	**3.12**	**2.71**	**2.57**
$LSD_{5\%}$ N rates		**0.277**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
$LSD_{5\%}$ magnetic time		**0.337**	**ns**	**ns**	**0.51**	**ns**	**ns**	**ns**	**0.26**
Interaction		**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

DISCUSSION

The present study presents optimized Roselle cultivation practices include the combination between mineral and bio-fertilization preceded by pre-sowing seeds' magnetization. Its goal to enhance the plant yield and quality as well as soil fertility status can be a result of the interactive effect of the studied practices. The study outputs agreed with many previous studies that reported the effect of single or combined application of the studied factors on both soil and plant.

Regarding the soil, it was mentioned that the application of the studied bio-fertilizer to the soil decreased the soil pH values during the cultivation season. This may be due to the organic acids produced by bacteria during the mineralization of organic materials (Hassan *et al.,* 2020). Previous studies also referred to that bio-fertilizer application combined with mineral N fertilizer slightly decreased the soil pH that may be due to activation of Dehydrogenase enzyme production by microorganisms and increased liberation of H_2 in the root zone, which react in rhizosphere to form hydrocarbon acid resulting in the soil pH decrease. Pre-sowing of seeds magnetization combined with high rates of mineral N fertilization also decreased the soil pH compared with the control (Shaban and Omar, 2006; Helmy *et al.,* 2023; Shaban *et al.,* 2023). Magnetically treated seeds may induce a decrease in soil salinity compared with control samples (Samarah *et al.,* 2021). Soil salinity (EC) values were also slightly decreased by bio-fertilizer treatments (Gaafar *et al.,* 2023). The decrease in EC can be due to the increased ability of electrolytic substances to precipitate by the action of magnetization and magnetic induction, which may increase solubility of some salts or minerals (Ashraf, 2014). Pre-sowing seeds' magnetization either alone or coupled with bio-fertilizer treatments decreased the EC and pH at MF exposure time ≥30 min (Hamed, *et al.,* 2024). Using the bio-fertilizer led to an increase in the activity of micro-flora and an increase in the stability of soil OM (El-Naggar and El-Kouny, 2011). The applications of bio-fertilizers increased the OM content in soil and improved the soil fertility in arable soils (Dębska *et al.,* 2016). The decreased soil salinity due to the pre-sowing seeds' magnetization at 15 min combined with the mineral fertilization can be explained by the MF effect that decreased the total dissolved solids in the soil solution. The magnetization may lead to changes in the hydrogen bonding that increase mobility of ions, which decreases the effect of high soil (EC) (Vashisth and Nagarajan, 2009; Abdel Fatah and Esmaeil, 2022). Different times of magnetization combined with bio-fertilization decreased the $CaCO_3$ (%) content that may be due to greater reduction in total $CaCO_3$ precipitation rate in the first 30 minutes of precipitation time compared to the rate by non-magnetized treatment. Magnetic exposure times longer than 10 min may reduce the nucleation of $CaCO_3$% in soil. Bio-fertilizer applications to calcareous soils lowers the $CaCO_3$, through activating soil microorganisms, which can decrease the soil pH and subsequently enhance solubility of inorganic minerals (Chibowski *et al.,* 2003; Abu-Hussin *et al.,* 2008; Saksono *et al.,* 2008). Additionally, (Sadek *et al.,* 2022) reported that the bio-fertilizer increased the macronutrient contents of N, P and K in soil resulting in a decreased pH and improved fertility of saline soils. El-Naggar and El-Kouny, (2011) found that applying bio-fertilizers to soil resulted in significantly highest N, P and K available contents. The microorganisms may produce growth-promoting substances resulting in more efficient absorption of nutrients. The application of bio-fertilizer to soil led to an increase in available N, P and K (mg kg^{-1} soil) and total microbial count of soil, antioxidant activity of soil (AOA), dehydrogenase, nitrogen fixers, and PSB counts (Alotaibi *et al.,* 2024). The magnetized seeds combined with different mineral fertilizers rates had high available N, P and K. The magnetic seed treatment increased the amount of microbial content of the soils such as nitrogen-fixing bacteria. This increase in microorganisms may improve the availability of elements in the soil to plant uptake. Pre-sowing magnetic treatment combined with mineral N-P-K fertilizers applications decreased soil pH and EC, while increasing the soil content of N, P, K, Fe, Mn and Zn (Ratushnyak *et al.,* 2008; Abdel Fattah and Esmaeil, 2022).

Regarding the plant, the seeds treated with MF alone or combined with different bio-fertilizer amendments showed higher N, P and K contents particularly in seeds exposed to long-time MF (45 min > 30 min > 15 min > 0 min) (Hamed *et al.,* 2024). There was a significant increase in the plant height (cm), No. of breaches and No. of calyxes/ plant resulted from the mineral N fertilizer rates or bio-fertilizer or magnetization for calyxes dark and bright. The interaction between mineral N fertilizer rates and bio-fertilizer combined with magnetization times was non-significant for the number of branches per plant for the dark and bright calyxes /plant. The 50% N fertilization rate combined with bio-fertilizer treatment resulted in the highest data of plant height, number of branches, and highest number of calyces per plant. The bio-fertilization with microorganisms significantly increased the fresh and dry weights, plant height, and number of sepals and branch (Al-Sayed *et al.,* 2020). Pre-sowing magnetization and bio-fertilization combined with 75%, mineral fertilizers were the most significant to increase in the plant length (cm) and No. branches /plant (Rashad *et al.,* 2022). It has been indicated previously that the application of the bio-fertilizer significantly increased the yield [fresh and dry weights of fruits / plant (g)] of Roselle (El-Naggar and El-Kouny, 2011). Bio-fertilizers had a significant effect on most of the Roselle growth and yield attributes measured. The bio-fertilizer had the highest dry calyx weight and final calyx yield (kg ha^{-1}) (El-Naim *et al.,* 2017). The bio-fertilizer application increases the plant growth that may be due to an increase in the soil microbial flora and the availability of plant nutrients in soil (Al-Sayed *et al.,* 2020). The MF can induce changes in seeds, especially phyto hormones (auxins, gibberellins and cytokinins), which affect the growth and development of plants. Magnetic treatment of seeds enhances the plant vigour by influencing the biochemical process that involves free radicals and by stimulating the activity of proteins and enzymes. The pre-sowing magnetic treatment of corn seeds for 15, 30, and 45 min has improved the chlorophyll content. Seeds that have been exposed to MF for 30 and 45 min have been found to be the best results compared with other studied treatments (Mukhtar and Friday, 2020). Bio-fertilizers increase the chlorophyll levels and stimulate the chlorophyll synthesis by encouraging the formation of pyridoxal enzymes, which play an essential role in α-amino levulinic acid synthetase as a primary compound in chlorophyll synthesis as mentioned previously (Kahil *et al.,* 2017). There was an increase in the plant chlorophyll content treated with MF. Increasing the exposure time to a MF increased the chlorophyll content in the Rosemary plant (Atak *et al.,* 2007; Abdul Hussain and Jawad, 2019). The combination of bio- and mineral fertilization significantly decreased the protein content in the soybean plant (Rashad *et al.,* 2022). The duration of exposure is more critical in protein content formation, which may be due to the excessively long exposure of pea plants (20 days) (Herman *et al.,* 2024).

Bio-fertilizers have the ability not only to fix N but also to release certain phyto hormones of GA3 and IAA nature which could stimulate plant growth, nutrients absorption, and photosynthesis. This can be attributed to the production of amino acids, vitamins and growth-promoting substances like indole acetic acid and gibberellic acid secreted by these introduced beneficial microorganisms. This enhances the nutrient uptake, translocation and synthesis of photosynthate assimilates which resulted in increased plant growth characteristics and in obtaining economically profitable yield. The magnetically treated seeds produced plants with significantly increase fruits, fruit weight, fruit yield per plant and per area than the control plants. Pre-sowing magnetic treatments enhanced the growth and yield of cultivation (Souza *et al.,* 2005). Pre- sowing seedling treatment with MF improves the early stages of growth resulting in higher yield and increases stress enzymes like APX in seedlings (Sunita and Lokesh, 2017). Seed exposed to the MF promoted IAA, cytokinins, and GA syntheses, and this may promotes the cell division and plant enlargement. Cytokinins play the key role in the modulation of symbiotic interactions and regulation of roots and nodule formation. The treatment with MF led to increase in the hormone content in young plants and stimulation satisfactory for further nitrogen fixation to increase of yield (Podleśny *et al.,* 2021).

The plant treated with MF showed an increase in the Enzyme activity, protein synthesis, cell efficiency and thus its production. It improves the metabolism of the plant or through its role in increasing the production of growth regulators especially cytokinins and auxins. Bio-fertilizers may increase the total carbohydrate percentage in Roselle plant tissues, which may be due to the role of these bio-fertilizers on the enzymatic systems responsible for the biosynthesis of these compounds (Hassan, 2009). The MF led to increase the compounds of Anthocyanin (mg/g.dw), which was more effective than in non-magnetized conditions. This reflects positively on increased absorption of nutrients and increased cell division, thereby increasing the levels of major compounds of active Anthocyanin for dark. The application of bio-fertilizer to Roselle was significantly increases in the sepal i.e. anthocyanin; chlorophyll and carbohydrates contents compared with control. The pH value was reduced due to bio-fertilizer treatments (Kahil *et al.,* 2017). Inoculating the Roselle seeds with bio-fertilizer combined with mineral fertilizer at a rate of 50 % led to a slight decrease in acidity pH compared to control (Matter, 2009). The magnetic treatment of the seeds before cultivation along with the utilization of the bio-fertilizers combined with mineral N fertilizer was significantly efficient in improving the calyx yield and quality.

CONCLUSION

The results suggested that improvement of soil fertility; calyx yield and quality of Roselle plant were resulted by different magnetic treatment times combined with the application of the bio-fertilizer and mineral N- fertilizer at different rates. The treatment 30 min magnetization time combined with 50 kg N fed^{-1} mineral fertilizer combined with bio-fertilizer showed the most significant enhanced parameters. The pre-sowing magnetic treatment of seeds can be a promising recommended technique for Roselle cultivation improvement under saline soil conditions especially when accompanied by mineral and bio-fertilization.

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