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EFFECT OF SOME SOIL AMENDMENTS ON GROWTH, YIELD AND QUALITY OF TOMATO PLANTS (*LYCOPERSICON ESCULENTUM* MILL.) CULTIVATED UNDER SALINITY CONDITIONS

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ABSTRACT

Two field experiments were conducted at Kalabsho region, El-Dakahlia Governorate, Egypt, during 2010 and 2011 seasons to evaluate the effect of some soil amendments, *i.e.*, agricultural gypsum, rice straw mulching and cyanobacteria inoculation as well as their combinations on growth, chemical composition, yield and fruit quality of tomato plants (Fiona F1 hybrid) cultivated under salinity conditions in northern of the Nile Delta.

The obtained results confirm that the combined addition of agricultural gypsum (applied according to the gypsum requirements at 4.34 ton fed^{-1}) + rice straw mulching (12 ton fed^{-1}) + inoculation of tomato seedlings before transplanting with cyanobacteria (2 liter fed^{-1}) had the highest significant vegetative growth characteristics (number of branches, relative growth rate and net assimilation rate) and chemical composition (N, P, K, Ca and K^+/Na^+ ratio as well as total chlorophyll contents) in tomato plant foliage. This treatment also had the significant increases in fruit setting percentage and marketable yield as well as the highest significant values of fruit quality characteristics (vitamin C, TSS and lycopene content) with the lowest nitrite accumulation comparing with the untreated plants (control), which had the minimum quality aspects of tomato fruits in both seasons. Such treatment is found to be economically and more agronomically feasible. It showed the highest net return and returned the highest benefit-cost ratio (1.87) in comparison with the other treatments.

In conclusion, this investigation demonstrates that the combined application of agricultural gypsum (4.34 ton fed^{-1}) + rice straw mulching (12 ton fed^{-1}) + inoculation of tomato seedlings before transplanting with cyanobacteria could be recommended to improve the vegetative growth characteristics, chemical composition, marketable yield and fruit quality. It proved to be the economical for tomato production under salinity conditions to ensure the optimum and the satisfactory utilization of the new reclaimed land.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most widely cultivated vegetables in Egypt. Beside the great nutritive value as a good source of minerals, vitamins and natural antioxidants, tomato has an economically attractive as a cash vegetable crop. Kalabsho region is a new reclaimed land located in Northern of the Nile Delta, Egypt. It is distinguished by the moderate weather, especially during the summer season, that unique weather is appropriate for the late summer cultivation of tomato plants, which has always been the most important for farmers because of high prices.

According to the classification salt content of soils (FAO, 2006) Kalabsho region soil is classified as strongly salty with EC of 6.55 and 6.82 dSm^{-1} in both seasons, respectively, meanwhile, the available irrigation source can be classified as medium saline water (FAO, 1985), it is a Nile water highly affected by saline agricultural drainage water with EC of 3.01 and 3.26 dSm^{-1}, during the two growing seasons, respectively.

Unfortunately, tomato plants have been classified as moderately salt sensitive crop with threshold value of 2.5 dSm^{-1} and a dramatically yield decrease about 9.9 % per dSm^{-1} (Mass, 1990). Salinity conditions of soil and irrigation water through their high osmotic pressures affect growth by restricting the uptake of water and essential nutritional ions by tomato plants roots (Tester and Devenport, 2003) that seriously limits the potential of tomato production, resulting in lowering the profitability of this important vegetable crop in such region. One of the known soil amendments commonly used in reclamation salinity-affected soils is the application of agricultural gypsum that led to reducing salinity hazards (Abbas *et al*., 2004 and Saeed and Ahmad, 2009). Recently, a great attention has been given to other new technologies of combating salinity depending on the use of friendly organic materials, such as organic mulching with rice straw which is one of the most plentiful crop residues in Egypt. Many studies showed that straw mulching is a promising management option for farmers to control soil salinity as it decreases soil water evaporation as well as regulates soil and water salt movement (Yang *et al*., 2006). Organic mulching directly provides organic C inputs to soil and has been used to effectively suppress weeds and reduce soil erosion (Jordan, 2004). Moreover, it has been used to obtain good vegetable growth and yield of tomato plants under salinity conditions (Rahman *et al*., 2006; Saeed and Ahmad, 2009). Abul-Hashem (2001) showed that cyanobacterial biofertilizer could be used to reclaim soil problems such as saline and low fertility soils. Cyanobacteria is a phylum of bacteria that obtain their energy through photosynthesis. The majorities of cyanobacteria are capable of fixing atmospheric nitrogen and are effectively used as biofertilizers and soil conditioner (Vaishampayan et al., 2001). Cyanobacteria inoculation was reported to increase plant growth and yield of many plants such as tomato (Rizvi and Sharma, 1994); rice (Song *et al*., 2005) and common bean (Hegazi *et al*., 2010).

This work is an attempt to improve the performance of tomato plants grown under salinity conditions by adding agricultural gypsum, rice straw mulching and cyanobacteria.

MATERIALS AND METHODS

Two field experiments were carried out at a private farm at Kalabsho region, El-Dakahlia Governorate, Egypt, during 2010 and 2011 seasons to investigate the effect of some soil amendments, *i.e.,* agricultural gypsum, rice straw mulching and cyanobacteria inoculation treatment on growth, chemical composition, yield and fruit quality of tomato plants cultivated under soil and water irrigation salinity conditions. Some physical and chemical properties of the experimental soil and irrigation water are present in Tables 1 and 2. The analysis was carried out according to the methods described by Page *et al*. (1982) and Klute (1986).

Table 1: Some physical and chemical properties of the experimental soil during the growing seasons of 2010 and 2011

Properties	1st Season	2nd season	Properties	1st season	2nd Season
Sand	81.1	79.4	Available macro-nutrients (ppm)		
Silt	14.3	16.7	N	3.11	3.74
Clay	4.6	4.9	P	3.61	3.24
Texture class	Loamy sand	Loamy sand	K	25.2	17.4
O.M. (%)	0.42	0.53	Soluble cations (meq 100 L^{-1})		
pH	8.20	8.24	Na^+	41.11	46.88
CEC (meq/100 g soil)	8.64	8.42	Ca^{++}	11.25	12.17
ESP (%)	31.07	33.44	Mg^{++}	12.33	8.74
EC (dSm^{-1})	6.55	6.82	K^+	0.81	0.39
$CaCO_3$ (%)	0.43	0.48	Soluble anions (meq 100 L^{-1})		
Bulk density (kg m^{-3})	1.62	1.57	$SO_4^=$	14.96	19.22
Field capacity (%)	14.2	13.4	HCO^-	3.41	4.51
GR* (ton fed^{-1})	4.16	4.51	Cl^-	44.11	42.77

***Gypsum requirement = 4.34 ton fed^{-1}**

Table 2: Chemical characteristics of the used irrigation water during the growing seasons of 2010 and 2011

Season	pH	EC (dSm^{-1})	Soluble cations (meq L-1)				Soluble anions (meq L-1)		
			K^+	Na^+	Mg^{2+}	Ca^{2+}	$SO^{4=}$	Cl^-	HCO^{3-}
1st season	7.63	3.01	0.67	18.2	6.84	4.41	4.78	12.12	5.41
2nd season	7.91	3.26	0.21	21.3	5.23	5.84	2.89	10.47	7.87

On July, 1st week in both seasons of the study, 45 day old tomato seedlings (Fiona F1 hybrid, product of Sluis & Groot, Erakhuizen, Holland) were transplanted in open field using furrow irrigation at 50 cm apart on one side of the ridge.

Layout of experiment and treatments:

The experimental unit consisted of eight ridges each of 1 m wide and 3.5 m long with plot area of 28 m^2. A complete randomized block design with three replicates was adopted to include eight treatments as follows: Control (T1); Agricultural gypsum (T2); Rice straw mulching (T3); Cyanobacteria inoculation (T4); Agricultural gypsum + Rice straw mulching (T5); Agricultural gypsum + Cyanobacteria inoculation (T6); Rice straw mulching + cyanobacteria inoculation (T7) and finally, Agricultural gypsum + Rice straw mulching + Cyanobacteria inoculation (T8).

The experiment included three main soil additions; agricultural gypsum (70% purity), which was applied at 4.16 and 4.51 ton fed^{-1} during the two seasons, respectively, according to the gypsum requirements calculation based on the soil analyses (Table 1) as stated by James and Topper (1993). Agricultural gypsum was added two weeks before transplanting by flipping thoroughly in the 30^{th} cm soil layer followed by heavy irrigation. Local rice straw as the organic mulching treatment, was applied 20 days after transplanting to the rows at 12 ton fed^{-1} (about 10 cm thickness). Two salt tolerant strains of cyanobacteria (*Anabaena variabilis* and *Nostoc calcicola*) obtained from Soils, Water and Environment Research Institute, Agricultural Research Center, Egypt, were used to inoculate tomato seedlings once before transplanting. Two liter fed^{-1} of active cyanobacteria cell suspension were dissolved in 4 liter of tap water and mixed with Arabic gum as an adhesive substance. The other agricultural treatments for growing tomato plants were followed according to the instruction laid down by Horticulture Research Institute, Agricultural Research Center, Egypt.

Data recorded:

Growth measurements:

Five plants from each plot at 75 days after transplanting were randomly taken for determination of number of branches per plant. At 45 and 75 days after transplanting, foliage dry weight and leaf area per plant were estimated and were used to calculate relative growth rate (Hunt, 1990) and net assimilation rate (Gardner *et al*., 1985) as follows:

RGR (mg/gm. day^{-1}) = $[(\ln W_2 - \ln W_1)/ (T_2 - T_1)] \times 1000$

NAR (mg/cm^2 day^{-1}) = $[(W_2 - W_1)/ (T_2 - T_1)] \times [(\ln LA_2 - \ln LA_1)/ (LA_2 - LA_1)] \times 1000$

Where; RGR: relative growth rate; NAR: net assimilation rate; In: natural logarithm; W_1: dry weight of plant shoots at time one (in gram); W_2: dry weight of plant shoots at time two (in gram); T_1: time one (in day); T_2: time two (in day); LA_1: leaf area/ plant (Koller, 1972) at time one (cm^2); LA_2: leaf area/ plant at time two.

Chemical analysis:

Representative samples of tomato plant foliage from each plot at 75 days after transplanting were used to determine N, P, K, Ca and Na contents (%) in dry weight. Total nitrogen was determined according to the methods described by Bremner and Mulvaney (1982). Phosphorus was estimated colormetrically according to Olsen and Sommers (1982). Potassium and sodium were assayed spectrophotometrically according to Johanson and Ulrichs (1959). Calcium was determined by titration with versinate (Page *et al*., 1982). The K^+/Na^+ ratio was determined by dividing the K^+ (%) on Na^+ (%). Representative samples from the fourth upper leaves were taken to determinate total chlorophyll content (SPAD units) using a portable leaf chlorophyll meter (Minolta Model SPAD 501) according to Murquard and Timpton (1987).

Fruit setting, yield and quality measurements:

Four uniform plants from each plot were randomly chosen and labeled then fruit setting percentage was recorded (all over the season). All harvested fruits from each plot at full maturity stage along the season were used to determine the unmarketable tomato yield (calculated from all disordered tomato fruits) and total marketable yield (calculated from all harvested marketable fruits) as tons per feddan. A representative sample of 10 tomato fruits from each experimental plot at the marketable ripe stage was taken from the third harvest for determination of fruits quality characteristics, *i.e.,* vitamin C, total soluble solids (TSS) and nitrite contents according to the methods described by AOAC (1990). Lycopene content in fruits was determinate as described by Fish *et al*. (2002).

Statistical analysis:

The obtained data were subjected to statistical analysis by the technique of analysis of variance (ANOVA) according to Snedecor and Cochran (1982). The means of treatments were compared using the least significant difference (LSD) at probability level (P) ≤ 0.05.

Economic feasibility of cultivation tomato plants, *i.e.,* gross return, treatment cost, total variable cost, net return and benefit-cost ratio were calculated based on market prices as average of the two seasons. The benefit-cost ratio was determined according to Boardman *et al*. (2001) by dividing the gross return (LE fed^{-1}) on total variable cost (LE fed^{-1}).

RESULTS AND DISCUSSION

Vegetative growth characteristics:

Some growth characteristics of tomato plants cultivated under salinity conditions are presented in Table 3. The obtained data clearly showed that addition of agricultural gypsum + rice straw mulching + cyanobacteria inoculation treatment (T8) had the significant effect on all studied vegetative growth parameters, *i.e*., number of branches, relative growth rate and net assimilation rate followed by the addition of agricultural gypsum + rice straw mulching treatment (T5) in comparison to the other treatments. It is also clear that the lowest significant values were recorded by the control treatment in both seasons of the study. The results are in agreement with that reported by Rahman *et al*. (2006) they found that plant height of tomato plants increased by mulching with rice straw under saline soil. Moreover, Saeed and Ahmad (2009) reported that plant height, fresh and dry vegetative biomass of tomato plants reached the highest significant values with the addition of organic mulching and agricultural gypsum under saline conditions. Furthermore, under Kalabsho region conditions, EL-Said (2009) stated that application of 2.5 ton of agricultural gypsum as soil amendment had a significant effect on number of leaves, plant height, roots, shoots and total dry weight of tomato plants. Meanwhile, Rizvi and Sharma (1994) demonstrated that soil inculation with cyanobacteria stimulated fresh and dry of tomato plants. Such results also are in agreement with Al-Khiat (2006) who reported that cyanobacteria induced a high significant increase in leaf area, dry weight of shoots and roots of tomato seedlings.

Table 3: Vegetative growth characteristics of tomato plants as affected by agricultural gypsum, rice straw mulching and cyanobacteria applications during 2010 and 2011 seasons

Treatment	No. branches/ plant		Relative growth rate ($mg/gm\ day^{-1}$)		Net assimilation rate ($mg/cm^2\ day^{-1}$)	
	1st Season	2nd season	1st season	2nd season	1st season	2nd season
T1	7.94	6.71	23.15	20.14	0.215	0.227
T2	8.91	7.88	30.47	27.99	0.255	0.269
T3	8.36	7.21	29.43	27.06	0.239	0.257
T4	7.98	6.82	28.10	25.67	0.228	0.244
T5	9.17	8.49	31.39	29.19	0.262	0.276
T6	8.94	8.17	30.82	28.44	0.257	0.271
T7	8.22	7.71	28.92	27.16	0.237	0.250
T8	9.42	8.78	32.27	29.94	0.269	0.284
LSD at 5%	0.211	0.229	0.709	0.724	0.006	0.007

T1: Control; T2: Agricultural gypsum; T3: Rice straw mulching; T4: Cyanobacteria; T5: Agricultural gypsum + Rice straw mulching; T6: Agricultural gypsum + Cyanobacteria; T7: Rice straw mulching + Cyanobacteria; T8: Agricultural gypsum + Rice straw mulching + Cyanobacteria.

The pronounced promotional effect of the agricultural gypsum on vegetative growth of tomato plants under salinity conditions may be due to the several benefits of agricultural gypsum as it contains 23% calcium and 18% sulfur, since calcium plays a great role to ameliorate the salinity hazards by reducing the water potential in plant leaves through preserve the structural and functional integrity of cell membranes, stabilize cell wall structure, regulate ion transport and selectivity as well as control ion-exchange behavior, also, calcium is needed to flocculate clays in alkaline soils (Marschner, 1995). Moreover, salt-affected soils are characterized by the occurrence of sodium (Na^+) at levels that result in poor physical properties and fertility problems, thereby threatening plant growth and productivity. Agricultural gypsum provides these soils with soluble source of calcium (Ca^{2+}) which replace excess Na^+ on the cation exchange sites; the replaced Na^+ is leached from the root zone through leaching irrigation (Oster, 1982). Furthermore, agricultural gypsum decreases soil pH (Andrade *et al*., 2002) and electrical conductivity (Soni *et al*., 1997) by the oxidation of sulphur to H_2SO_4, which is particularly beneficial in alkaline soils to reduce pH, supply SO_4 to plants, make P and micronutrients more available (Burns, 1967) and easily absorbed by plant roots. Additionally, mulching with straw under saline conditions was reported to decrease salt content in about 0-40 cm deep soil and lower the water potential in leaves consequently reduces the salinity hazard (Rahman *et al*., 2006 and Yang *et al*., 2006). Moreover, soil inoculation with cyanobacteria was reported to produce many growth-promoting hormones such as auxin, gibberellins, vitamins and amino acids (Rodriguez *et al*., 2006). Cyanobacteria influences positively the biological activity and chemical properties of soil, where the soil pH and electrical conductivity (EC) were reported to decrease by inoculation with cyanobacteria (Hegazi *et al*., 2010). Such flocculation led to remarkable enhancement in vegetative growth of tomato plants under salinity conditions. On the other hand, the negative effect on the untreated (control) tomato plants (T1) can be explained based on the deleterious effect of salinity on the water status, ions uptake, protein and nucleic acid synthesis as well as on photosynthesis, enzyme activities and hormonal balance, as accordingly, restricting the cellular processes including cell division and expansion (Rodriguez *et al*., 2006) that eventually reduces plant growth. In this respect, Dehan and Tal (1977) reported that when tomato plants grown in high salt media, Na^+ ions are transported and accumulated in leaf tissues and consequently become inhibitory to photosynthetic activities. Such behaviors resulted in the disturbance of all metabolic process and led to flimsy vegetative growth. However, all these obstacles may be avoided by the application of the proposed combination (agricultural gypsum + rice straw mulching + cyanobacteria) that reported in this study.

Chemical composition of plant foliage:

The chemical profile of tomato plant foliage is presented in Tables 4 and 5. There were significant differences among the different treatments on the concentration of N, P, K, Ca, Na and K^+/Na^+ ratio as well as total chlorophyll contents of tomato plant foliage.

Table 4: Chemical composition of tomato plant foliage as affected by agricultural gypsum, rice straw mulching and cyanobacteria applications during 2010 and 2011 seasons

Treatment	N (%)		P (%)		K (%)	
	1st Season	2nd season	1st season	2nd season	1st season	2nd season
T1	1.93	2.07	0.225	0.210	2.61	2.74
T2	2.42	2.64	0.296	0.270	3.32	3.41
T3	2.38	2.58	0.267	0.256	2.98	3.30
T4	2.24	2.46	0.232	0.218	2.72	2.85
T5	2.48	2.68	0.305	0.270	3.35	3.50
T6	2.44	2.61	0.297	0.263	3.24	3.43
T7	2.28	2.47	0.248	0.231	2.81	2.91
T8	2.65	2.80	0.307	0.288	3.49	3.76
LSD at 5%	0.121	0.101	0.013	0.011	0.145	0.133

T1: Control; T2: Agricultural gypsum; T3: Rice straw mulching; T4: Cyanobacteria; T5: Agricultural gypsum + Rice straw mulching; T6: Agricultural gypsum + Cyanobacteria; T7: Rice straw mulching + Cyanobacteria; T8: Agricultural gypsum + Rice straw mulching + Cyanobacteria.

Table 5: Chemical composition of tomato plant foliage as affected by agricultural gypsum, rice straw mulching and cyanobacteria applications during 2010 and 2011 seasons

Treatment	Ca (%)		Na (%)		K^+/Na^+ ratio		Total chlorophyll (SPAD unit)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
T1	1.82	1.77	1.28	1.15	2.04	2.38	44.18	48.31
T2	2.18	2.06	1.16	1.07	2.86	3.19	50.96	56.78
T3	2.06	1.88	1.22	1.11	2.44	2.97	50.34	55.49
T4	1.85	1.81	1.28	1.16	2.13	2.46	43.83	45.90
T5	2.27	2.14	1.12	1.04	2.99	3.37	53.95	58.02
T6	2.28	2.10	1.15	1.06	2.82	3.24	53.32	56.27
T7	1.97	1.93	1.22	1.14	2.30	2.55	53.11	54.30
T8	2.37	2.23	1.09	1.02	3.20	3.69	55.38	61.06
LSD at 5%	0.035	0.045	0.021	0.019	0.051	0.037	1.35	1.81

T1: Control; T2: Agricultural gypsum; T3: Rice straw mulching; T4: Cyanobacteria; T5: Agricultural gypsum + Rice straw mulching; T6: Agricultural gypsum + Cyanobacteria; T7: Rice straw mulching + Cyanobacteria; T8: Agricultural gypsum + Rice straw mulching + Cyanobacteria.

It is clear that the increment of element content, *i.e.*, N, P, K, Ca, Na and K^+/Na^+ ratio as well as total chlorophyll reached the highest significant values with the combined addition of agricultural gypsum + organic mulching + inculation with cyanobacteria treatment (T8) followed by the addition of agricultural gypsum + rice straw mulching treatment (T5) in comparison with the other treatments and control in both seasons. The exception was that of Na content during both seasons, which reach the highest significant value with the untreated plants (T1), while the minimum value was obtained by the integrated addition of agricultural gypsum + rice straw mulching + inculation with cyanobacteria treatment (T8) followed by the addition of agricultural gypsum + rice straw mulching treatment (T5). The results had the same trend during both seasons. Such results are in agreement with the previously confirmed results by several authors, *e.g.*, Saeed and Ahmad (2009) they observed that application of organic mulch and agricultural gypsum under soil salinity conditions increased total chlorophyll, total protein, total soluble carbohydrate and K^+ uptake as well as K^+/Na^+ ratio, whereas, the Na^+ content in dry weight of tomato leaves was significantly reduced. Moreover, EL-Said (2009) illustrated that the addition of 2.5 ton fed^{-1} of agricultural gypsum under Kalabsho region conditions resulted in the highest significant N and P concentration and N, P and K uptake of tomato plants. Al-Khiat (2006) mentioned that addition of cyanobacteria as a soil conditioner increased K, chlorophyll a and b as well as decreased Na content in tomato shoots.

The balanced and improved chemical composition of tomato foliage is expected, especially when applying agricultural gypsum + rice straw mulching + cyanobacteria inculation treatment (T8), in which the combined action of such treatment markedly alleviated the salinity hazards of the soil, it was observed that such treatment tended to be more effective than the other treatments and control in improving and recovering mineral status of tomato plants, particularly the minerals of tomato foliar N, P, K and Ca with the lowest Na^+ content. Such gains could be attributed based on the known role that addition of agricultural gypsum to the saline soil was the most effective to increase soluble Ca ions, available N, P and K, soil total porosity, field capacity, wilting point and available water content, also decreasing soluble Na^+, exchangeable sodium percent (ESP) and soil bulk density (Abbas *et al*., 2004). Moreover, it was reported that high K^+/Na^+ ratio is important for plant salt tolerance (Gao *et al*, 2007). Additionally, the surface organic mulching has shown to reduce evaporation and decrease salinity hazards (Yang *et al*., 2006). Another possible reason for such improvement in tomato foliage chemical composition is that the combined application of organic mulching and agricultural gypsum under salinity stress increased the osmotic potential, carbohydrate, protein and the inorganic contents of tomato leaves, also showed a significant increase in K^+/Na^+ ratio (Saeed and Ahmad, 2009). Moreover, the positive effect of cyanobacteria on chemical composition of tomato plant foliage under salinity condition may be due to the ability of cyanobacteria to remove Na^+ (Fernandes *et al*., 1993) by the production of exopolysaccharides, which had a decisive role in binding sodium ions from saline medium, thereby alleviating salt stress (Arora *et al*., 2010). Moreover, cyanobacteria produced many of growth promoting hormones, *i.e.*, auxins, cytokinins and gibberellins (Hussain *et al*., 2010) the latter has been reported to reduce the bad effect of NaCl (Rodriguez *et al*., 2006) and hence, alleviation salinity hazards of the soil.

Fruit setting, unmarketable and marketable yield:

The following data presented in Table 6 are concerned with the effect of agricultural gypsum, rice straw mulching and cyanobacteria inoculation treatment on fruit setting, unmarketable and marketable yield of tomato plants cultivated under salinity conditions. The obtained data clearly show that the combined application of agricultural gypsum + rice straw mulching + cyanobacteria inoculation treatment (T8) show the highest significant values of fruit setting percentage and marketable yield of tomato followed by the addition of agricultural gypsum + rice straw mulching treatment (T5). Meanwhile, the lowest significant values in this respect were obtained with the control treatment (T1) which show the highest significant unmarketable tomato yield fed^{-1}. On the contrary the lowest unmarketable tomato yield was obtained by the combined application of agricultural gypsum + rice straw mulching + cyanobacteria inoculation treatment (T8). The results had the same trend during the two seasons. Such results are in line with Saeed and Ahmad (2009) they reported that number and weight of tomato fruits were maximized with organic mulching + agricultural gypsum treatment under saline conditions. Moreover, EL-Said (2009) indicated that addition of 2.5 ton fed^{-1} of agricultural gypsum under Kalabsho region conditions enhanced average fruit weight, number of fruits and fruit yield of tomato plant as well as total yield fed^{-1}. Furthermore, cyanobacteria inoculation was reported to increase yield of tomato (Rizvi and Sharma, 1994) and common bean (Hegazi *et al*., 2010).

Table 6: Fruit setting and yield characteristics of tomato plants as affected agricultural gypsum, rice straw mulching and cyanobacteria applications during 2010 and 2011 seasons

Treatment	Fruit setting (%)		Unmarketable yield (ton fed^{-1})		Marketable yield (ton fed^{-1})	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
T1	61.47	64.77	4.06	3.66	10.85	12.74
T2	67.99	72.64	3.21	3.01	13.39	14.13
T3	64.66	66.14	3.41	3.10	12.53	14.60
T4	60.42	63.41	4.15	3.59	11.02	12.54
T5	71.88	74.27	2.84	2.65	14.03	16.12
T6	71.08	72.91	2.94	2.88	13.51	15.62
T7	65.72	68.12	3.74	2.97	12.61	15.12
T8	74.01	77.15	2.53	2.34	15.32	17.24
LSD at 5%	2.02	1.87	0.110	0.092	0.422	0.473

T1: Control; T2: Agricultural gypsum; T3: Rice straw mulching; T4: Cyanobacteria; T5: Agricultural gypsum + Rice straw mulching; T6: Agricultural gypsum + Cyanobacteria; T7: Rice straw mulching + Cyanobacteria; T8: Agricultural gypsum + Rice straw mulching + Cyanobacteria.

The mentioned cited interpretation due the application of agricultural gypsum, rice straw mulch and cyanobacteria may be due to their enhancing impact on vegetative growth behaviors of tomato plants (Table 3), that associated with the recovering of the mineral status of tomato plants (Table 4 and 5), particularly Ca contents that certainly reflected on the bioassimilation process of the whole metabolic machinery, those known to be reflected in similar beneficial way on fruit yield responses of tomato plants. Meanwhile, the adverse impact on fruit setting percentage with the untreated plants (T1) is mainly due to the negative effect of soil and water salinity as it showed the highest N^+ content and the lowest K^+/Na^+ ratio in tomato plant foliage (Table 5) that closely related with the decreasing in fruit sitting under such conditions. However, fruit setting percentage and yield of tomato responded negatively to the increment in salinity level (Tantawy *et al*., 2009). Moreover, surface organic mulching with rice straw is an effective application to isolate tomato fruits from direct contact with soil this isolation reflected on the significant decrease in unmarketable tomato yield.

Fruit quality characteristics:

Regarding to the effect of agricultural gypsum, rice straw mulching and inoculation with cyanobacteria on the quality aspects of tomato fruits, it is obvious from data in Table 7 that vitamin C, TSS and lycopene contents were significantly affected positively by the combined application of agricultural gypsum + rice straw mulching + cyanobacteria inoculation treatment (T8). Meanwhile, nitrite content reached the lowest value with such treatment in comparison with the untreated plants (control), which showed the lowest vitamin C, TSS and lycopene as well as the highest nitrite content in tomato fruits in both seasons. Similar results were reported by EL-Said (2009) on tomato who showed that application of 2.5 ton fed^{-1} of agricultural gypsum as a soil amendment under Kalabsho region conditions had a significant improvements on vitamin C and total carbohydrates content of tomato fruits.

Table 7: Quality characteristics of tomato fruits as affected by agricultural gypsum, rice straw mulching and cyanobacteria applications during 2010 and 2011 seasons

Treatment	Vitamin C (mg/100g FW)		TSS (%)		Nitrite content (mg kg^{-1} fresh fruit)		Lycopene (mg kg^{-1} fresh fruit)	
	1st Season	2nd season	1st season	2nd season	1st season	2nd season	1st Season	2nd season
T1	19.52	22.97	7.10	6.32	0.358	0.496	55.41	52.74
T2	20.57	23.75	6.92	6.21	0.319	0.442	62.66	57.88
T3	20.12	22.69	6.78	6.23	0.325	0.462	58.73	54.19
T4	19.63	21.87	6.99	6.28	0.331	0.481	54.47	52.34
T5	21.70	24.40	7.16	6.31	0.315	0.419	64.21	60.06
T6	21.01	23.86	7.05	6.28	0.321	0.438	61.96	57.44
T7	20.03	22.98	7.08	6.27	0.327	0.451	58.81	56.26
T8	23.46	25.97	7.31	6.44	0.290	0.398	67.33	62.55
LSD at 5%	1.34	1.41	0.14	0.11	0.025	0.030	2.67	2.41

T1: Control; T2: Agricultural gypsum; T3: Rice straw mulching; T4: Cyanobacteria; T5: Agricultural gypsum + Rice straw mulching; T6: Agricultural gypsum + Cyanobacteria; T7: Rice straw mulching + Cyanobacteria; T8: Agricultural gypsum + Rice straw mulching + Cyanobacteria.

The stimulatory effect of the combined addition of agricultural gypsum + rice straw mulching + cyanobacteria inoculation treatment (T8) on quality characteristics of tomato fruits may be related to their ameliorative effect on potassium content as well as K^+/Na^+ ratio in plant foliage (Table 5), as potassium is closely related with fruit quality characters, it plays an important role in water status of plant, promoting the translocation of newly synthesized photosynthesis and mobilization of stored materials as well as promoting the synthesis of sugars and polysaccharides (Mengel and Kirkby, 1982). Herein, the increment of nitrite content in tomato fruits with the control treatment may be due to the metabolic toxicity of Na^+ and its great ability to compete with K^+ for binding sites essential for cellular function, thus, high levels of Na^+ (Table 5) can disrupt various enzymatic processes in the cytoplasm including protein synthesis that requires high concentration of K^+ (Tester and Davenport, 2003). Furthermore, polysaccharides, which produced by cyanobacteria increases soil water holding capacity through their jelly structure (Rogers and Burns, 1994) such behavior are known to be closely associated with the water status in plant tissues, particularly under salinity conditions that related positively with fruit quality (Mitchell and Shennan, 1991).

Economic feasibility:

The economic feasibility of cultivation tomato plants in the presence of agricultural gypsum, rice straw mulching and cyanobacteria inoculation treatment under salinity conditions are presented in Table 8. The results showed that the highest net return (11328 LE fed^{-1}) was obtained under the combined application of agricultural gypsum + rice straw mulching + cyanobacteria inoculation treatment (T8); such treatment returns the highest benefit-cost ratio (1.87) in comparison with the other treatments. Thus, this treatment proved to be economical for tomato production under the conditions of this study.

Table 8: Economic performance of tomato plants as affected agricultural gypsum, rice straw mulching and cyanobacteria applications during 2010 and 2011 seasons

Treatment	Marketable yield (ton fed^{-1})$^{(1)}$	Gross return (LE fed^{-1})$^{(2)}$	Treatment cost (LE fed^{-1})$^{(3)}$	Total variable cost (LE fed^{-1})$^{(4)}$	Net return (LE fed^{-1})$^{(5)}$	Benefit-cost ratio$^{(6)}$	Order
T1	11.80	17693	0	11370	6323	1.56	7
T2	13.76	20640	892	12262	8378	1.68	6
T3	13.57	20348	660	12030	8318	1.69	5
T4	11.78	17670	170	11540	6130	1.53	8
T5	15.08	22613	1552	12922	9691	1.75	3
T6	14.57	21848	1062	12432	9416	1.76	2
T7	13.87	20798	830	12200	8598	1.70	4
T8	16.28	24420	1722	13092	11328	1.87	1

(1) Tomato marketable yield as average of two seasons. (2) Gross return as marketable yield (ton fed^{-1}) X 1500 LE ton^{-1}. (3) Treatment cost was calculated according to the following prices; agricultural gypsum = 170 LE ton^{-1}, Rice straw = 45 LE ton^{-1}, Cyanobacteria = 60 LE liter^{-1}. (4) Total variable cost (LE fed^{-1}) include; Treatment cost plus land leasehold, transplants, NPK fertilizers, microelements, pesticides, labors, and other agricultural practices, which equal nearly 11370 LE fed^{-1}; (5) = (2)-(4). (6) = (2)/ (4).
T1: Control; T2: Agricultural gypsum; T3: Rice straw mulching; T4: Cyanobacteria; T5: Agricultural gypsum + Rice straw mulching; T6: Agricultural gypsum + Cyanobacteria; T7: Rice straw mulching + Cyanobacteria; T8: Agricultural gypsum + Rice straw mulching + Cyanobacteria.

In conclusion, this investigation demonstrates that the combined application of agricultural gypsum (5.94 ton fed^{-1}), rice straw mulching (12 ton fed^{-1}) and inoculation of tomato seedlings before transplanting with cyanobacteria could be recommended to improve the vegetative growth characteristics, chemical composition, marketable yield and tomato fruit quality. It proved to be the economical for tomato production under salinity conditions to ensure the optimum and the satisfactory utilization of the new reclaimed land.

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تأثير بعض محسنات التربة علي نمو ومحصول وجودة ثمار الطماطم المنزرعة تحت ظروف الملوحة

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أجريت تجربتان حقليتان بناحية قلبشو-محافظة الدقهلية -مصر خلال موسمي ٢٠١٠ و٢٠١١ وذلك لدراسة تأثير بعض محسنات التربة (الجبس الزراعي وتغطية التربة بقش الأرز وتلقيح الشتلات بالسيانوبكتريا) علي نمو ومحصول وجودة ثمار الطماطم المنزرعة تحت ظروف ملوحة التربة والمياه وقد بينت الدراسة بوضوح التأثير المعنوي لمعاملة الإضافة المتكاملة لمحسنات التربة المستخدمة وهي الجبس الزراعي بمعدل ٤.٣٤ طن/فدان (علي أساس الاحتياجات الجبسية طبقاً لتحليل التربة) بالإضافة إلي التغطية العضوية للتربة بقش الأرز بمعدل ١٢ طن/فدان مع تلقيح شتلات الطماطم قبل الزراعة بالسيانوبكتريا وذلك علي حدوث زيادة معنوية في صفات النمو الخضري لنباتات الطماطم متمثلة في عدد الأفرع ومعدل النمو النسبي ومعدل التمثيل الصافي وكذلك التركيب الكيماوي لأوراق نباتات الطماطم من النيتروجين والفوسفور والبوتاسيوم والكالسيوم ونسبة البوتاسيوم الي الصوديوم وكذلك محتوي الأوراق من الكلوروفيل. كما أدت تلك المعاملة أيضاً إلى الحصول علي أعلي القيم فيما يخص نسبة عقد الثمار والمحصول التسويقي للفدان. وقد أوضحت النتائج كذلك التأثير المعنوي لتلك المعاملة علي تحسين صفات جودة ثمار الطماطم فيما يخص محتوي الثمار من فيتامين ج والمواد الصلبة الذائبة الكلية وكذلك الليكوبين، مع أفضل تأثير معنوي علي خفض تركيز النيتريت في الثمار بالمقارنة مع معاملة المقارنة والتي أظهرت أقل القيم فيما يخص صفات جودة الثمار وذلك مقارنة بباقي المعاملات. وقد بين التحليل الاقتصادي أن استخدام تلك المعاملة قد أدي إلى الحصول علي أكبر عائد اقتصادي مع تحقيق أكبر قيمة لنسبة المنافع إلى التكاليف (١.٨٧) بالمقارنة مع المعاملات الأخرى تحت ظروف التجربة.

وبناء على ذلك توصي هذه الدراسة بالإضافة المتكاملة لمحسنات التربة مثل الجبس الزراعي والتغطية العضوية للتربة بقش الأرز مع تلقيح شتلات الطماطم قبل الزراعة بالسيانوبكتريا وذلك للحصول على أفضل النتائج بالنسبة للنمو والتركيب الكيماوي والمحصول التسويقي وجودة ثمار الطماطم مع تحقيق أفضل عائد اقتصادي تحت ظروف ملوحة التربة والمياه بما يكفل الاستغلال الأمثل لتلك الأرض المستصلحة.

قام بتحكيم البحث

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