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Alleviating adverse effect of saline irrigation water on growth and productivity of tomato plants via some repellant salinity agents

Shahein M.M[1], Husein M.E[2], Abou-El-Hassan S[3]

1. Soil Vegetable Dept., Faculty of Agric., Cairo Univ., Egypt.
2. Dept., Faculty of Agric., Cairo Univ., Egypt.
3. Central Lab of Organic Agriculture, Agriculture Research Center, Egypt.

Corresponding author email: shahein97@yahoo.com

ABSTRACT: A field experiment was carried out on a newly reclaimed land at the Agricultural Experimental Desert Station, Faculty of Agriculture, Cairo University, in Wady El-Natroon district, El-Beheira Governorate, Egypt, cultivated with tomato plants (Supper Strain B F1 cultivar) and irrigated with saline water (2500 ppm) during the summer growing seasons of 2013 and 2014 to study the potential benefit of some repellant salinity agents (Dinamic, Uni-sal and humic acid) for alleviating adverse effect of saline irrigation water on vegetative growth, yield and fruit quality of tomato. This experiment was designed in completely randomized block design with three replications. Seven soil treatments, namely, Dinamic, Uni-sal, humic acid and all possible combinations among them were compared with control (untreated soil). Each compound was used four times (at the transplanting and 15, 30 and 45 days after transplanting) through drip irrigation system at rate of 4 liter/feddan. The effects of these repellant salinity agents on plant length, number of branches, fresh, dry of shoot weight, nutrients content in leaves, total yield, fruit firmness, TSS, titratable acidity and vitamin C in fruits were studied. Results revealed that, all repellant salinity agents were effective in alleviating the adverse effect of salinity on vegetative growth and yield in compared to the control treatment. Using combination between Dinamic and Uni-sal with or without humic acid gave the highest value of vegetative growth, nutritional content, yield and fruit characters compared to other treatments.
Key Words: Tomato, salinity, repellant salinity agents, Dinamic, Uni-sal, humic acid

INTRODUCTION

Salinity of soil or irrigation water is a major factor limiting the growth of vegetable crops. The horizontal expansion in agricultural land depends partially at least on the availability and quality of irrigation water and the level of soil salinity. Use of saline water led to the gradual increase of salinity in the root zone of tomato plants (Mitchell et al., 1991 and Feleafel & Mirdad, 2014). The maximum soil salinity level tolerated by tomato without reduction in the yield is EC 2.5 dS m^{-1} (Campos et al., 2006). Scholberg and Locascio (1999) illustrated that use of saline water (4 dS m^{-1}) for drip irrigation led to a linear reduction in the number of fruits, yield, and average fruit mass of tomato. The use of irrigation water with EC 1.7, 2.3, 3.4 and 5.0 dS m^{-1} led to reductions in tomato yield by 0, 10, 25 and 50%, respectively (Boamah et al., 2011). The majority of the new lands in Egypt are sandy and calcareous soils. The main problems of these soils are their poor structure, low availability of water & nutrients, low fertility, higher salinity and calcium carbonate, the possibility of forming a surface crust and indurate layers at shallow depths. The reclamation of these soils was mainly depended upon the addition of anti-salinity agents to alleviate the adverse effects of salinity on growth, nutritional status and fruiting of crops (Abada et al., 2010).

Dinamic contains potassium humate as main component and 7% fulvic acid. Soil application of humate led to alleviate the negative effects of any stress (unfavorable temperature, pH, and salinity) as were reported by Serenella et al (2002), Salama (2009), El-Hefny (2010) and Cimrin et al (2010) where the application of humate led to a significant increase in soil organic matter, improve the nutrient balance and plant vitality (Boehme et al., 2005), thus improve plant growth and productivity of vegetable (Hayes & Wilson, 1997; Hafez, 2003 and Zandonadi et al., 2007). The humic substances (HS) also enhance plant growth significantly due to the increasing cell membrane permeability, respiration, photosynthesis, oxygen and phosphorus uptake and supplying root cell growth

(Gulser et al., 2010 and Pizzeghello et al., 2013). The uptake of humic substances in the plant tissue resulting in various biochemical effects through the increase in nutrient uptake, maintaining vitamins and amino acids level in plant tissues thus stimulate roots growth and whole plant (Tipping, 2002). Fulvic acid is more efficient to penetrate to the plant roots due to the small molecular structure. Fulvic acid increased the shoot growth, the uptake of N, P, K, Ca, Mg and the yield of plants quantity and quality as was reported by Rauthan & Schnitzer (1981) on cucumber and Samavat & Samavat (2014) on tomato. Potassium acted as an ameliorative agent and decreased the negative effects of sodium chloride (NaCl) where potassium ions compete with sodium ions in the root zone (Chen et al., 2007). Potassium increased the vegetative growth, yield and fruit quality of tomato under salt stress, as well as it reduced the negative effects of salinity (Yurtseven et al., 2005 and Amjad et al., 2014).

Soil application of humic acid (HA) led to improved soil properties such as aggregation, aeration, permeability, water-holding capacity, ion transport and availability through pH buffering (McDonnell et al., 2001). Humic acid can be used as a growth regulator to control hormone level, improve plant growth and enhance stress tolerance (Cimrin et al., 2010).

Uni-sal contains polyethylene glycol (PEG), some elements (especially Ca) and amino acids. Munir and Aftab (2009) reported that “PEG” decreases the osmotic potential of nutrient solutions and is not phytotoxic. Also, Kawasaki et al (1983a,b) and Slama et al (2007) indicated that, polyethylene glycol has been successfully used as an osmotic for subjecting plant tissues. Calcium can be adversely affected by salinity induced by exchangeable sodium content or remove it (Caines and Shennanb, 1999). On the other hand, sodium ions may compete with Ca ions in membrane-binding sites. Therefore, high Ca concentration plays an important role in protecting the cell membrane against salinity stress (Busch, 1995). Moreover, calcium also prevents the uptake of sodium ion to injurious levels and increasing the uptake of calcium and potassium resulting in enhancing in plant growth and reduction in the harmful effect of salinity on plant (Rengel, 1992 and Abd El-Hady 2003). Application of Uni-sal, which contains amino acids (gliteric acid), makes activation by bio formation of proline, which is considered one of the most important amino acid that help the plant for resisting most of stress like salinity and drought (Wareing and Phillips, 1973). Furthermore, amino acids increased chlorophyll content due to their role in increasing protein biosynthesis that is essential for chlorophyll formation, as well as their role in enhancing growth, yield and physical and chemical characteristics of the fruits (Wareing & Phillips, 1973 and Sabry et al., 2009).

This work was conducted to alleviate the deleterious impacts of salinity stress on the vegetative growth, yield and fruit quality of tomato, irrigated with saline water by using repellant salinity agents.

MATERIALS AND METHODS

The field experiment was carried out during the two growing summer seasons of 2013 and 2014 at the Agricultural Experimental Desert Station, Faculty of Agriculture, Cairo University, Wady El-Natroon district, El-Beheira Governorate, Egypt to investigate the potential benefit of some repellant salinity agents for alleviating adverse effect of saline irrigation water on tomato yield and fruit quality. Tomato (*Solanum lycopersicum*) transplants (Supper Strain B F1 cultivar) were planted in the soil on 20 and 25 of February in the first and second seasons, respectively. The experimental trial was conducted in sandy soil using drip irrigation system. Physical and chemical properties of the experimental soil were analyzed according to FAO (1980) and the results are tabulated in Table (1).

Table 1. The analyses of the experimental soil.

Sand	Clay	Silt	Texture	pH	EC	Cations meq/l				Anions meq/l			
%	%	%			dS/m	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	Co_3^{-}	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
91.84	4.52	3.64	Sandy	7.31	2.07	3.60	4.40	0.26	10.60	1.14	1.80	13.5	3.92

The soil of the experiment was ploughed after addition of 7 ton commercial compost/feddan and divided into rows; each plot consisted of three rows of 1 m width and 10 m length. The space between plants was 50 cm on each row. The drip irrigation system consisted of polyethylene hoses GR (4 l h^{-1}) of 16 mm in diameter, allocating one hose for each row. Irrigation water was obtained from a local well; its salinity degree was 2500 ppm. Irrigation frequency was every day to maintain soil moisture above 50% according to Qassim and Ashcroft (2002), which is the optimum moisture level of tomato plants.

All plots received N, P and K fertilizers at the rates of 150 - 60 - 72 kg $feddan^{-1}$ as ammonium sulfate (20.5%N), phosphoric acid (58% P_2O_5) and potassium sulfate (48% K_2O), respectively. The fertilizer solutions were

injected directly into the irrigation water using a venture injector at two doses weekly. Other recommended agricultural practices were followed as commonly used in the commercial production of tomato.

Seven soil treatments, namely, Dinamic, Uni-sal, humic acid and all possible combinations among them were used in addition to control treatment (untreated soil). Each compound was used four times (at the transplanting and 15, 30 and 45 days after transplanting) through drip irrigation system at rate of 4 liter/feddan. Dinamic contains potassium humate as main component and 7% fulvic acid. Uni-sal contains 9% polyethylene glycol (PEG) 7.5% calcium, 5% nitrogen, 7% glutric acid and 1% citric acid.

The treatments of this experiment were arranged in a completely randomized block design with three replicates. After 60 days from transplanting, three plants from each plot were randomly chosen to measure plant length and number of branches per plant. Total nitrogen, phosphorous, potassium, calcium and sodium were determined in the dry matter of fourth leaf, according to Cottenie et al (1982). Total nitrogen was determined by Kjeldahl method according to the procedure described by FAO (1980). Phosphorus content was determined using spectrophotometer according to Watanabe and Olsen (1965). Potassium, calcium and sodium content were determined spectrometrically using Phillips Unicum Atomic Absorption Spectrometer as described by Chapman and Pratt (1961). Fresh and dry shoot weight of plants was measured at harvesting.

Total yield for each plot were recorded accumulatively after each harvest and were calculated for feddan. Five ripe fruits from each treatment were selected randomly to measure some fruit characters. Fruit firmness was measured by penetrometer (Lfra Texture Analyzer) using a penetrating needle of 1 mm of diameter, 3 mm in distance and speed of 2 mm/second. Total soluble solids (TSS) were measured by using a digital Refractometer. Titratable acidity was determined in fresh juice of fruit samples by titration against sodium hydroxide (NaOH) using phenolphthalein as well as, vitamin C was determined in fruits according to the described method in AOAC (2005).

Data of the two seasons were arranged and statistically analyzed by the analysis of variance using one way ANOVA with SAS package. Comparison of treatment means was done using Tukey test at significance level 0.05.

RESULTS AND DISCUSSION

Vegetative Growth

Data presented in Table 2 show that, all repellant salinity agents under saline irrigation water conditions were significantly effective in increasing vegetative growth of tomato plants expressed as plant length, number of branches, fresh and dry shoot weight compared to untreated plants. The maximum significant values of vegetative growth were obtained with plants received mixture of Dainamic and Uni-sal with or without humic acid. In contrast, the untreated plants produced the minimum values. This means that the growth of the plants growing under saline was greatly inhibited without using repellant salinity agents. These results were true in both seasons. These results may be due to containing the repellant on salinity compounds materials that reduced the adverse effect of salinity. Dinamic compound contains humate potassium and fulvic acid. As humate led to a significant increase in soil organic matter, improvement in the nutrient balance and plant vitality (Boehme et al., 2005), potassium ions compete with sodium ions in the root zone (Chen et al., 2007), Fulvic acid has a small molecular structure that makes it more efficient in penetration of the plant roots (Tipping, 2002). On the other hand, Uni-sal compound contains polyethylene glycol (PEG), calcium and glutric acid. As PEG increases the osmotic pressure in root cell that leads to diminution of water flow through root (Slama et al., 2007). Calcium prevents the uptake of sodium ion to injurious levels and increases the uptake of calcium and potassium that leads to enhancement in plant growth and reduction in harmful effect of salinity on plant (Rengel, 1992, Busch, 1995, Caines & Shennanb, 1999 and Abd El-Hady 2003), Glutric acid makes activation by bio formation of proline, which is considered one of the most important amino acid that help the plant for resisting most of stress like salinity and drought (Wareing and Phillips, 1973). As regard, the effect of Uni-sal was due to decreasing of the osmotic potential of nutrient solutions and increasing tolerance to osmotic stress (Kawasaki et al., 1983a,b and Munir & Aftab, 2009).

Table 2. Effect of some repellants salinity agents on fresh & dry weight of shoot, plant length and branch number of tomato plants during 2013 and 2014 seasons.

Treatments	Fresh shoot weight (kg)		Dry shoot weight (kg)		Plant length (m)		Branch No	
	First season							
Dinamic	2.337	cd	0.332	c	0.512	cd	4.000	a
Uni-Sal	2.333	c	0.330	c	0.509	cd	4.000	a
Humic acid	2.213	e	0.325	c	0.491	d	4.000	a
D + HA	2.430	bc	0.343	b	0.532	bc	4.333	a
U + HA	2.463	b	0.349	b	0.548	b	4.333	a
D + U	2.587	a	0.367	a	0.577	ab	4.333	a
D + U + HA	2.630	a	0.369	a	0.598	a	4.667	a
Control	1.807	f	0.255	d	0.428	e	2.333	b
	Second season							
Dinamic	2.253	bc	0.321	bc	0.499	bc	3.667	ab
Uni-Sal	2.236	c	0.318	c	0.489	cd	3.667	ab
Humic acid	2.110	d	0.303	d	0.482	d	3.333	ab
D + HA	2.340	bc	0.331	bc	0.515	bc	3.667	ab
U + HA	2.360	b	0.333	b	0.518	b	3.667	ab
D + U	2.523	a	0.354	a	0.564	a	4.330	a
D + U + HA	2.540	a	0.358	a	0.581	a	4.333	a
Control	1.716	e	0.253	e	0.404	e	2.333	b

Means followed in same column by similar letters are not statistically different at 0.05 level of probability according to Tukey test.

D = Dinamic
U = Uni-Sal
HA = Humic acid

Humic acid increases soil organic matter and causes balance in nutrients and improves root growth. (Tipping, 2002, Serenella et al., 2002, Boehme et al., 2005, Gulser et al., 2010 and Pizzeghello et al., 2013). The superior of the mixture of Dinamics and Uni-sal with or without humic acid treatments may be due to the occurrence of integration among the components of these compounds, which led to the most minimization in adverse influence of salinity on the vegetative growth of plants.

Nutritional Status

The nutritional status in tomato plants is presented in Table 3. Data showed that application of repellant salinity agents significantly decreased Na, whereas increased the nutrient content of N, P, K and Ca in the leaves. The pronouncing effect on the mineral content of the leaves was observed on plants received the mixture of Dainamic and Uni-sal with or without humic acid. These results are in the same line with those obtained by

Table 3. Effect of some repellants salinity agents on nutrient content of tomato plants during 2013 and 2014 seasons

Treatments	N		P		K		Ca		Na	
	%									
	First season									
Dinamic	2.745	cd	0.384	b	2.733	c	1.840	d	0.606	c
Uni-Sal	2.667	d	0.346	cd	2.617	c	2.102	c	0.576	c
Humic acid	2.314	e	0.318	d	2.401	d	1.347	e	0.673	b
D + HA	3.053	b	0.403	b	3.012	b	2.138	bc	0.503	d
U + HA	2.951	bc	0.377	bc	2.911	b	2.265	ab	0.469	d
D + U	3.342	a	0.446	a	3.247	a	2.362	a	0.356	e
D + U + HA	3.519	a	0.460	a	3.307	a	2.392	a	0.336	e
Control	1.981	f	0.204	e	1.617	e	0.720	f	1.276	a
	Second season									
Dinamic	2.577	b	0.327	bc	2.597	c	1.663	c	0.743	c
Uni-Sal	2.499	b	0.286	d	2.547	c	1.898	b	0.713	c
Humic acid	2.146	c	0.269	d	2.264	d	1.170	d	0.810	b
D + HA	2.468	b	0.349	b	2.819	b	1.995	b	0.663	d
U + HA	2.468	b	0.318	c	2.795	b	1.995	b	0.550	e
D + U	3.152	a	0.386	a	3.121	a	2.185	a	0.483	f
D + U + HA	3.351	a	0.401	a	3.170	a	2.215	a	0.457	f
Control	1.879	c	0.182	e	1.527	e	0.677	e	1.453	a

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

D = Dinamic
U = Uni-Sal
HA = Humic acid

Nijjar (1985) who mentioned that Ca replaced sodium through complex exchanges by many reactions. Also, Abada (2009) stated that improving plant nutrition by humate is due to stimulating the absorption of mineral elements through roots. Thus, stimulating root growth thereby, enabling better uptake of nutrients. Some mechanisms have been suggested to explain effects of Uni-sal and humic acid such as improving salt tolerance through inducing osmotic adjustment, increased ability of soil to get rid of salts that resulted in a better assimilation of nutrients and fertilizer in plants. (Munir and Aftab, 2009). Overall, the positive action of repellant salinity agents on alleviating the adverse effects of salinity on growth and nutritional status of plants might be attributed to their beneficial effect on lowering **soil pH**, increasing **organic matter**, enhancing the uptake of water and nutrients (Cooke, 1982; Serenella et al., 2002; Boehme et al., 2005; Gulser et al., 2010 and Pizzeghello et al., 2013). These results are in agreement with obtained by Sabry et al (2009) and Kassem (2012).

Yield

The effect of different treatments on total yield is illustrated in Table 4. Data indicated that all treatments of repellant salinity agents significantly increased plants yield of tomato in comparison with untreated plants. Using mixture of Dainamic and Uni-sal with or without humic acid gave the highest values of total yield (23.94, 23.65 and 22.80, 22.41 ton/feddan respectively in the first and second seasons). While Uni-sal plus humic acid and Dinamic plus humic came in the second position in this respect (19.87, 18.62 and 18.79, 18.52 ton/feddan respectively in the both seasons), the individual treatments of repellant salinity agents (Uni-sal, Dainamic and Humic acid) came in the third position (18.74, 18.38, 16.88 and 17.57, 17.62, 16.18 ton/feddan respectively in the both seasons). Lastly, untreated plants gave the lowest yield (13.96 and 12.04 ton/feddan respectively in the both seasons). This may be due to a positive effect of Uni-sal on growth parameters and yield, where its enrichment with polyethylene glycol lowered osmotic potential of nutrient solutions and increased nutrient availability. Besides, the improving effect of Dinamic (that contains potassium humate and fulvic acid) on yield and its components could be attributed to its vital role in lowering soil pH, consequently nutritional status is being improved in producing a higher yield. These results are nearly in the same line with those obtained by Boehme et al (2005), Hussien et al (2005) and Abada (2009).

Fruit characters

Concerning fruit characters (physical and chemical characteristics) of tomato fruits the results in Table 4 revealed that fruit firmness, total soluble solid and vitamin C content of tomato fruits had significantly increased affecting by all used treatments. On the contrary, titratable acidity in tomato fruits significantly was decreased in both seasons. The best result in this respect was obtained from plants received the mixture of treatments that caused a gradual promotion on fruits quality. Conversely, unfavorable effects on fruit quality were observed when the plants grown under salinity and untreated with repellant salinity materials. The positive influence of these materials may be due to the increased availability of nutrients in the soil, leading to an increase in vegetative growth of plants that may result in accumulating more carbohydrates thereby enhancing yield and fruit quality. Many workers in this field supported the improving effect of these materials on fruits quality (Wareing & Phillips, 1973 and Sabry et al., 2009). The negative influence of untreated plants may be due to expose these plants to salinity negative effect on reducing roots feeder (NPK uptake) and reduction its ability to withstand stress, thereby decreasing yield and fruit quality (Scholberg & Locascio, 1999, Campos et al., 2006 and Boamah et al., 2011).

Table 4. Effect of some repellants salinity agents on yield and some fruit characters of tomato during 2013 and 2014 seasons.

Treatments	Total yield (ton / fed)	Firmness (g/mm^2)	TSS (%)	Titratable acidity (%)	V. C (mg/100g)
	First season				

Dinamic	18.376	bc	51.333	a	6.600	bc	2.500	b	15.667	ab
Uni-Sal	18.742	b	52.667	a	6.733	bc	2.567	ab	15.333	ab
Humic acid	16.881	c	50.333	a	6.360	c	2.550	ab	14.833	ab
D + HA	18.617	bc	52.333	a	6.700	bc	2.533	b	15.833	ab
U + HA	19.867	b	54.333	a	6.833	b	2.500	b	16.667	ab
D + U	23.652	a	53.667	a	7.300	a	2.500	b	17.000	ab
D + U + HA	23.937	a	55.000	a	7.700	a	2.533	b	17.333	a
Control	13.963	d	39.000	b	5.533	d	2.800	a	13.833	b
	Second season									
Dinamic	17.623	bc	50.500	a	6.917	b	2.487	b	14.727	ab
Uni-Sal	17.570	bc	54.333	a	7.066	b	2.453	b	14.227	ab
Humic acid	16.180	c	47.333	ab	6.710	b	2.593	ab	14.060	ab
D + HA	18.517	b	53.333	a	7.099	b	2.500	b	14.880	ab
U + HA	18.787	b	53.000	a	7.199	b	2.500	b	15.760	Ab
D + U	22.413	a	55.667	a	7.920	a	2.483	b	15.840	A
D + U + HA	22.797	a	56.667	a	7.989	a	2.467	b	16.147	A
Control	12.037	d	40.667	b	5.697	c	2.873	a	13.538	B

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

D = Dinamic

U = Uni-Sal

HA = Humic acid

CONCLUSION

Overall, it can be concluded that application of Dainamic, Uni-sal and humic acid have profoundly alleviated negative salinity effects and improved the production of tomato plants under irrigation water condition. Using mixture of Dainamic and Uni-sal with or without humic acid gave the highest yield and fruits quality.

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