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Effect of Polymer on Drought Tolerance of Tomato (*Solanum lycopersicum L.*)

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Abstract: An experiment was performed in Desert Research Center experimental station Baloza. North Sinai governorate through 2013/2014 and 2014/2015 seasons to investigate the effect of super absorbent polymers (SAP) was applied as soil addition at the rate of 0, 5, 10, and 15 kg/fed. under different irrigation levels, subjected to five irrigation levels; 40%, 60 %, 80%, 100% and 120% ETc based on crop evapotranspiration (ETc), on growth, yield, chemical composition, water use efficiency and investment ratio of tomato plants. Results revealed that the highest values of growth parameters, yield and its components, Ca (%) and chlorophyll contents were recorded with 100%ETc. There were no significant differences between irrigation treatment 120% and 80% Etc. in most growth and yield parameters. Also, no significant differences between 10 and 15 ton/fed SAP in most studied parameters in both growing seasons. Also, the maximum water use efficiency and investment ratio values were contributed to high (SAP)15 kg/fed combined with 80% of Etc that means we can get high revenue of yield from unit of applied water and save 20% of irrigation water.

Linear correlation and regression of tomato traits on each other were carried out. Also, Multiple regression was computed for total yield on the amount of irrigation water (m^3/fed.) and rate of SAP (kg/fed.) It may be worth to mention that yield increasing due to amount of irrigation water which was higher than that due to SAP at equal cost.

Keywords: Tomato – Super Absorbent Polymers – Growth - Yield – Irrigation-WUE – I R**.**

1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the widely grown vegetable crops in the world. The tomato is protective supplementary food and considered as a short duration crop and gives high yield, it is important from an economic point of especially the area under its cultivation is increasing gradually in the newly reclaimed lands. In Egypt, it is the first of vegetable crops according to the cultivated area and one of the most important exported crops. Egypt is ranked as the 5^{th} one among the top countries tomato producers according. [1].

Tomato Plants are exposed to a range of environmental stresses and have to adapt physiologically to them as the local environment changes. The tomato is regarded as a sensitive crop to water stress, revealing the high correlation between evapotranspiration (ET) and crop production, since (ET) is a direct measure of crop water loss [2]. Insufficient availability of water *i.e.,* drought, is presumably the most common stress experienced by plants. Drought is one of the main factors for the yield loss of plants and the major inevitable and recurring feature of semi-arid tropics. Drought tolerance is the ability of plants to survive under water stress and to maintain plant growth under water deficit conditions **[3].** Drought induces a reduction of water content in plant tissue and subsequently water potential leading to reductions in yield [4].

The supply of the required water to the tomato plants is critical for its growth and economic production **[5]**. High marketable yield of tomato fruits can be obtained under the conditions of optimal soil moisture. However, shortage of irrigation water results in decreased fruit yield and quality [6]. Moreover, Inoculated tomato plants with *arbuscular mycorrhizal* fungi, under a moderate irrigation level (80% ETc) may contribute to good compromise between fruit yield and fruit quality in tomato and allow to save about (20%) of irrigation water [7].

Irrigation scheduling has a large effect on root's development, the root containers results indicated that a water stress equivalent to 50%ETc and 20% frequency can lead to deep root system; that makes possible to sustain a suitable vegetative canopy if doses and frequencies are well managed in a daily scale; It was possible saving 50% of irrigation water [8]. Drying soil later in the growing season adversely on the fruit quality, while total yields may not be affected [9]. However, plant water status controls the physiological process and conditions which are determine the quality and quantity of its growth [10]. Plants increased growth rates in roots above the waterlogged zone probably as compensation for the suboptimal conditions in the waterlogged zone which eventually was led to roots dying [11].

Water shortage and low water quality are becoming an international issue and unfortunately it seems that rapid growth of population and water resources reduction are less in harmony with future demands, thus, it is essential to save water by using soil amendments. One of soil amendments methods is using water absorbents material or hydrophilic polymers [12]-[13]. Hydrogels are three-dimensional networks of super absorbent polymer swelling in an aquatic environment, but do not dissolve in the solvent because of cross links, rather hold a part of solvent in their structure. Their performance is determined by the chemistry and formation conditions of hydrophilic polymer and the chemical composition of the soil solution or irrigation water [14]. Super absorb polymer prohibit washing out of micronutrient to water tables, reduction in irrigation costs, and improvement in plant viability and seed germination. Reduction in water stress and in transplant transferring, improvement in ventilation and increase in soil porosity [15].

Super absorbent polymers cause improvement in plant growth by increasing water holding capacity in soils [16]-[17] and delaying the duration to wilting point in drought stress [18]. Also, application of super absorbent polymer (powder or gel) and inoculation of grain with biofertilizer (*A. lipoferum* +*P. putida*) increased grain and biological yields in both stress and normal conditions [19].

[20] They reported that application of 65% cow manure and 35% super absorbent polymer (26 t/ha cow manure + 70 kg/ha super absorbent polymer) increased grain yield by 16.2% compared with the control. This treatment increased the uptake of N by 15.9%, K by 17.6%, and Ca by 14.7%. Moreover, [21] they found that application of super absorbent polymer improve the negative effect of deficit irrigation, especially in high rates of polymer (2.25 and 3 g/kg of soil). The above mentioned rates of polymer have the best effect to all characteristics of sunflower in all levels of water stress treatment.

The aim of this work to study the effect of super absorb polymers (SAP) and amount of irrigation water application on growth, yield and chemical composition of tomato cv. Cristal under North Sinai Governorate under Baloza region conditions.

2. Material and methods

Two field experiments were carried out at Baloza Station of the Desert Research Center, North Sinai Governorate during two consecutive seasons of 2013/2014 and 2014/2015. The experiments were conducted to study the response of tomato plants cv. Cristal grown under low tunnel in sandy soil to super absorb polymers (SAP) application and amount of irrigation water. Twenty treatments were used which were the combination of five water quantities of *i.e.*, control (100% Etc), 40, 60, 80 and 120% of Etc and four levels of (SAP) as a soil conditioner *i.e*. 0, 5, 10 and 15 kg/fed.

The physical and chemical soil characteristics of the studied site recorded in Table (1) which were determined according to [22] and [23] respectively. The chemical analysis of irrigation water was carried out using the standard method of [22] and presented in Table (2).

Table 1. Some physical and chemical properties of the experimental soil site.

Particle size distribution (%)			**Texture soil**	**EC dsm^{-1}**	**pH**
Sand	**Silt**	**Clay**			
90	5	5	Sand	1.37	8.20
Available nutrients (Cations)			**Available nutrients (Anions)**		
P%	0.42		$CO_3^{=}$	-	
Na^{+}%	4.78		HCO_3^{-}Meg/l	3.85	
K^{+}%	0.54		$SO_4^{=}$	6.5	
Ca^{++} Meg/l	3.65		Cl^{-}	3.3	
Mg^{++} Meg/l	4.40				

Table 2. Chemical analysis of the irrigation water.

	pH	**E.C. (ppm)**		**S.A.R**	
1 st. sea	7.45	1456		3.80	
2 nd. sea	7.10	1512		3.52	
Available nutrients (Cations)			**Available nutrients (Anions)**		
seasons	1 st.	2 nd		1 st.	2 nd
Na^{+}%	8.60	9.50	$CO_3^{=}$	0.10	0.50
K^{+}%	0.60	0.40	HCO_3^{-}Meg/l	5.60	3.81
Ca^{++} Meg/l	2.90	3.25	$SO_4^{=}$	2.10	3.69
Mg^{++} Meg/l	3.20	3.05	Cl^{-}	7.50	8.20

pH: Acidity, E.C.: Electrical conductivity, dSm^{-1}: decimenz per meter, S.A.R: Sodium adsorption ratio, me/l: mille equivalent per lit

Organic manure was added at the rate of 30 m³/fed., while calcium super-phosphate (15.5% P2O5) at the rate of 400 kg /fed., in addition to (SAP) levels were added at the time of final land preparation. Nitrogen fertilizer was added as ammonium sulphate (20.5% N) at the rate of 350Kg/fed. and potassium sulphate (48% K2O) at the rate of 250 kg /fed. Nitrogen and potassium quantities were divided to small quantities and applied all over the season through lines of irrigation. Drip irrigation system starting after two weeks from transplanting. Tomato seedlings of Crystal cultivar were transplanted 50 cm between plants apart on one side of the ridge. The ridges were 150 cm width among drip irrigation lines and 50 m long of line. Tomato seedlings were transplanted during the last week of November of both 2013/2014 and 2014/2015 seasons. All agricultural practices for tomato plants were followed according to the recommendation of Ministry of Agriculture.

As one of the main targets of this research was to detect the effect of water stress as applied for the upper part of pF curve, so the lower irrigation level was fixed at 30% of available soil moisture. Therefore, all plots were irrigated at 30% soil moisture depletion from available soil water. Soil moisture was measured with gravimetric method at depths of 0 -25, 25 - 50 and 50 - 75 cm. The values of soil moisture content were calculated. ETo was computed using Penman – Monteith equation [24]. Crop coefficients Kc of tomato at different stage of growth recommended by [25] were used to calculate ETc. The amounts of irrigation water (m³/fed.) for both seasons were calculated using the equation of [26] as shown in Table (3).

Table 3. the amount of irrigation water (m³/fed./month) for the growing seasons of 2013/2014 and 2014/2015.

Months / w. irrig. Levels	irrigation water amount m³/month					
	Dec.	Jan.	Feb.	Mar.	April	m^3/fed/sea
(100% Etc)	344.5	496.8	721.5	729	647	2939
(40 % ETc)	137.8	198.7	288.6	291.6	258.8	1176
(60 % ETc)	206	298.1	432.9	437.4	388.2	1763
(80 % ETc)	275.6	397.4	577.2	583.2	517.6	2351
(120%ETc)	413.4	596.1	865.8	874.8	776.4	3526

2.1. Vegetative growth parameters:

After two weeks from transplanting survival plants were be counted. After 75 days from transplanting three plants from each experimental unit were randomly taken for recording vegetative growth characteristics, *i.e.,* plant height, number of aerial stems/plant, dry matter percentage of shoot and total chlorophyll in plant laves was measured as SPAD units using Minolta chlorophyll meter (model SPAD 502) chlorophyll measurements were made on the recently fully expanded leaf (fourth leaf) and 10 readings were averaged per experimental unit according to [27].

2.2. Yield and its components:

At maturity stage (100 days from transplanting date), a sample of 3 plants were randomly taken from each experimental plot for recording fruit characteristics, *i.e.,* fruit number and average fruit weight/plant, percentage of fruit dry matter and total soluble solids (TSS) were determined for each sample fruit using an JK-SR-113ATC digital Refractometer (Shanghi Co. Ld., China). In addition, average plant yield, total yield (ton/fed.) and marketable yield.

2.3. Fruits chemical compositions:

Three samples of fruit from each experimental unit were taken and dried in oven at 70ºC until stable weight, then grinded to fine particles and used to determine chemical fruit quality such as mineral contents K, P and Ca. Phosphorus was determined using the colorimetric method using spectrophotometer according to [28], potassium and calcium percentage was measured using flame photometer method as described by [29].

2.4. Water use efficiency and investment ratio:

Crop water use efficiency (**WUE**) was calculated by dividing the crop economic yield by the amount of seasonal evapotranspiration according to **[**30]. Investment Ratio (IR) = (total revenue, LE / total cost, LE) following [31].

2.5. Statistical analysis:

The experimental treatments were arranged in a split plot design with three replicates. Main plots were assigned for irrigation treatments, whereas, (SAP) rates were randomly arranged in the sub plots. Obtained data were subjected to statistical analysis according to [32].

3. Results and discussion

3.1. Growth parameters:

Growth parameters *i.e.,* survival plant percentage, plant height, No. of stems /plant and shoot dry matter per cent were presented in Table (4). Obtained results indicated significant positive effect with increasing both irrigation water quantity and super absorb polymers (SAP).

The highest values in survival plant percentage, plant height, No. of stem/plant and shoot dry matter percentage were recorded with 100% ETc in both seasons. No significant differences were found between 100 and 120% of ETc in No. of stems/plant the first season, in plant height in the second season and percentage of survival plants in both growing seasons. Moreover, no significant differences were found among 80%, 100% and 120% of ETc in shoot dry matter percentage in both seasons.

The improvement of vegetative growth traits of tomato plants observed with increasing water level the results obtained that may be attributed to the appropriate balance of moisture in plant and achieve good conditions for nutrients uptake, photosynthesis and metabolites translocation, which are led to speed up the rate of vegetative growth. These results agree with those obtained by [33]-[5] or shortage of irrigation water led to decrease in tomato growth [6].

The highest values in survival plant percentage, plant height No. of stems/plant and shoot dry matter percentage were recorded with 15 kg and 10 kg soil addition of super absorb polymers in both growing seasons. No significant differences were found between 15 and 10 kg in both seasons except 15 kg surpassed significant in survival plant percentage in the first season only.

The results are in the same line with those found by [15]-[20]. They reported that SAP improved in plant viability and seed germination, reduction in water stress and in transplant transferring, improved ventilation and increase in soil porosity.

Obviously, the interaction of both compound treatments cleared that vegetative growth surpassed than individual treatments. Such results were clear with survival plant percentage, plant height and No. of stem in the both seasons. The highest values in survival plant percentage and No. of stems were recorded with treatment 100% ETc combined with SAP at the rate of 15 kg and the highest values in plant height were recorded with treatment 100% ETc with SAP at the rate of 10 kg in both seasons. The highest values presented in Table (4) increased significantly when compared with other compound treatments for characters.

3.2. Yield and its components:

Tables (5&6) displayed data of fruit No./plant, average of fruit weight, fruit dry matter percentage, T.S.S, plant yield, marketable yield and total yield/ fed. which are indicated that increasing all parameters as affected with the two investigated factors *i.e*., amount of irrigation water and SAP application.

Table 4. Effect of irrigation water amount and super absorb polymers (SPA) rate on survival plant percentage, plant height, No. of stems/plant and shoot dry matter percentage during 2013/2014 and 2014/2015 growing seasons.

Season	***2013 / 2014***									
Characters	**Survival plant percentage**					**Plant height (cm)**				
SPA	**Cont.**	**5kg**	**10kg**	**15kg**	**$\bar{X}$**	**Cont.**	**5kg**	**10kg**	**15kg**	**$\bar{X}$**
W. amount										
40 % ETc.	59.2	71.7	76.3	79.3	71.6	51.8	52.2	56.3	59.2	54.9
60 % ETc.	65.5	82.4	83.5	87.8	79.8	61.6	63.1	67.1	69.5	65.3
80 % ETc.	90.9	92.5	92.9	95.7	93.0	73.7	77.1	81.3	88.0	80.0
100 % ETc.	95.5	95.8	97.3	98.1	96.7	80.8	83.2	91.8	86.5	85.6
120% ETc	95.6	96.5	95.4	97.2	96.2	82.9	84.5	83.8	77.1	82.1
$\bar{X}$	81.3	87.8	89.1	91.6		70.1	72.0	76.1	76.1	
Season	**2014 / 2015**									
	Cont.	**5kg**	**10kg**	**15kg**	**$\bar{X}$**	**Cont.**	**5kg**	**10kg**	**15kg**	**$\bar{X}$**
40 % ETc.	62.3	66.1	73.4	74.6	69.1	50.4	60.3	66.5	69.0	61.6
60 % ETc.	67.6	74.5	74.5	77.9	73.6	68.0	74.1	77.6	79.1	74.7
80 % ETc.	82.1	87.5	88.0	87.5	86.3	84.6	88.9	90.9	97.0	90.3
100 % ETc.	91.9	95.4	95.8	97.0	95.0	93.9	94.2	99.7	94.6	95.6
120% ETc	92.6	91.8	95.6	94.7	93.7	96.3	92.7	95.9	93.1	94.5
$\bar{X}$	79.3	83.1	85.5	86.3		78.7	82.0	86.1	86.6	
L.S.D at 0.05			Sea. (1)		Sea. (2)			Sea. (1)		Sea. (2)
Water			1.63		2.65			2.93		4.33
SAp			1.75		1.73			2.53		2.71
W.. X SAP			3.92		3.87			5.66		6.07

	2013 / 2014									
Characters	**No. of stems/plant**					**Shoot dry matter percentage**				
SPA	**Cont.**	**5kg**	**10kg**	**15kg**	**$\bar{X}$**	**Cont.**	**5kg**	**10kg**	**15kg**	**$\bar{X}$**
W. amount										
40 % ETc.	6.7	8.7	9.7	9.7	8.7	13.4	14.6	15.7	15.4	14.8
60 % ETc.	12.0	11.0	12.3	13.0	12.1	16.7	17.7	16.1	17.5	17.0
80 % ETc.	14.7	15.3	18.7	19.3	17.0	17.0	17.8	19.4	20.1	18.6
100 % ETc.	18.0	18.7	19.7	20.3	19.2	19.3	19.6	20.1	19.2	19.6
120% ETc	19.0	18.3	18.7	17.0	18.3	17.7	19.8	19.8	19.7	19.2
$\bar{X}$	14.1	14.4	15.8	15.9		16.8	17.9	18.2	18.4	
	2014 /2015									
	Cont.	**5kg**	**10kg**	**15kg**	**$\bar{X}$**	**Cont.**	**5kg**	**10kg**	**15kg**	**$\bar{X}$**
40 % ETc.	7.2	9.0	11.0	12.3	9.9	14.5	15.3	15.5	15.7	15.3
60 % ETc.	12.5	13.5	14.2	15.7	14.0	15.9	17.8	16.5	17.1	16.8
80 % ETc.	14.9	15.4	18.9	20.9	17.5	16.9	18.0	19.7	20.7	18.8
100 % ETc.	21.2	22.1	22.2	21.2	21.7	19.6	19.9	20.2	19.3	19.7
120% ETc	21.1	18.2	19.5	17.5	19.1	17.7	19.5	20.1	19.4	19.2
$\bar{X}$	15.4	15.7	17.2	17.5		16.9	18.1	18.4	18.4	
L.S.D at 0.05			Sea. (1)		Sea. (2)			Sea. (1)		Sea. (2)
Water			1.05		1.07			1.57		1.46
SAp			0.89		1.05			NS		1.16
W.. X SAP			1.98		2.36			NS		NS

It was clear from the data that the values of fruit number /plant and marketable yield gave significant increase with 100% ETc treatment when compare with other treatments followed by 80% ETc with no significant differences between them. The high values of average fruit weight, plant yield and total yield were recorded significant differences with 100% ETc treatment when compare with other treatments except 120% and 80% of Etc treatment on plant yield in the first season and on 120% of Etc treatment on average fruit weightin the both growing seasons. On the other hand, 40% ETc treatment surpassed significantly in fruit dry matter percentage and T.S.S when compare to other treatments of irrigation water. Plant growth and yield traits were affected by different irrigation water levels linearly with increasing water levels up to 100% Etc. the results are true in both growing seasons. These results agree with those obtained with **[5]** they found that the supply of the required water to tomato plants is crucial for growth, yield and quality of tomato fruits which can be obtained under the conditions of optimal soil moisture. However, shortages of irrigation water result in decreasing fruit yield and quality [6]. Also, drying soil later in the growing season adversely affects the fruit quality even though total yield may not be affected [9]. Moreover, the positive effect of water stress on tomato fruit quality traits may be explain by a reduction in water accumulation in fruit without any significant change in the amount of the accumulation TSS and sugars [34].Yield and its components significantly surpassed with increasing application of SAP 10and 15kg SAP treatments, no significant differences were found between them. Super absorbent polymers cleared improvement in plant growth may be due to increasing water holding capacity in soils [16]-[17] and delaying the duration to wilting point in drought stress [18].

Table 5. Effect of irrigation water amount and super absorb polymers (SPA) rate on fruit No./plant, average fruit weight, fruit dry matter (%), T.S.S. plant yield and marketable yield during 2013/2014 and 2014/2015 growing seasons.

Characters		**Fruit No./plant**					**Average fruit weight (g)**				
SPA / **W. amount**		**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**
Season (1)	40 % ETc.	21.3	25.8	27.2	28.9	25.8	56.9	58.2	66.0	68.1	62.3
	60 % ETc.	29.3	31.4	30.6	30.8	30.5	67.1	74.6	78.3	76.0	74.0
	80 % ETc.	37.5	56.8	50.4	60.1	51.2	76.0	93.3	91.4	97.9	89.7
	100 % ETc.	52.5	53.8	60.2	57.9	56.1	89.6	93.3	101.1	93.1	94.3
	120% ETc	50.2	50.6	53.4	47.5	50.4	89.5	90.0	92.5	95.8	91.9
X⁻		38.2	43.7	44.3	45.1		75.8	81.9	85.9	86.2	
		Cont.	**5kg**	**10kg**	**15kg**	**X⁻**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**
Season (2)	40 % ETc	30.3	30.0	30.6	33.5	31.1	65.2	64.3	73.5	77.6	70.1
	60 % ETc.	33.5	37.0	36.7	35.8	35.8	86.7	93.5	99.7	97.1	94.3
	80 % ETc.	50.0	58.6	61.5	62.9	58.2	89.5	106.7	107.6	116.5	105.1
	100 %ETc.	57.3	58.9	63.2	61.4	60.2	119.3	121.8	125.3	126.8	123.2
	120% ETc	54.7	53.8	55.8	50.1	53.6	109.8	114.1	118.2	117.0	114.8
X⁻		45.1	47.6	49.6	48.7		94.1	100.1	104.8	107.0	
L.S.D at 0.05				Sea. (1)		Sea. (2)			Sea. (1)		Sea. (2)
Water				7.23		5.55			3.21		10.41
SAp				NS		1.70			2.92		4.81
W.. X SAP				5.76		3.81			6.54		10.75

Characters		**Fruit dry matter (%)**					**T.S.S.**				
SPA / **W. amount**		**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**
Season (1)	40 % ETc.	9.51	9.50	9.35	9.73	9.52	7.17	6.73	7.03	6.97	6.98
	60 % ETc.	8.83	8.90	8.67	8.40	8.70	6.97	6.27	6.03	6.00	6.32
	80 % ETc.	8.27	7.23	6.70	6.87	7.27	5.93	5.63	5.57	5.70	5.71
	100 % ETc.	6.87	6.37	6.23	6.17	6.41	5.30	5.13	4.90	4.87	5.05
	120% ETc	6.30	6.27	6.60	6.10	6.32	5.03	5.97	5.60	5.27	5.47
X⁻		7.96	7.65	7.51	7.45		6.08	5.95	5.83	5.76	
		Cont.	**5kg**	**10kg**	**15kg**	**X⁻**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**
Season (2)	40 % ETc.	10.11	10.00	9.76	10.27	10.04	6.80	7.00	6.77	6.90	6.87
	60 % ETc.	9.72	9.63	9.27	9.27	9.47	6.83	6.63	6.47	6.97	6.73
	80 % ETc.	8.82	7.78	7.33	7.43	7.84	5.87	5.80	5.80	5.83	5.83
	100 % ETc.	7.21	6.76	6.75	6.79	6.88	5.63	5.50	5.27	4.57	5.24
	120% ETc	7.17	6.63	7.35	7.10	7.06	5.27	5.13	5.40	5.37	5.29
X⁻		8.61	8.16	8.09	8.17		6.08	6.01	5.94	5.93	
L.S.D at 0.05				Sea. (1)		Sea. (2)			Sea. (1)		Sea. (2)
Water				0.49		0.97			0.48		0.33
SAp				NS		NS			NS		NS
W. X SAP				NS		NS			0.66		NS

		Plant yield (kg)					**Marketable yield (ton /fed.)**				
SPA / **W. amount**		**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**
Season (1)	40 % ETc.	2.28	2.59	2.84	3.01	2.68	3.22	4.99	6.70	7.01	5.48
	60 % ETc.	3.20	3.57	3.61	3.59	3.49	5.51	8.99	8.85	9.25	8.15
	80 % ETc.	3.79	5.59	5.88	6.64	5.48	12.53	25.07	20.67	31.91	22.54
	100 % ETc.	5.61	5.91	6.99	6.64	6.29	20.91	22.15	29.79	24.79	24.41
	120% ETc	5.34	5.41	5.80	5.42	5.49	19.95	19.09	20.54	20.56	20.04
X⁻		4.04	4.61	5.03	5.06		12.42	16.06	17.31	18.70	
Season (2)	40 % ETc.	3.03	2.98	3.31	3.64	3.24	6.59	6.11	8.73	8.94	7.59
	60 % ETc.	4.13	4.70	4.89	4.71	4.61	9.47	12.61	13.13	12.92	12.03
	80 % ETc.	5.42	7.18	7.90	8.59	7.27	19.91	27.69	29.71	33.72	27.76
	100 % ETc.	7.74	8.08	8.14	8.69	8.16	29.62	30.44	30.03	30.74	30.21
	120% ETc	6.85	6.98	7.44	6.71	6.99	27.27	25.74	29.50	26.53	27.26
X⁻		5.43	5.98	6.34	6.47		18.57	20.52	22.22	22.57	
L.S.D at 0.05				Sea. (1)		Sea. (2)			Sea. (1)		Sea. (2)
Water				0.73		0.57			3.93		2.63
SAp				0.25		0.27			1.52		1.58
W. X SAP				0.56		0.60			3.41		3.54

The results of interaction between water depletion levels and SAP rates showed that the combination between 100 % ETc and 15 kg of SAP gave the highest values in fruit number/plant in the first season only and recorded the highest values in average fruits weight, plant yield and total yield in the second season only. Also, the combination between 100 % ETc and 10 kg of SAP had the highest values in average fruit weight, plant yield and total yield and recorded the highest values in fruits number/plant in the second season only. But there were no significant differences between above mentioned results and compound treatment 80% ETc with 15kg SAP which is surpassed significantly in marketable yield in both growing seasons. Moreover, the combination between 40% ETc with control SAP showed significant increase in T.S.S values in the first season only.

Table 6. Effect of irrigation water amount and super absorb polymers (SPA) rate on total yield during 2013/2014 and 2014/2015 growing seasons.

season	**2013 /2014**				
Character	**Total yield (ton/fed.)**				
SPA / **W. amount**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**
40 % ETc.	4.15	6.33	7.94	8.99	6.85
60 % ETc.	7.39	11.13	11.52	12.02	10.51
80 % ETc.	15.02	28.56	24.88	35.36	25.95
100 % ETc.	26.08	27.84	36.26	30.76	30.24
120% ETc	24.93	25.57	27.35	25.73	25.90
X⁻	15.51	19.89	21.59	22.57	
	2014 /2015				
40 % ETc.	7.15	7.39	9.62	11.22	8.84
60 % ETc.	11.35	14.99	15.80	15.69	14.46
80 % ETc.	21.32	31.70	33.92	37.17	31.03
100 % ETc.	36.46	36.27	37.05	37.91	36.92
120% ETc	32.25	32.67	36.52	32.21	33.41
X⁻	21.71	24.60	26.58	26.84	
L.S.D at 0.05		**Sea 1**			**Sea 2**
Water		3.93			2.84
SAp		1.52			1.88
W. X SAP		3.41			4.20

3.3. Chemical compositions:

Data recorded in Table (8) showed significant effect of the water application at the rate of 120 % Etc on P and K content followed by 100% ETc with no significant differences between them. 100%ETc was significantly increased Ca and chlorophyll contents. The results are true in both growing seasons.

The highest significant value in K content was recorded with 10 kg SPA application in both growing seasons. Moreover, the interaction between two studies factors showed that highest values in K content were recorded with 100%ETc and10 or 15 kg of SAP in the first season only. The highest value in chlorophyll content are presented with 100%ETc and SAP at the rate of 15 kg treatment. No significant differences were found between100% and 80% ETc with 15 kg SAP in both growing seasons**.**

The improvement of vegetative growth traits of tomato plants with increasing water level may be attributed to the appropriate balance of moisture in plant, which creates good conditions for nutrients uptake, photosynthesis and metabolites translocation, which are led to speed up the rate of vegetative growth. This result agrees with those optioned by [33]-[5]. Also, the positive effect of SPA materials were prohibit washing out of micronutrient and reduce in irrigation costs, also improve plant availability to nutrients and seed germination. SAP reduce water stress and transplant transferring, improve in ventilation and increase in soil porosity [15].

3.4. Water use efficiency:

Water use efficiency as the value of productive capacity of the unit of irrigation water amount could be expressed in two forms: either Kg of economic yield/ unit of consumed water (m^3) or as amount of consumed water (m^3) /Kg of economic yield; both are important.

Table (7) gave the WUE as Kg of yield (both marketable and non marketable yields) per one m^3 of actual consumed water. From the table it can be concluded the following:

1- The maximum WUE values were contributed with high SAP treatments; i.e., 15 kg/fed combined with 80% of Etc. in both growing seasons. This means we can get high yield from unit of applied water under arid and semi arid conditions and save 20% from irrigation water
2- Reducing amount of in irrigation water from 100% to 80% of Etc could be compensated with increasing SAP application from 5 to 15 kg/fed.
3- The increment of irrigation water from 100 to 120% of Etc damped greatly the WUE values which mean more water used without sensible yield as gain.
4- The high rate of SAP: *i.e.* 15 kg/fed improved WUE by means of increasing the productivity of water unit from the crop yield.
5- The positive effect on WUE of irrigation water at 80% ETc may be due to the beneficial rate (BR) which was increased with decreasing irrigation water amount, these results agree with those results obtained by [35].

Table 7. water use efficiency (WUE) as gross yield / one m^3 water of Eta.

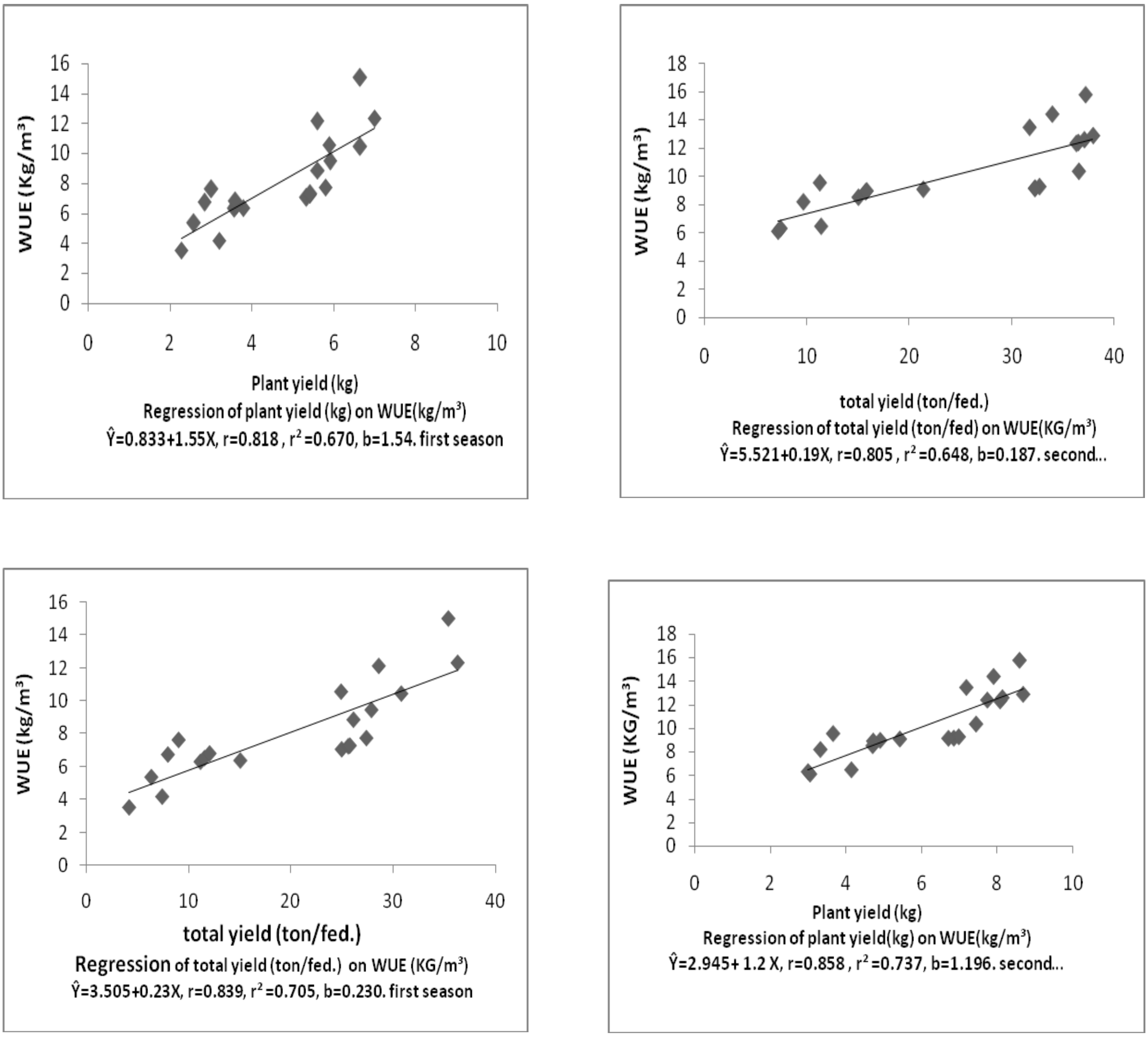
season	**2013 /2014**			
Character	**Water use** efficiency **(LE./LE.)**			
SPA / **W. amount**	**Cont.**	**5kg**	**10kg**	**15kg**
40 % ETc.	3.5	5.4	6.8	7.6
60 % ETc.	4.2	6.3	6.5	6.8
80 % ETc.	6.4	12.1	10.6	15.0
100 % ETc.	8.9	9.5	12.3	10.5
120% ETc	7.1	7.3	7.8	7.3
	2014 /2015			
40 % ETc.	6.1	6.3	8.2	9.5
60 % ETc.	6.4	8.5	9.0	8.9
80 % ETc.	9.1	13.5	14.4	15.8
100 % ETc.	12.4	12.3	12.6	12.9
120% ETc	9.1	9.3	10.4	9.1

Table 8. Effect of irrigation water amount and super absorb polymers (SPA) rate on P, K, Ca percentage total chlorophyll (ppm) during 2013/2014 and 2014/2015 growing seasons.

Season	***2013 / 2014***									
Characters	P (%)					K (%)				
SPA / **W. amount**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**
40 % ETc.	0.409	0.421	0.426	0.433	0.422	3.00	3.28	3.22	3.48	3.25
60 % ETc.	0.448	0.455	0.479	0.464	0.461	3.38	3.53	3.53	3.28	3.43
80 % ETc.	0.502	0.527	0.550	0.555	0.534	3.27	3.62	3.88	3.60	3.59
100 % ETc.	0.586	0.542	0.577	0.575	0.570	3.53	3.65	3.90	3.90	3.75
120% ETc	0.580	0.619	0.609	0.582	0.598	3.82	3.87	3.67	3.72	3.77
X⁻	0.505	0.513	0.528	0.522		3.40	3.59	3.64	3.60	
Season	**2014 / 2015**									
	Cont.	**5kg**	**10kg**	**15kg**	**X⁻**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**
40 % ETc.	0.461	0.464	0.480	0.485	0.472	3.03	3.32	3.37	3.38	3.28
60 % ETc.	0.509	0.515	0.517	0.545	0.522	3.43	3.38	3.40	3.37	3.40
80 % ETc.	0.545	0.561	0.569	0.571	0.562	3.58	3.70	3.78	4.07	3.78
100 % ETc.	0.571	0.639	0.603	0.631	0.611	3.75	3.93	4.00	3.88	3.89
120% ETc	0.614	0.602	0.662	0.626	0.626	3.73	3.80	4.15	3.97	3.91
X⁻	0.540	0.556	0.566	0.572		3.51	3.63	3.74	3.73	
L.S.D at 0.05			Sea. (1)		Sea. (2)			Sea. (1)		Sea. (2)
Water			0.043		0.032			0.178		0.16
SAp			NS		NS			0.143		0.14
W.. X SAP			NS		NS			0.321		NS

	2013 / 2014									
Characters	Ca (%)					Total chlorophyll (ppm)				
SPA / **W. amount**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**
40 % ETc.	0.164	0.147	0.139	0.148	0.149	47.4	45.7	48.0	45.6	46.7
60 % ETc.	0.179	0.196	0.182	0.168	0.181	45.4	49.4	51.6	49.2	48.9
80 % ETc.	0.186	0.185	0.184	0.184	0.185	55.3	55.8	53.9	59.2	56.1
100 % ETc.	0.206	0.212	0.218	0.233	0.217	58.0	57.6	61.0	62.4	59.7
120% ETc	0.168	0.186	0.213	0.210	0.194	57.6	58.8	50.6	53.9	55.2
X⁻	0.181	0.185	0.187	0.189		52.7	53.5	53.0	54.0	
	2014 /2015									
	Cont.	**5kg**	**10kg**	**15kg**	**X⁻**	**Cont.**	**5kg**	**10kg**	**15kg**	**X⁻**
40 % ETc.	0.193	0.190	0.176	0.197	0.189	44.1	46.8	46.8	45.3	45.8
60 % ETc.	0.208	0.200	0.196	0.202	0.202	48.9	47.6	48.5	50.2	48.8
80 % ETc.	0.182	0.218	0.214	0.209	0.206	51.0	53.2	54.6	57.8	54.2
100 % ETc.	0.241	0.235	0.226	0.243	0.236	56.3	58.4	60.8	61.7	59.3
120% ETc	0.196	0.203	0.190	0.238	0.206	55.5	56.1	52.7	52.3	54.2
X⁻	0.204	0.209	0.200	0.218		51.2	52.4	52.7	53.5	
L.S.D at 0.05			Sea. (1)		Sea. (2)			Sea. (1)		Sea. (2)
Water			0.015		0.014			1.56		2.22
SAp			NS		NS			NS		NS
W.. X SAP			NS		NS			4.95		4.38

It is great important to know in how far the different investigated parameters are correlated of each other. It can be seen from Fig. (1) that WUE was significantly correlated with plant yield. Correlation coefficients (r) were 0.818 and 0.858in the first and second seasons, respectively. Corresponding coefficients of determination (r^2) were 0.670 and 0.737, indicating that 67% to 73.7% of the variation in plant yield was related to the WUE. On the other hand, the regression coefficients (b) were 1.54 and 1.19 in the first and second seasons, respectively. This indicated that for each increase of WUE, plant yield corresponding to increase by 1.54 and 1.19 kg. Similarly, highly significant positive correlations were existed between total yield (ton/fed.) and WUS (Fig.,1). A linear regression showed that for each increase of one WUE, total yield correspondingly increased by 0.230 and 0.187 ton/fed. during the first and second seasons, respectively.



Fig(1): Linear regression; correlation coefficients (r), coefficients of determination (r^2) and regression coefficients (b) of tomato plant yield (kg) and total yield(ton/fed) on WUE (kg/m³) in both seasons.

3.5. Investment ratio (IR):

The final goal of any agricultural application is to get profitable yield as gain from the invested cost. The agricultural process is mainly economic, so the net gain of each pound from the input is important to get the highest rate of revenue. Table (9) showed the calculation of fixed cost input for all treatments; while Table (10) gave the gross input, total output for all treatments and gave the IR values ranged from 0.47 as minimum and 4.17 as maximum. The highest values were obtained with 80% of Etc combined with 15kg SAP / fed.

As regards, multiple regression of tomato yield (ton/fed) on the amount of irrigation water (m³ / fed.) and rate of SAP (kg/fed.) revealed the following equations:

$Y^\wedge = -6.678 + 0.0098 X1 + 0.457 X2$

in the first season

$Y^\wedge = -6.328 + 0.0121 X1 + 0.347 X2$

in the second season

Where Y^ is the dependent estimated yield its line on the regression line, X1 and X2 are the independent variables, *i.e.*, amount of irrigation water and rate of SAP, respectively. The meaning of this is the total yield of tomato was increased by 0.0098 and 0.0121 ton/fed., for each one cubic meter water /fed. in the first and second seasons, respectively, also by 0.457 and 0.347 ton/fed for each one kg SAP /fed. the consideration that the cost of one kg SAP was equal to 270 m³ of water. Increases in yield due to 270 m³ of water produced 2.64 and 3.26 ton/fed. in the first and second seasons, respectively which are indicated that yield increasing due to amount of irrigation water which was higher than that due to SAP at equal cost.

Table 9. Fixed input and output for tomato production under low tunnel (LE./fed.)

Items	Unit	Counts	Unit cost L.E.	Total L.E.
Fixed cost/fed.				
Land preparation	Hour	6	50	300
Organic fertilizer	M3	30	100	3000
Plastic tunnels and wires				4500
Chemical fertilizer				2700
Seddling	Tray	30	60	1800
Labor cost	Worker/day			
1- Fertilizer add		5	60	300
2- Planting seedling		4	60	240
3- Seasonal labor		30	60	1800
4- Harvest labor		30	60	1800
Pesticides	Liter	7	100	700
Foliar fertilizer	Liter	3	100	300
Total				**17440**
Variable cost				
SAP cost/ kg	Kg	1	135	
Water cost/ m³	m³	1	0.5	
Output				
1- Marketable yield	Kg	1	2.5	
2- Non marketable	Kg	1	0.5	

Table 10. Gross input, total output and investment ratio (IR) for water and SAP treatments.

Characters	Water application cost			SAP application cost (L.E)/fed.			
SPA / **W. amount**	The amount of added water	Cost L.E/fed	Fixed cost LE/fed	**Cont.**	**5kg**	**10kg**	**15kg**
				0	675 L.E	1350 L.E	2025 L.E
40 % ETc.	**1176**	588	17440	18028.0	18703.0	19378.0	20053.0
60 % ETc.	**1763**	881.5		18321.5	18996.5	19671.5	20346.5
80 % ETc.	**2351**	1175.5		18615.5	19290.5	19965.5	20640.5
100 % ETc.	**2939**	1469.5		18909.5	19584.5	20259.5	20934.5
120% ETc	**3526**	1763		19203.0	19878.0	20553.0	21228.0
X⁻							

Season	Total output (L.E/fed.) 2013 / 2014				2014 / 2015			
	Cont.	**5kg**	**10kg**	**15kg**	**Cont.**	**5kg**	**10kg**	**15kg**
40 % ETc.	8523.6	13136.3	17376.9	18512.2	16753.8	15912.1	22267.0	23500.0
60 % ETc.	14703.1	23551.6	23458.2	24507.7	24611.4	32706.7	34156.7	33692.2
80 % ETc.	32565.6	64426.1	53776.0	81495.6	50481.6	71240.8	76374.0	86022.7
100 % ETc.	54867.2	58220.0	77721.7	64958.1	77470.6	79010.6	78593.3	80442.4
120% ETc	52372.4	50974.3	54749.6	53974.9	70670.3	67818.4	77267.3	69158.3

Characters / **SPA** / **W. amount**	Investment ratio(L.E input/ L.E output) 2013 / 2014				2014 / 2015			
	Cont.	**5kg**	**10kg**	**15kg**	**Cont.**	**5kg**	**10kg**	**15kg**
40 % ETc.	0.47	0.70	0.90	0.92	0.93	0.85	1.15	1.17
60 % ETc.	0.80	1.24	1.19	1.20	1.34	1.72	1.74	1.66
80 % ETc.	1.75	3.34	2.69	3.95	2.71	3.69	3.83	4.17
100 % ETc.	2.90	2.97	3.84	3.10	4.10	4.03	3.88	3.84
120% ETc	2.73	2.56	2.66	2.54	3.68	3.41	3.76	3.26

X⁻	

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