



## تأثير الري التسميدي بالأزوت والبوتاسيوم والري بالتنقيط مع التسميد التقليدي في إنتاجية ونوعية البندورة

# The Effects of N and K Fertigation and Drip Irrigation with Traditional Fertilization on Tomato Yield and Quality

Received 16 September 2012 / Accepted 26 March 2013

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### المُلخَص

يهدف مراقبة مزايا الري التسميدي مقارنة بالطريقة التقليدية في التسميد من خلال الري بالتنقيط وتأثيرها في مردود البندورة ونوعيتها وكفاءة استعمال المياه، تم تنفيذ تجربة حقلية لموسمين في محطة بحوث المركز العربي لدراسات المناطق الجافة والأراضي القاحلة / أكساد في محافظة دير الزور في سورية، والتي تقع على خط الطول  $40^{\circ} 11'$  شرقاً و خط العرض  $25^{\circ} 22'$  شمالاً، ويبلغ ارتفاعها عن سطح البحر 203 م. ضمنت التجربة وفق القطاعات العشوائية الكاملة (RCBD) باستعمال نظام الري بالتنقيط من خلال معاملتين هما: الري التسميدي (F) والري بالتنقيط مع التسميد بالطريقة التقليدية (DTF) مع ثلاثة مكررات لكل معاملة. تصنف التربة من النوع Thermic torrifluent مختلطة مع قوام طيني بين عمق 20 و 40 سم، وقوام لومي طيني في الأعماق الأخرى. وتظهر طبقة تحوي الجبس على عمق 120 سم تحت سطح التربة. زودت أرض التجربة بشبكة صرف زراعي تم تركيبها على عمق 140 سم وتباعد 40 م. أظهرت التحاليل الكيميائية أن التربة قليلة الملوحة وقلوية. تم إجراء تحاليل التربة والنبات لمراقبة حالة خصوبة التربة ونوعية المردود إضافة إلى تقدير المردود من الثمار وكفاءة استعمال المياه في محصول البندورة الذي تمت زراعته خلال موسمي عامي 2009 و 2010.

أظهرت نتائج الموسم الأول تفوق المعاملة (F) بإنتاجيتها من الثمار (66.81 طن.هكتار<sup>-1</sup>) بشكل معنوي على المعاملة DTF (57.76 طن.هكتار<sup>-1</sup>) بأقل فرق معنوي ( $LSD_{0.05} = 8.63$ )، وكانت قيم كفاءة استعمال المياه WUE 4.43 و 3.78 كغ.م<sup>-3</sup> لعاملات (F) و (DTF) على التوالي. وبلغت قيم حموضة عصير البندورة (pH) نحو 3.80 و 3.9 لكل من المعاملة (F) و (DTF) على التوالي، وكان متوسط قيم Brix في المعاملة F 5.48 وهو أعلى من قيم DTF البالغة 5.16. كما انخفضت إنتاجية معاملة الري التسميدي قليلاً في الموسم الثاني ليصبح الفرق غير معنوي بين المعاملتين، حيث انخفض مردود المعاملة (F) حوالي 2% ليصبح 55.536 طن.هـ<sup>-1</sup> ويرتفع مردود المعاملة (DTF) أقل من حوالي 2% ليصبح 58.338 طن.هـ<sup>-1</sup>.

abundance of the ticks vector as a result of the suitable climatic conditions and lack of sanitations, so it's important to controlling the tick vector which can break the transmission cycle.

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كما لوحظ انخفاض في خصوبة التربة عند نهاية موسمي النمو، وهذا مؤشر على أن التوصية السمادية لـ NPK الموصى بها لمنطقة التجربة من قبل وزارة الزراعة والإصلاح الزراعي (MAAR) في سورية غير كافية.

الكلمات المفتاحية: البندورة، الري التسميدي، التسميد التقليدي، الري بالتنقيط، كفاءة استخدام الماء.

## Abstract

In order to monitor the advantages of fertigation over traditional fertilizers application with drip irrigation on tomato yield, quality, and Water Use Efficiency (WUE), an experiment was conducted for two seasons at the experimental station of the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) in Deir Al-Zoor province (Syria). The station is located on 40° 11' E and 25° 22' N at an elevation of 203 m ASL. The experimental design of both experiments was RCBD with three replicates using drip irrigation system with two treatments namely Fertigation (F) and Drip irrigation with Traditional Fertilizer application (DTF). The soil classified as mixed thermic torrifuvent with clay texture between 20 and 40 cm depth and clay loam texture in other depths. A layer containing gypsum appears about 120 cm below the soil surface. Drainage tiles installed at 140 cm depth with spacing of 40 m. The chemical analysis shows that the soil is slightly saline and slightly alkaline. Soil and plant analysis performed to monitor soil fertility status, yield quality in addition to yield and WUE of tomato grown during 2009 and 2010 seasons.

Tomato fertigation treatment (66.81 T.ha<sup>-1</sup>) significantly over yielded (DTF) treatment (57.76 T.ha<sup>-1</sup>) with LSD<sub>0.05</sub> = 8.63 T.ha<sup>-1</sup>, and (WUE) values were 4.43 and 3.78 Kg.m<sup>-3</sup> for (F) and (DTF) treatments respectively. Tomato juice acidity values with pH meter was 3.8 and 3.9 for F and DTF respectively and average Brix values under F treatment 5.48 was higher than that of DTF values 5.16.

Yield of the F treatment decreased a little during the second growing season to end up with no significant differences between the two treatments. Where the yield of (F) treatment decreased about 2% to become 55.54 T.ha<sup>-1</sup> and the yield of (DTF) increased about 2% to end up with 58.34 T.ha<sup>-1</sup>. A reduction in soil fertility observed by the end of the two growing seasons, which is an indication of the underestimation of NPK fertilizers application recommendation of Ministry of Agriculture / Syria for the experimental site.

**Keywords:** Tomato, Fertigation, Tradition Fertilization, Drip irrigation, Water Use Efficiency.

## Introduction

Water problems are emerging as the most compelling issues facing agricultural production in Syria because of rapid population increase and climatic changes in the Eastern part of the Mediterranean Sea. This necessitated looking for improving water and fertilizers use efficiency of

cultivated crops. In the Euphrates basin, where surface water provided by the Syrian government for almost free of charges for agricultural use, farmers consume large quantities of water using traditional basin or furrow irrigation methods to grow field crops, forages, fruits and vegetables.

Farmers in developed countries successfully practice drip irrigation and fertigation for crop production for many years but it is not practiced in

this basin because of the high initial cost and lack of expertise except in some research stations. The beneficial effects of drip irrigation compared with other forms of water management attributed to a uniform water application, controlled root zone development and better disease management since only the soil is wetted whereas the leaf surface stays dry. Another advantage is the possibility of injecting fertilizers directly into the root zone of the crop to enable a uniform and adequate nutrition according to actual plant demand (Holmer et al., 1997).

Drip irrigation can be much more efficient than sprinkler irrigation since only the root zone of the cropped area irrigated. However, improper irrigation management can lead to waste water and leaching of soluble chemicals such as nitrate (Dukes et al., 2006).

Fertilizer application through drip irrigation (fertigation) can reduce fertilizer usage and minimize groundwater pollution due to fertilizer leaching from excessive irrigation (Badr and Abou El-Yazied, 2007). Nutrients can be injected at various frequencies (daily to monthly), depending on system design constraints, soil type and grower preference. Drip irrigation and fertigation with N fertilizer sources offer what is probably the ultimate in flexibility for N fertilizer management. Fertigation through drip irrigation lines can reduce overall fertilizer application rates and minimize adverse environmental impact of vegetable production, consequently N use efficiency (NUE) increases. Fertigation increases efficient use of water and fertilizers, produces higher yields, improves quality of the production and protects environment. With a drip-fertigation system uptake of N, P and K are substantially improved. In this respect per unit of fertilizer and water applied, higher yield and better

quality obtained (Khogali et al., 2011). Daily or weekly fertigation significantly increased yield compared with monthly fertigation, drip irrigation and surface irrigation methods (Badr and Abou El-Yazied, 2007).

Tomato (*Lycopersicon esculentum* L.) is one of the most popular and widely grown vegetable crops in the world and Syria. All the phosphorus, micronutrients and about one third of the nitrogen and potassium should be applied and incorporated before planting. Nitrogen and K fertigation scheduling on daily basis according to growing season was suggested by Rosen et al., (2004). Irrigation scheduling for tomatoes on daily basis according to growing season is sometimes practiced. Nutrients uptake, recovery and fertilizer use efficiency (FUE) in tomato as affected by fertilization method and fertigation studied by (Papadopoulos et al., 2000) were 81, 103, 114, 127 and 138 Kg yield.Kg<sup>-1</sup> NPK for furrow, drip irrigation, ½ soil ½ fertigation, ¼ soil ¾ fertigation and 100 % fertigation respectively. That attributed to even distribution of nutrients in fertigation treatments improved fertilizer use efficiency and resulted in lesser leaching of NO<sub>3</sub> and K to deeper soil layers. Hebbar, et al., (2004) Noticed significant yield reduction with 75% rate fertigation (72.7 T. ha<sup>-1</sup>) and normal fertilizer fertigation (73.27 T. ha<sup>-1</sup>) compared to water-soluble fertilizers fertigation (WSF). The WSF fertigation recorded significantly higher number of fruits per plant and fertilizer-use efficiency compared to drip- and furrow-irrigated controls. Fertigation resulted in lesser leaching of NO<sub>3</sub> N and K to deeper layer of soil and fruit yield of tomato was 28% higher in drip irrigation (43.87T.ha<sup>-1</sup>) over furrow irrigation (34.38T.ha<sup>-1</sup>). Fertigation with 100% NPK water-soluble fertilizers increased fruit yield significantly

(58.76 T.ha<sup>-1</sup>) over furrow irrigated control, drip irrigation, 50% fertigation (48.18 T.ha<sup>-1</sup>) and 75% NPK fertigation (54.16 T.ha<sup>-1</sup>). Similarly, fertigation treatments recorded significantly higher number of fruits and mean fruit weight per plant compared to drip and furrow irrigation (Papadopoulos et al., 2000). Due to the local consumption need for large quantities of fresh tomato and for food industry, we have grown tomato in a sequence with fodder beet using improved localized irrigation in a study aiming to determine:

- 1- Water requirement using drip irrigation under the Lower Euphrates basin climatic conditions.
- 2- The effects of N and K application rates and fertigation on yield and quality.

## Materials and Methods

The experiment was conducted in the experimental station of the Arab Center for the Studies of Arid zones and Dry lands (ACSAD) in Deir Al-Zoor province,

which is located on 40° 11' E and 25° 22' N at an elevation of 203 m ASL. The chemical and physical soil, water and plant analysis took place in ACSAD laboratories. The soil classified as mixed Thermic torrifluent with clay texture between 20 and 40 cm depth and clay loam texture in other depths (Table 1). The clay percentage in each layer is in agreement with the CEC. Available P was very good at the top layer and low underneath. Available K was low all over the profile. A layer containing gypsum appears about 120 cm below the soil surface. Drainage tiles installed at 140 cm depth with spacing of 40 m. The chemical analysis shows that the soil is slightly saline and slightly alkaline (Table 2). Soil is slightly saline down to 60 cm depth to become moderately saline below according to Smith and Price (2009). On contrary to soil salinity, the pH of the saturated paste decrease with depth in general. Although the EC<sub>e</sub> is in the slightly to moderately salinity range, the SAR values are relatively low because of the presence of high concentrations of Ca and Mg in the saturated paste extract as result of presence of very small amounts of

**Table 1.** Initial physical and fertility soil properties of the experimental site.

Depth (cm)	Sand	Silt	Clay	Texture	Total. N (%)	available.P	avai.K	avai. B
	(%)					(mg.Kg <sup>-1</sup> )		
00-20	30	40	30	Clay loam	0.065	50.6	136.7	1.8
20-40	20	36	44	Clay	0.048	21.2	103.4	1.4
40-60	34	32	34	Clay loam	0.005	8.5	56.3	1.6
60-80	36	32	32	Clay loam	0.005	6.5	40.6	2.0

**Table 2.** The pH, EC<sub>e</sub> (dS. m<sup>-1</sup>), and concentration of ions in the saturated paste extract (mmol<sub>c</sub>.l<sup>-1</sup>), CEC of the soil (mmol<sub>c</sub>.100g<sup>-1</sup>soil) and SAR of the studied soil.

Depth (cm)	pH	EC <sub>e</sub> (dS.m <sup>-1</sup> )	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>++</sup>	Mg <sup>++</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>-</sup>	CEC (mmol <sub>c</sub> .100g <sup>-1</sup> )	SAR
			(mmol <sub>c</sub> .l <sup>-1</sup> )								
00-20	7.94	3.25	10.38	0.54	19.4	6.96	2.20	3.44	31.72	26.7	2.86
20-40	7.86	3.47	10.38	0.42	22.8	7.96	1.52	1.94	38.08	43.2	2.65
40-60	7.77	3.65	11.08	0.26	19.2	5.14	1.10	2.06	31.42	33.2	3.18
60-80	7.79	4.21	19.08	0.18	26.1	11.34	1.74	3.86	51.10	32.2	4.41

gypsum, which is clear from the high concentration of sulfate in the saturated paste extract.

The experimental design of both seasons is RCBD with three replicates using drip irrigation system with two treatments namely Fertigation (F) and Drip irrigation with Traditional Fertilizer application (DTF). Each experimental plot covered 100 m<sup>2</sup> (5 × 20 m). Drippers were 40 cm apart, and had discharge rates of 4 l.h<sup>-1</sup> and dripper lines were 100 cm apart.

### A. First season (2009)

After the harvest of the previous crop (Faba Bean), composite soil samples were taken before manure addition at a rate of five T.h<sup>-1</sup> and tomato planting. Soil samples were taken for the second time from the four depths between two plant rows and on the planting row mid growing season. After the last harvest, soil samples taken in a manner similar to the second sampling. The EC of the irrigation water ranged between 0.6 -1.4 dS.m<sup>-1</sup> Soil moisture monitored using the gravimetric method and the amount of water to be added when the available water goes down to 80% to reach field capacity was calculated and measured using a discharge gauge. For traditional fertilization with drip irrigation treatment, all the required P, K, and 1/3 of N added at planting and the rest in two portions until maturity. The total amounts of fertilizers were 200 Kg N.h<sup>-1</sup> as Urea 46%, 80 Kg.h<sup>-1</sup> P<sub>2</sub>O<sub>5</sub> as TSP 46% and 80 Kg.h<sup>-1</sup> K<sub>2</sub>O as Potassium Sulfate 50%. Concerning fertigation treatment, all P fertilizer incorporated in the top layer with 10% of N and K fertilizers before planting. The amounts of rain during the season were less than 7 mm (many events) therefore it was considered as negligible. We had 37 irrigations cycles with a calculated value of 1321 mm and application of 1599 mm (15% leaching fraction and application

efficiency of 95%) and 11 harvests. The fertigation treatment received all P fertilizer and 1/10 of N and K before planting, and received the rest of N and K fertilizers on nine dates during the growing season and added with the irrigation water after 10% to 90% of each irrigation cycle. The rest of the time fresh water was passed through the system to reduce the chance of fertilizers precipitation in the irrigation tubes. High rate of K fertilizer was applied at late stages of the growth, and N and K fertilizers were applied according to the rates presented in Table 3.

**Table 3.** Rates of N, P and K fertilizers applied in fertigation treatment at different growth stages.

Growth stages	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Planting - flowering	1	0	1
Flowering - start fruiting	2	0	4
start fruiting - ripening	2.4	0	4
Ripening - harvest	3	0	6

Adapted from: Maar (1993), Holmer and Schnitzler (1997), El Fadl (2004).

Seeds of *Lycopersicon lycopersicum* L. var., Pakmor tolerant to *Fusarium* wilt, race 0, *Stemphylium* (Grey leaf spot) and *Verticillium* planted in the greenhouse on 22/2/2009 and transplanted to the field on 4/4/2009. Phonological stages recorded in addition to some parameters such as plant height, fruit weight, fruit volume, total acidity, sugar content and nitrate concentration of the fruit juice. The acidity measured using pH meter and titration with sodium hydroxide. The results analyzed using Genstat 8.

### B. Second season (2010)

The previous crop was fodder beet, which was planted in the same places as tomato and using the same treatments. Soil samples after fodder beet

harvest were taken on 2/2/2010. Transplanting the variety of tomato seedlings were on 20/3/2010. The same amounts of manure and mineral fertilizers were applied during the second season too.

Soil moisture monitored using the gravimetric method and the amount of water to be added when the available water goes down to 80% to reach field capacity was calculated and measured using a discharge gauge. The amounts of rain during the season were less than 4 mm (many events) therefore it was considered as negligible. We had 29 irrigations cycles with a calculated value of 798 mm and application of 997 mm (15% leaching fraction and application efficiency of 95%), N and K fertilizers were applied 8 times only with the irrigation water and plane irrigation water were applied for the rest. Tomato fruit were collected 10 times.

## Results and Discussion

### A. First season (2009)

Fertigation treatment ( $66.81 \text{ T. h}^{-1}$ ) significantly over yielded DTF treatment ( $57.76 \text{ T. ha}^{-1}$ ) with CV(%) 3.94 and  $\text{LSD}_{0.05} = 8.63 \text{ T. ha}^{-1}$  (Table 4). These results are in agreement with (Hebbar, et al., 2004, Shaymaa et al., 2009, Badr, and Abou El-Yazied, 2007) who suggested daily and weekly fertigation for increasing yield compared with monthly fertigation on loamy sand soil. In our experiment, we applied fertigation almost at fourth irrigation in average and applied N and K fertilizers starting from 10% of irrigation time to 90% of the time, which resulted small yield advantage of F over DTF. Water use under F treatment was less than DTF treatment, that is due to higher water content remained in the soil at the end of the experiment, although the same amount of water was applied under both treatments

( $15995 \text{ m}^3.\text{ha}^{-1}$ ). Higher yield and smaller amount of water used under F treatment improved WUE where the difference was about 17% and the values were 4.42 and 3.78  $\text{Kg.m}^3$  for F and DTF treatments respectively (Table 4).

**Table 4. Amounts of irrigation water applied, water used, yield and WUE of tomato under both treatments (2009 season).**

Treatment	Irrigation water applied	Water use	Irrigation efficiency	yield	WUE
	( $\text{m}^3.\text{ha}^{-1}$ )	( $\text{m}^3.\text{ha}^{-1}$ )	(%)	( $\text{Kg}.\text{ha}^{-1}$ )	( $\text{Kg}.\text{m}^{-3}$ )
F	15995	15100	95	66809	4.42
DTF	15995	15290	95	57763	3.78

The difference in average fruit size between F ( $193.8 \text{ cm}^3$ ) and DTF ( $200.8 \text{ cm}^3$ ) treatments was small which was around the potential volume of the standard volume of the seed producer (Pop Vriend Seeds B.V.). The differences in average fruit weight 203.3g and 214.9 g were not significant between F and DTF treatments too. Tomato juice acidity difference was significant with pH = 3.803 and 3.9 for F and DTF respectively ( $\text{LSD}_{0.05} = 0.035$ ). Average Brix values under F treatment were higher than DTF values 5.48 and 5.16 respectively where the acceptable range is between 4 and 9 which means better quality fruits were produced under F treatments containing larger amounts of soluble solids. sweeter minimum level for Brix reconstituted fruit juices and reconstituted puree is 5 (Codex Stan 247-2005). Plant height under DTF treatment 80.33 cm in average was significantly higher than under F treatment 63.47 cm in average ( $\text{LSD}_{0.05} = 6.33 \text{ cm}$ ), which can be attributed to the application of larger amounts of N fertilizers at early stages of growth. Higher significant nitrate concentration was observed in F treatment fruits  $38.15 \text{ mg.l}^{-1}$  compared

with DTF treatment 29.95 mg.l<sup>-1</sup>. (LSD<sub>0.05</sub> = 0.99). These values are smaller than the average value of tomato grown in Romania, which is 104.69 mg.kg<sup>-1</sup> (Valérie H. et al., 2011), and that is the safe limit under Romanian legislation. The high concentration of nitrate in tomato fruits under F treatment can be attributed to the concentration of nutrients in the wetted bulb of the soil under the emitters where almost all active plant roots exist, which is considered an important advantage of fertigation.

The concentration of available K of the composite samples taken before planting was small. It increased after the application of K fertilizer by mid season and the use of small amounts of K during the vegetative growth period under both treatments between plants on the planting rows and between rows (Fig. 1). The high use of K nutrient at later stages of growth reduced

K concentration in soil in spite of the continuous application of K. These results encourage altering the application rate of K to keep the largest amounts to the latest stages of growth. This is the case with many tomato growers in the world. Moreover, the concentration of Available P between rows remains smaller than between plants especially under DTF treatment.

Available P was high at the surface layer (about 50 mg.kg<sup>-1</sup>) at planting and decreases with depth due to P fertilizer application to soil surface and mixing it with the surface soil layer and its very slow movement in the soil. It decreased from planting to mid season and to the end of season especially in the upper layer, which means that the P recommendation was not adequate under both F and DTF treatments. Most of the P reduction was in the upper layer due

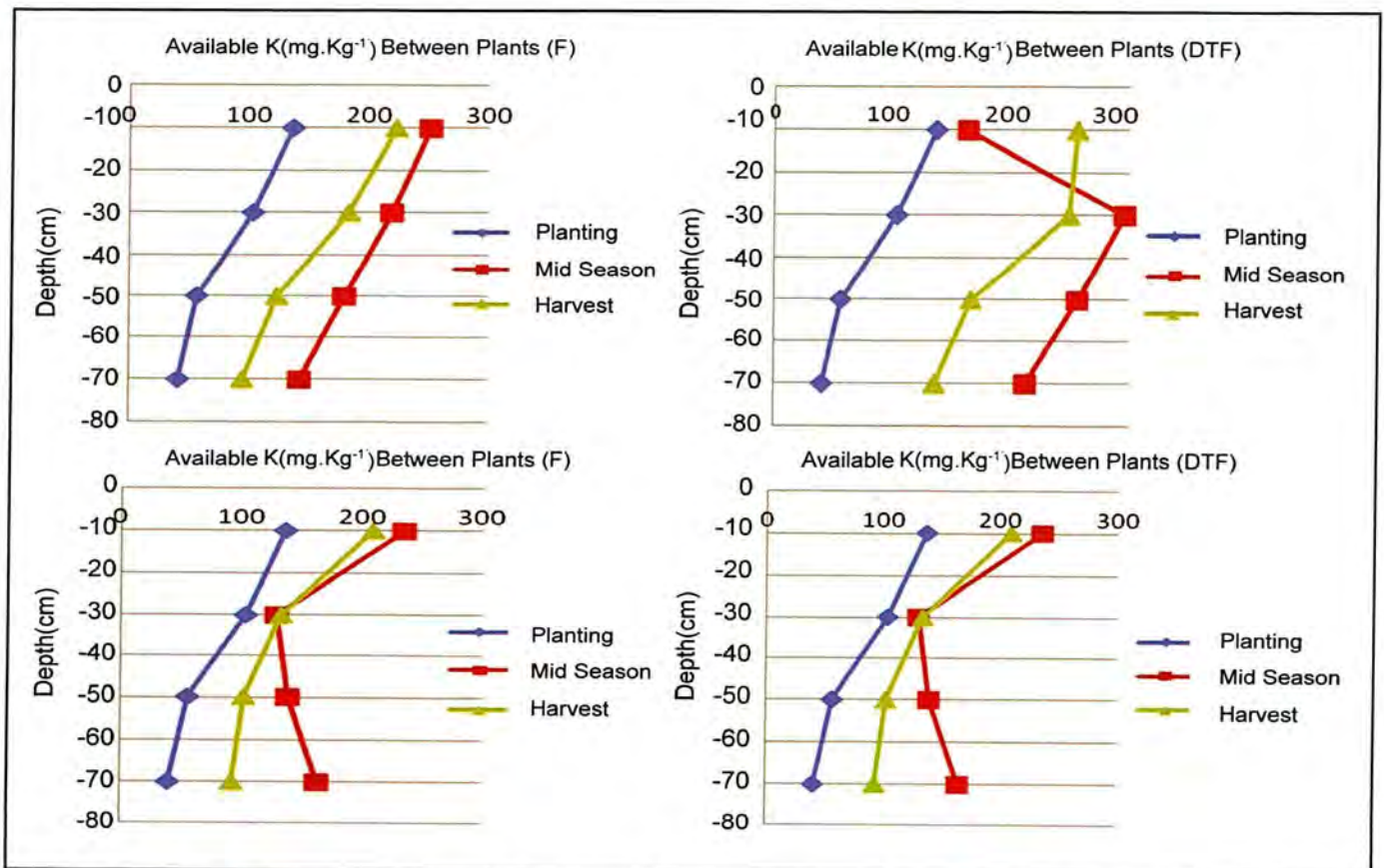
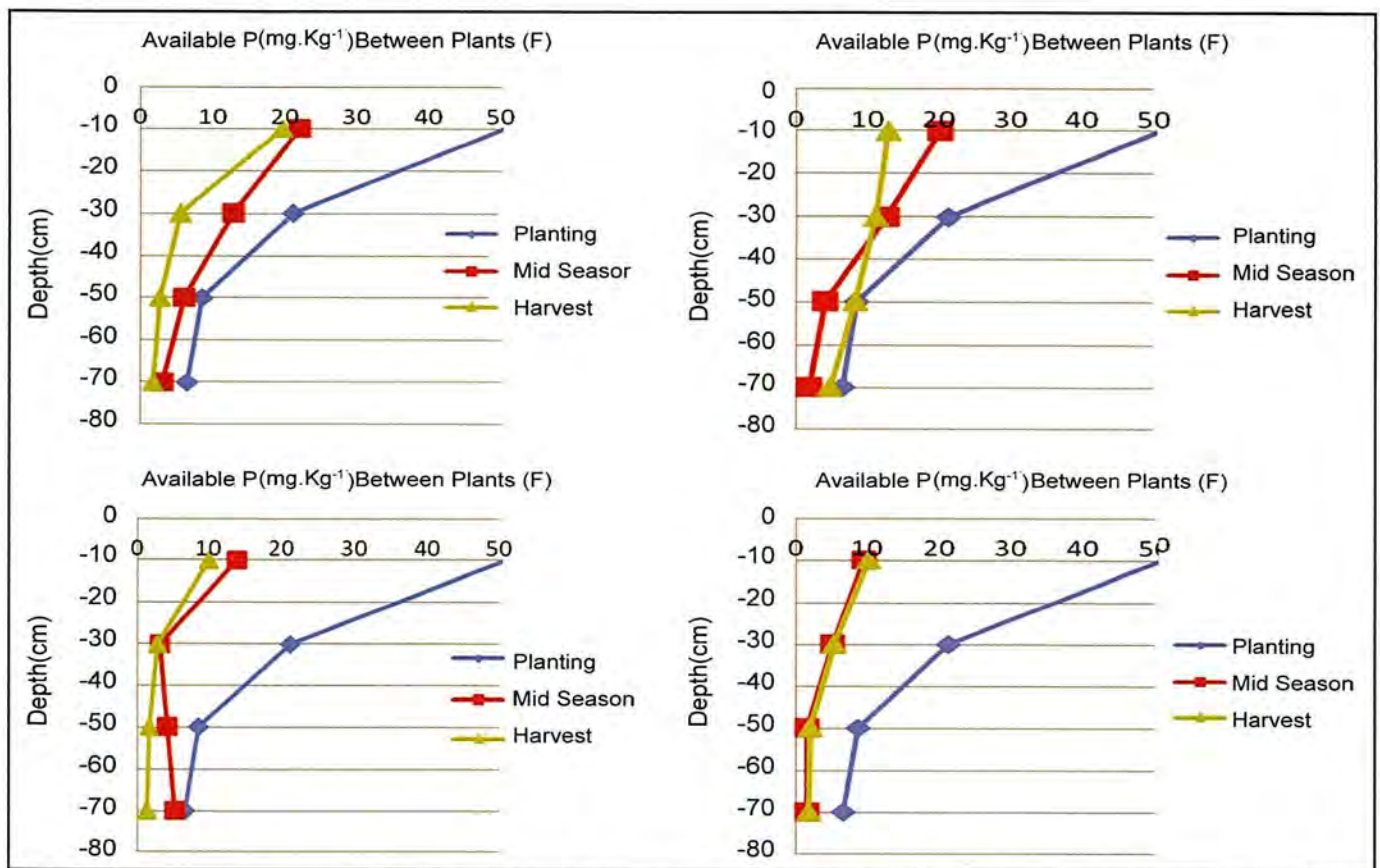


Fig. 1. Available K (mg.kg<sup>-1</sup>) with soil depth (cm) between rows and between plants under (F) and (DTF) treatment at three dates during 2009 tomato growing season.





**Fig. 2.** Available P (mg.kg<sup>-1</sup>) with soil depth (cm) between rows and between plants under F and DTF treatment at three dates during 2009 tomato growing season.

to its use by plant.

Although large amounts of irrigation water was used during the growing period (16000 m<sup>3</sup>.ha<sup>-1</sup>) with medium salinity of 1.1 dS.m, soil salinity increased in all depths by midseason under both treatments between plants on the same row and between rows. However, it decreased by the end season (harvest) to end up with salinities just a little above the planting readings (Fig. 3). It is clear in Fig. 3 that the salinity between rows is smaller than between plants.

Although soil salinity increased in general (Fig. 3), SAR values decreased with time from planting to harvest (Fig. 4) which can be attributed to the composition of the irrigation water (SAR = 2.23) soluble Na compared with Ca and Mg. The fast movement of the mono-valent Na compared with

the di-valent Ca and Mg could be another reason of SAR reduction with time.

#### A. Second season (2010)

Fertigation treatment tomato fruit yield (55.54 T.ha<sup>-1</sup>) was insignificantly lower than DTF treatment (58.34 T/ha) with CV 7.81% (Table 5), which is in disagreement with (Hebbar *et al.*, 2004., Badr and Abou El-Yazied, 2007., Shaymaa *et al.*, 2009). The reason for the lower F treatment yield might be attributed to the application of fertilizers as fertigation just in 9 cycles out of 29 irrigation cycles in disagreement with Hebbar *et al.*, (2004.), Badr and Abou El-Yazied (2007.), Shaymaa *et al.*, (2009) too who suggested daily and weekly fertigation for increasing yield. In this experiment, fertigation was applied almost at fourth irrigation in average and

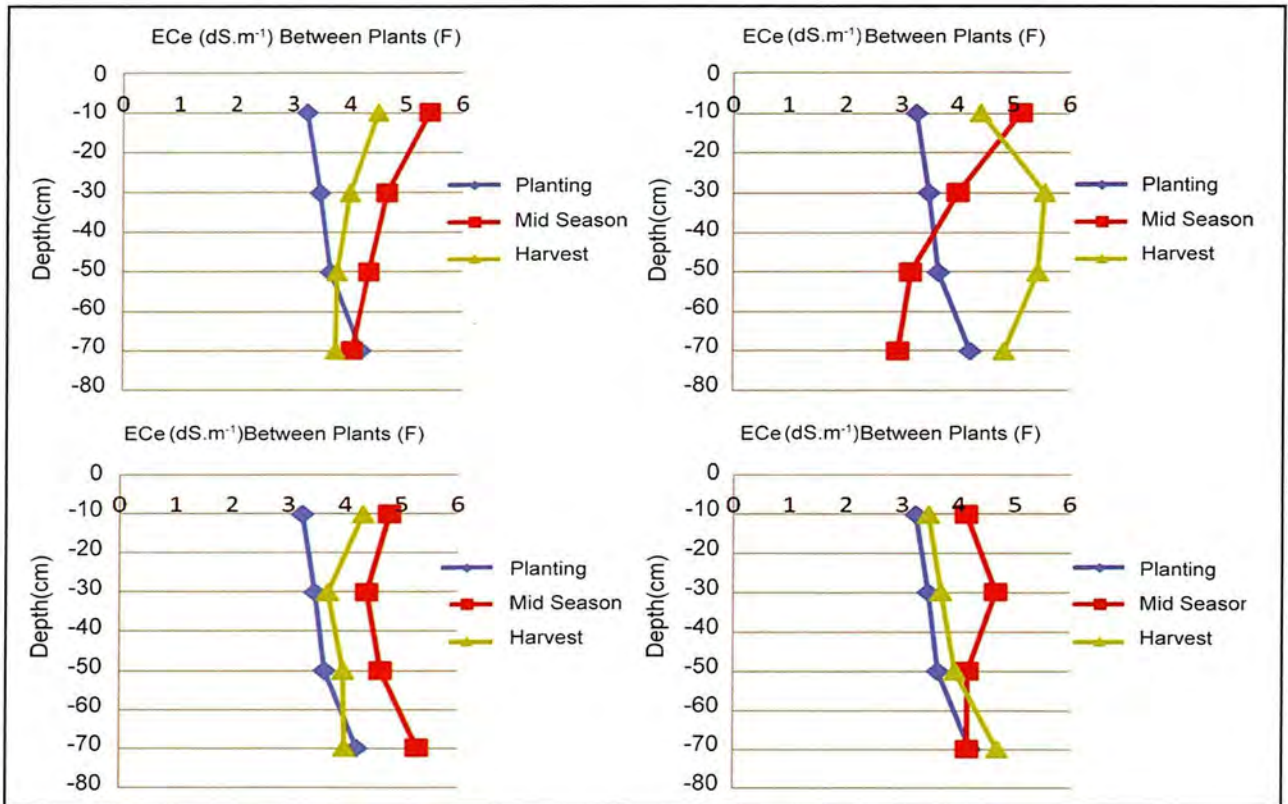


Fig. 3.  $EC_e$  ( $dS.m^{-1}$ ) with soil depth (cm) between rows and between plants under F and DTF treatment at three dates during 2009 tomato growing season.

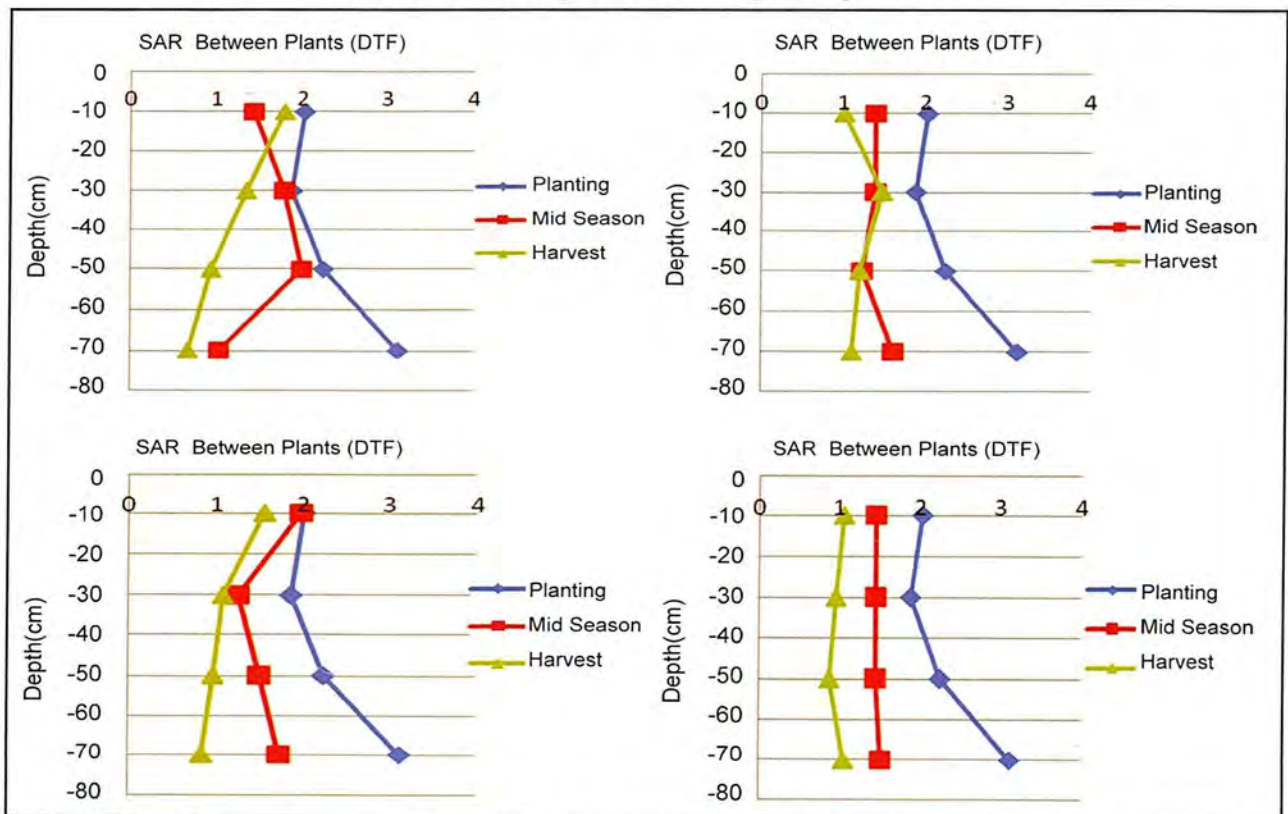


Fig 4. SAR with soil depth (cm) between rows and between plants under F and DTF treatment at three dates during 2009 tomato growing season.

applied N and K fertilizers were applied in portions starting from 10% of irrigation time to 90% of the time, which resulted small yield advantage of DTF over F. Another reason for lower F treatment yield might be leaching a part of the soluble N and P fertilizers with the additional leaching fraction in order to sustain the productivity of the soil by keeping its salinity low.

Water use under DTF treatment ( $9361\text{m}^3.\text{ha}^{-1}$ ) was less than F treatment ( $9580\text{ m}^3.\text{ha}^{-1}$ ), that is due to higher water content at the start of growing season under F ( $1051\text{ m}^3.\text{ha}^{-1}$ ) treatment compared with ( $973\text{ m}^3.\text{ha}^{-1}$ ) for DTF treatment that is left over from the previous crop (fodder beet), in addition to lower water content remained at final harvest of F treatment ( $1559\text{ m}^3.\text{ha}^{-1}$ ) compared with ( $1600\text{ m}^3.\text{ha}^{-1}$ ) for DTF treatment.

Higher yield and smaller amount of water used under DTF treatment improved WUE where the difference was 7% and the values were  $6.23\text{ Kg.m}^3$  and  $5.80\text{ Kg.m}^3$  for DTF and F treatments respectively (Table 5).

**Table 5. Amount of irrigation water applied, water used, yield and WUE of Tomato under both treatments (2010 season).**

Treatment	Irrigation water applied ( $\text{m}^3.\text{ha}^{-1}$ )	Water use ( $\text{m}^3.\text{ha}^{-1}$ )	Irrigation efficiency (%)	yield ( $\text{Kg}.\text{ha}^{-1}$ )	WUE ( $\text{Kg}.\text{m}^3$ )
F	9971	9580	95	55536	5.80
DTF	9971	9361	95	58338	6.23

The difference in average fruit size between F ( $193.8\text{ cm}^3$ ) and DTF ( $200.8\text{ cm}^3$ ) treatments was small which was around the potential volume of the

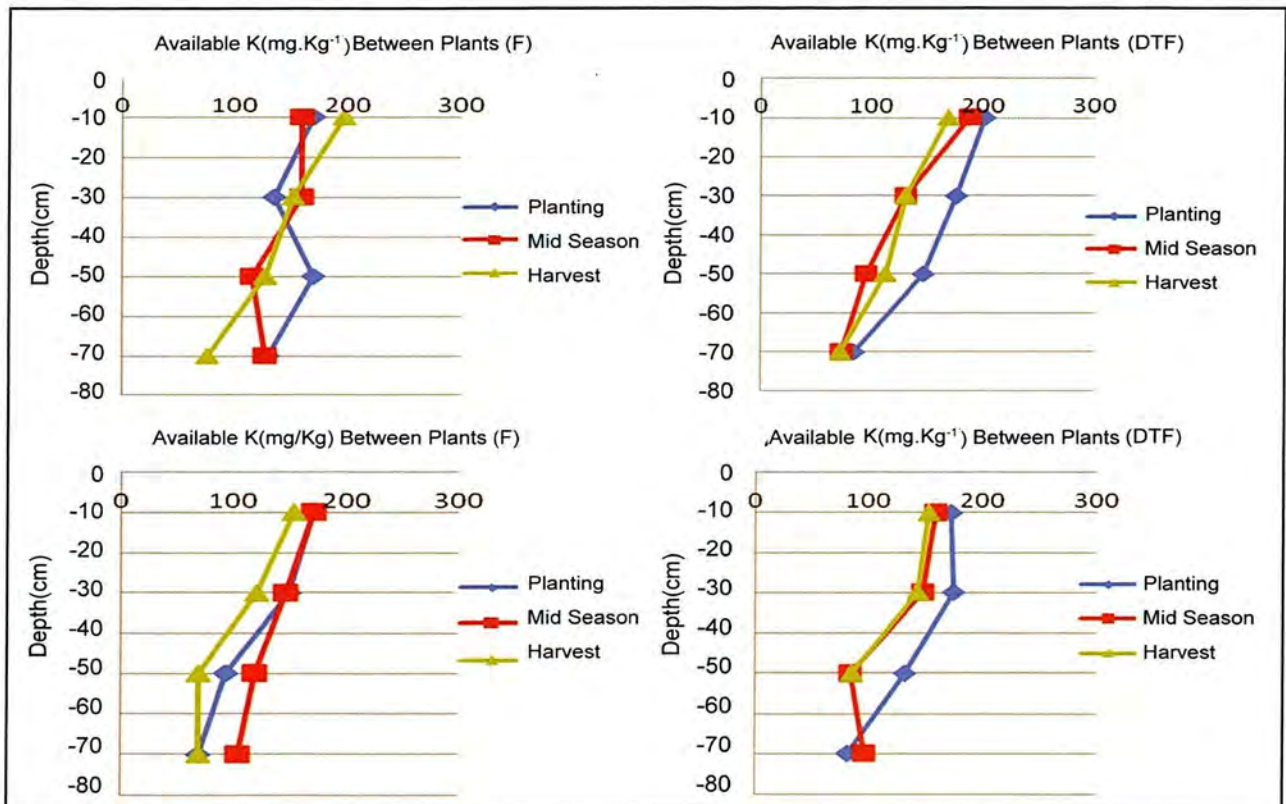
standard volume of the seed producer (Pop Vriend Seeds B.V.). The differences in average fruit weight  $163.6\text{ g}$  and  $203.9\text{ g}$  were not significant between F and DTF treatments too. Tomato juice acidity difference was not significant with  $\text{pH} = 3.873$  and  $3.870$  for F and DTF.

The concentration of available K in the top layer was low at transplanting with a decreasing trend toward the bottom of the rooting zone (Fig. 5). This can be attributed to the high consumption of fodder beet (the previous crop). Changes in K concentration at mid season and at harvest were not significant. The low K concentration during the entire growing season had a negative effect on yield of both treatments. These results encourage the application higher rates of K as many tomato growers in the world do (Rosen *et al.*, 2004., Badr and Abou El-Yazied, 2007). Moreover, the concentration of Available K between rows remained smaller than between plants especially under DTF treatment.

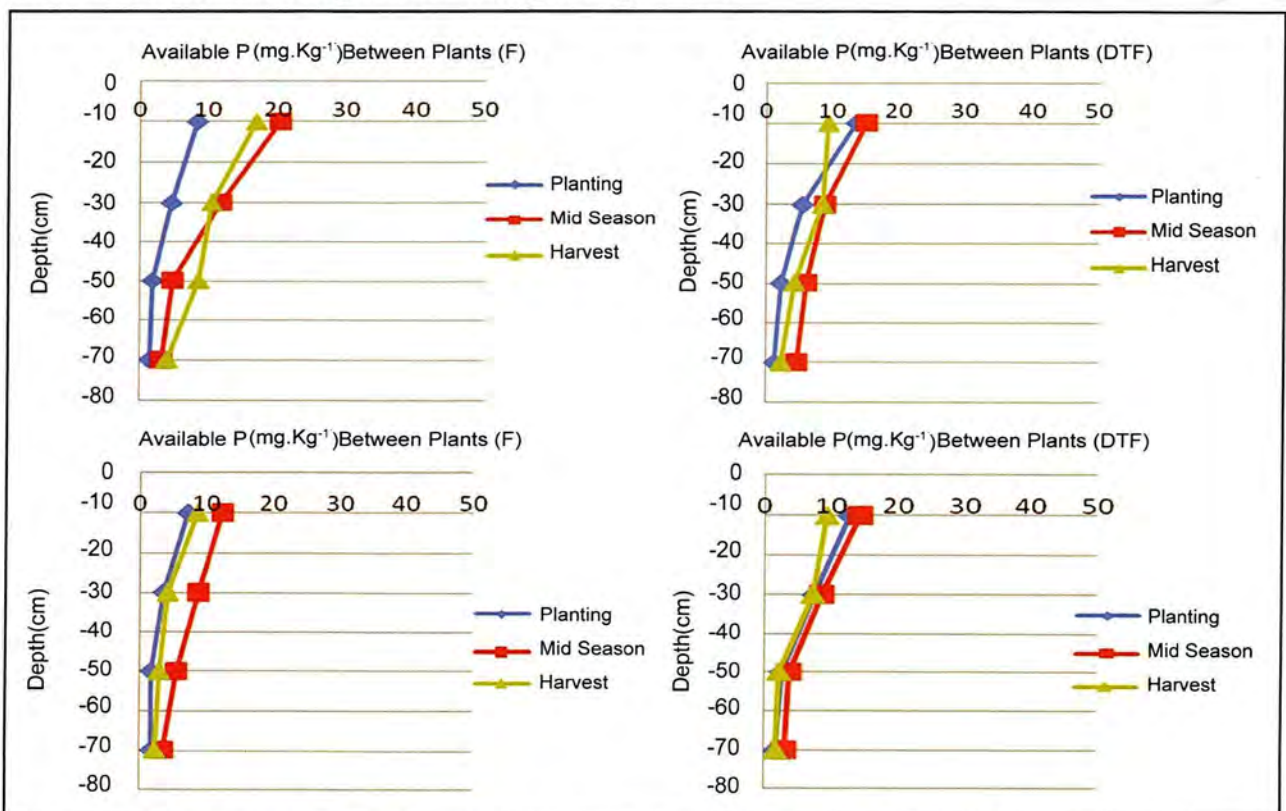
Available P was low before transplanting (after fodder beet harvest) it increased just a little at mid season and harvest time. The increase was clearer in F treatment compared with DTF. As convenient P concentration at the surface layer decreases with depth, due to P fertilizer application to soil surface and mixing it with the surface soil layer and its very slow movement in the soil. The P recommendation of MAAR and applying the same amounts of as the first growing season are the main reasons of the low P under both F and DTF treatments and that might had a negative effect on tomato yield.

### Soil salinity

Although large amounts of irrigation water were used during the growing period ( $9471\text{ m}^3.\text{ha}^{-1}$ ) with medium salinity of  $1.1\text{ dS}.\text{m}^{-1}$ , soil salinity increased



**Fig. 5.** Available K (mg.Kg<sup>-1</sup>) with soil depth (cm) between rows and between plants under (F) and (DTF) treatment at three dates during 2010 tomato growing season.



**Fig. 6.** Available P (mg.Kg<sup>-1</sup>) with soil depth (cm) between rows and between plants under F and DTF treatment at three dates during 2010 tomato growing season.

in all depths by midseason under both treatments between plants on the same row and between rows. However, it decreased by the end season (harvest) to end up with salinities above the planting readings (Fig. 7). This increase in salinity moved the salinity to the moderately saline soil under both treatments according to Smith and Price (2009). The increase in salinity during the mid season can be attributed to hot condition and inadequate irrigation water supply to cover crop water requirements and leaching fraction. The high  $EC_e$  at soil surface in spite of applying fresh irrigation water to soil surface is an indication of high evaporation rate in the experimental site.

Changes in SAR values were small and did not have a clear trend with time from planting to harvest (Fig. 8) although a clear increase in soil salinity was observed in all layers during the growing season,

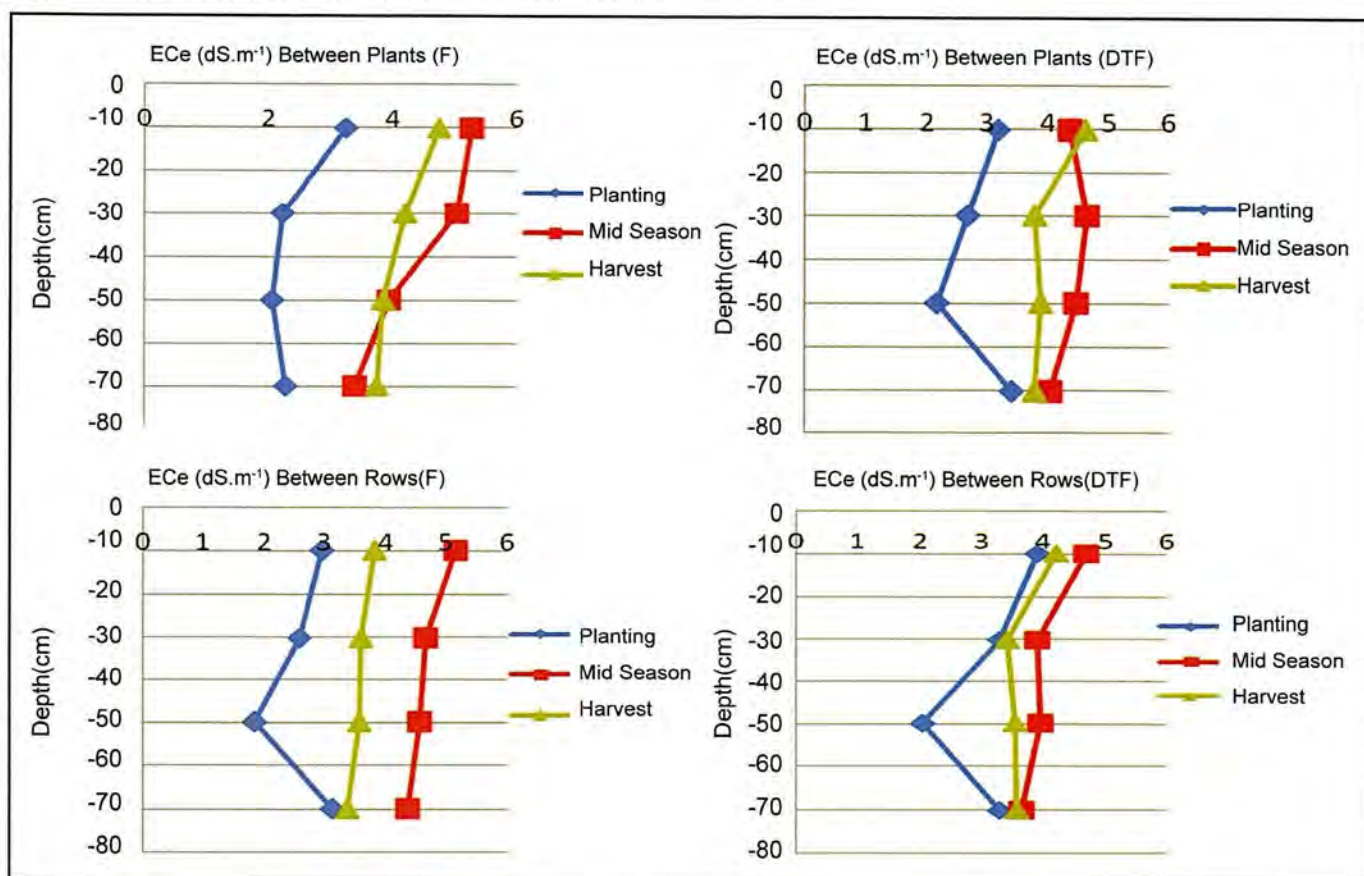
which can be attributed to the composition of the irrigation water ( $SAR = 2.23$ ) soluble Na compared with Ca and Mg.

### General discussion

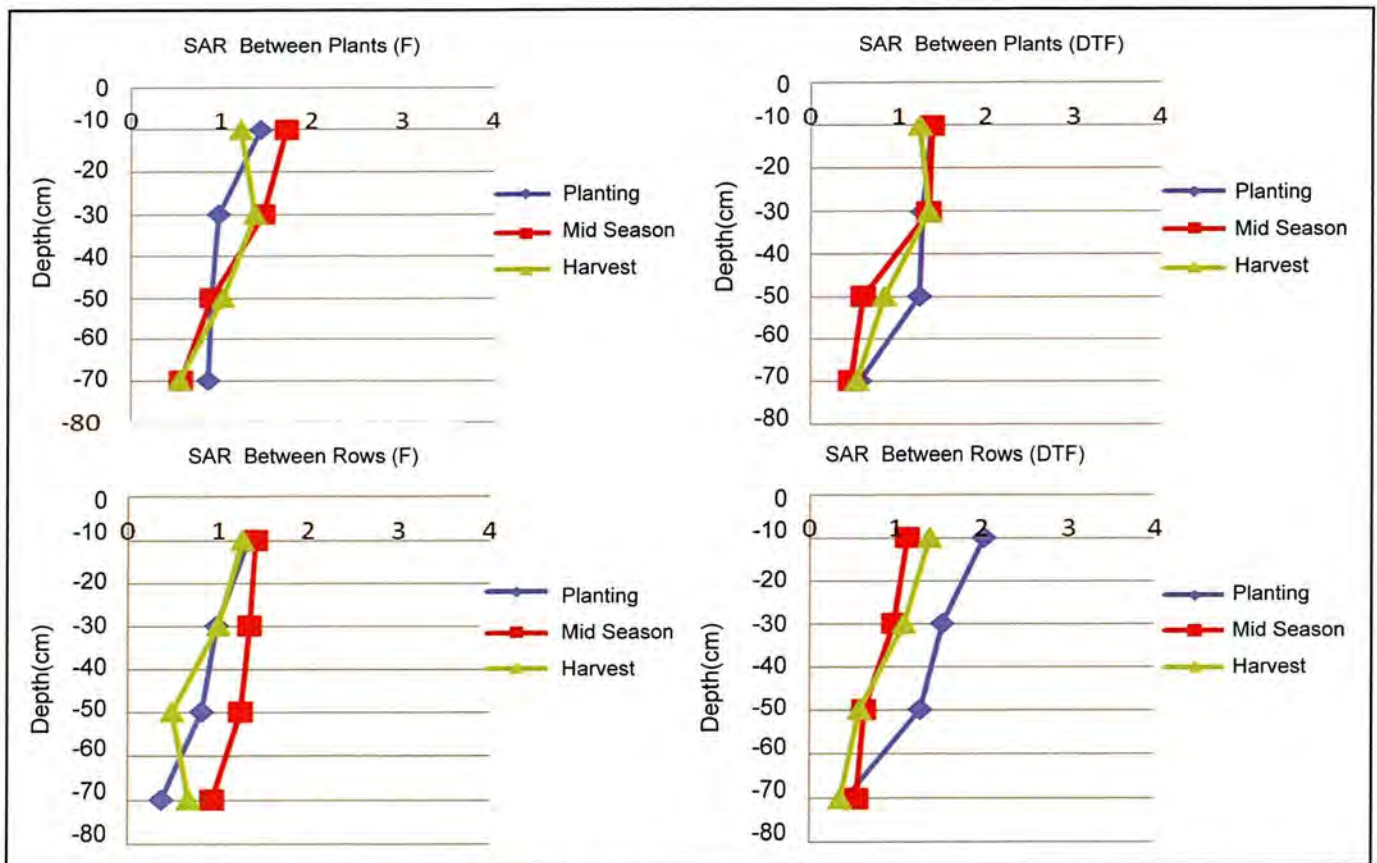
Previous crop and soil fertility status have significant effects on tomato yield, where the yield of the first season (after Faba bean) was 9.4% higher than that of the second (after Fodder beet). The lower fertility status (N, P, and K) at the start of the second growing season compared with the first had negative effects too on the second season tomato yield too (Fig. 1, 2, 5 and 6).

### Conclusion

The conclusions, which can be drawn from this study, are:



**Fig. 7.**  $EC_e$  ( $dS.m^{-1}$ ) with soil depth (cm) between rows and between plants under F and DTF treatment at three dates during 2010 tomato growing season.



**Fig 8.** SAR with soil depth (cm) between rows and between plants under F and DTF treatment at three dates during 2010 tomato growing season.

- Higher yield, WUE and better fruit quality were obtained using F compared with DTF treatment and larger differences in yield and quality could be obtained by applying fertigation with each irrigation cycle.
- A reduction in soil fertility was observed by the end of the two growing seasons, which are indications of the underestimation of NPK fertilizers recommendation of MAAR, Syria.

### Acknowledgement

This work is the outcome of the Convention on scientific and technical cooperation between the Arab Center for the Studies of Arid Zones and Dry arid lands (ACSAD) and the International Institute for Plant Nutrition (IPNI).

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