

Impact of Fertigation Scheduling on Tomato Yield under Arid Ecosystem Conditions

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Abstract: Fertigation has ensured to improve stability of crops productivity; its use is being discontinued due to its potentially hazardous even and even so applied improperly. Therefore, two field experiments were carried out during two successful growing seasons (2005 and 2006) at Desert Farm of Faculty of Agriculture, Ain Shams University, EL-Bustan Region, Beheira Governorate, which represents sandy soil conditions, to improve tomato yields based on fertigation technique scheduling under surface drip and solid-set sprinkler irrigation systems. Results revealed that tomato yields, water and fertilizer use efficiencies had been enhanced with about 25.6, 49.3 and 20.3% under surface drip compared with solid-set sprinkler irrigation systems respectively. On the other hand, data indicated that there was a positive proportional trend with the applied nutrient amounts and the NPK residues in the fruits under the investigated irrigation systems. Moreover, the cost of tomato production unit under fertigation was lower than that when using traditional method of fertilization (broadcasting) by 15.72% and 12.78% under drip and sprinkler irrigation systems at rate of 100% of the total nutrient requirements, respectively.

Key words: Drip irrigation, Sprinkler irrigation, Sandy soil, Costs, Quality.

INTRODUCTION

Tomato is the major vegetable crop in Egypt. The annual cultivated area is estimated to be 110657 feddans amounting to 38.5% of the total vegetable area according to ^[1]. Growth yield were the biggest in 30%-reduction treatment and standard (drip fertigation with the same amounts as control), ^[2]. Meanwhile, Boujelbn et al) ^[3] stated that daily drip irrigation may be help tomato crop to resist higher summer temperatures. Moreover, El-Gindy and Abdel-Aziz ^[4] and Khalifa ^[5] stated that drip irrigation systems may enhance crop yield with about 7.9 and 26.19% compared with sprinkler irrigation systems according to the irrigated crop type and the applied fertigation scheduling and management.

Chemigation technology has been introduced to improve the application of agro-chemicals via irrigation systems. Chemigation has ensured to improve stability of crops productivity, its use is being discontinued due to its potentially hazardous to the environment and its role in the physical resources degradation even and even so if applied improperly ^[6]. Therefore, uniform application of such chemicals is necessary to insure considerable increase in vegetable production and real decrease in production costs ^[7]. Abdel-Aziz ^[8] found that injection the fertilizers through irrigation systems produced 23.41% more in potato yield than that the conventional method of fertilization. Deshmukh ^[9]

stated that the application of about 80 percent of the recommended rate were superior to the other treatments, however, 16% increase in yield had been observed.

Therefore, the objective of this study was to scheduling phase-out of the applied crop nutrients requirements via irrigation water (fertigation technique) and the tomato productivity response under sandy soil conditions.

MATERIALS AND METHODS

Experimental Layouts and Design: Field experiments carried out in the Desert Farm of the Faculty of Agriculture, Ain Shams University (sandy soil), EL-Bustan Region, Beheira Governorate. Some physical properties of soil and chemical analysis of irrigation water were conducted according to standard procedures and represented in Tables (1, 2 and 3). Two pressurized irrigation systems (surface drip and solid-set sprinkler) were investigated as shown in Fig.(1).

I- Irrigation Systems: The control head unit consists of electrical centrifugal pump (50 m³/h and 40 m head), media filter (2 tanks each one is 36" in diameter), two screen filter (3" in diameter for each one- 120 mesh), flow meter and pressure gauges. However, venture meter (2" in diameter) had been used for the application of the crop nutrient requirements via

Table 1: Physical properties of sandy soil.

Sample Depth, cm	Particle Size Distribution, %				F.C.,%	P. W.P.,%	B.D.,g/cm ³	Texture Class
	C. sand	F. sand	Silt	Clay				
0-30	52.8	41.4	4.1	1.7	9.4	4.3	1.68	Sandy
30-60	50.0	43.5	5.0	1.5	8.5	4.4	1.57	Sandy

Table 2: Chemical analysis of sandy soil

Sample Depth, cm	pH: 1.25	EC,dS/m	Soluble Cations, meq/l				Soluble Anions, meq/l		
			Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	HCO ₃ ⁻	SO ₄ ⁻	CL ⁻
0-30	8.2	1.27	2.9	2.8	5.1	0.6	3.6	2	6.1
30-60	8.3	1.22	2.9	2.1	5.2	0.6	3.7	2.1	6.3

Table 3: Chemical analysis of irrigation water.

pH	EC,dS/m	Soluble Cations, meq/l				Soluble Anions, meq/l			SAR
		Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	HCO ₃ ⁻	SO ₄ ⁻	CL ⁻	
7.74	1.02	1.03	0.74	8.01	0.42	1.95	4.52	3.73	8.51

irrigation water. 125/110 mm PVC pipeline was used as a mainline for delivering water from the water source to the sub-main lines which was 75 mm in diameter. Meanwhile, the manifold lines were 40 mm in diameter for the sprinkler irrigation system and it was 32mm in diameter for the drip irrigation system. Solid-set sprinkler irrigation systems: sprinklers were fixed at 12 x 12 m spacing (six sprinklers for each plot), they were 1.0 m³/h discharge at 2.5 bar operating pressure.

Surface drip irrigation: PE laterals of 16 mm diameter with 0.5 m spacing and 20 m length. Drippers built-in with discharge of 4 lph/50cm spacing at 1.0 bar operating pressure.

ii- Agricultural Practices: Irrigation water requirements had been applied according to the weather data of El-Bustan region, which had been collected from the Central Laboratory of Agricultural Climate (CLAC), ARC and had been calculated according to FAO [10]. All other agronomic practices for tomatoes had been applied according to the recommendations of the Veg. Res. Inst., ARC, for cultivating under El-Bustan region. Tomato seedlings (Castle rock) were transplanted on 3rd of May, 2005 and 10th May, 2006. However, other tomato nutrient requirements had been applied as following:

- Soil-bed preparation by ploughing of the soil two times using chisel plow with added 10m³ of fertilizer manure.
- Add 250kg/fed of super phosphate, 15.5% P₂O₅ during soil-bed preparation.
- Soil planning (furrow every 0.75 meter).

iii- Experimental Treatments:

A- Irrigation Systems:

- Solid-set sprinkler irrigation system.
- Surface drip irrigation system.

B- Fertigation Scheduling Treatments:

- Traditional method of fertilization (broadcasting) using the recommended rate (100% of the total required amount of Nitrogen elements).
- Fertigation scheduling: three rates of 100, 75 and 50 percent of the total required amount of Nitrogen element.

However, the applied N was in form of ammonium nitrate, 33%. These fertilizer amounts were divided into 10 doses and applied either broadcasting (traditional method, which considered as control) or injecting via irrigation water (fertigation) during the growing season.

iv- Measurements and calculations

At harvest, total tomato yield in Mgram (ton) per hectare was estimated for each treatment.

a- Vegetation growth and yield indices

- * Plant height, cm.
- * No. of branches/plant
- * No. of fruits/ plant
- * Total yield, Mgram/ha.

b- Determine the residual effect of the applied fertilizers in the tomato fruits

c- Estimate either Field-water or fertilizer use efficiencies

$$FWUE (Mgram / m^3) = \frac{\text{Total economical yield (Mgram / ha)}}{\text{Total amount of irrigation water (m}^3 \text{ / ha)}}$$

$$FUE (Mgram / Mgram - N) = \frac{\text{Total economic yield (Mgram / ha)}}{\text{Total amount of Nitrogen element (Mgram - N / ha)}}$$

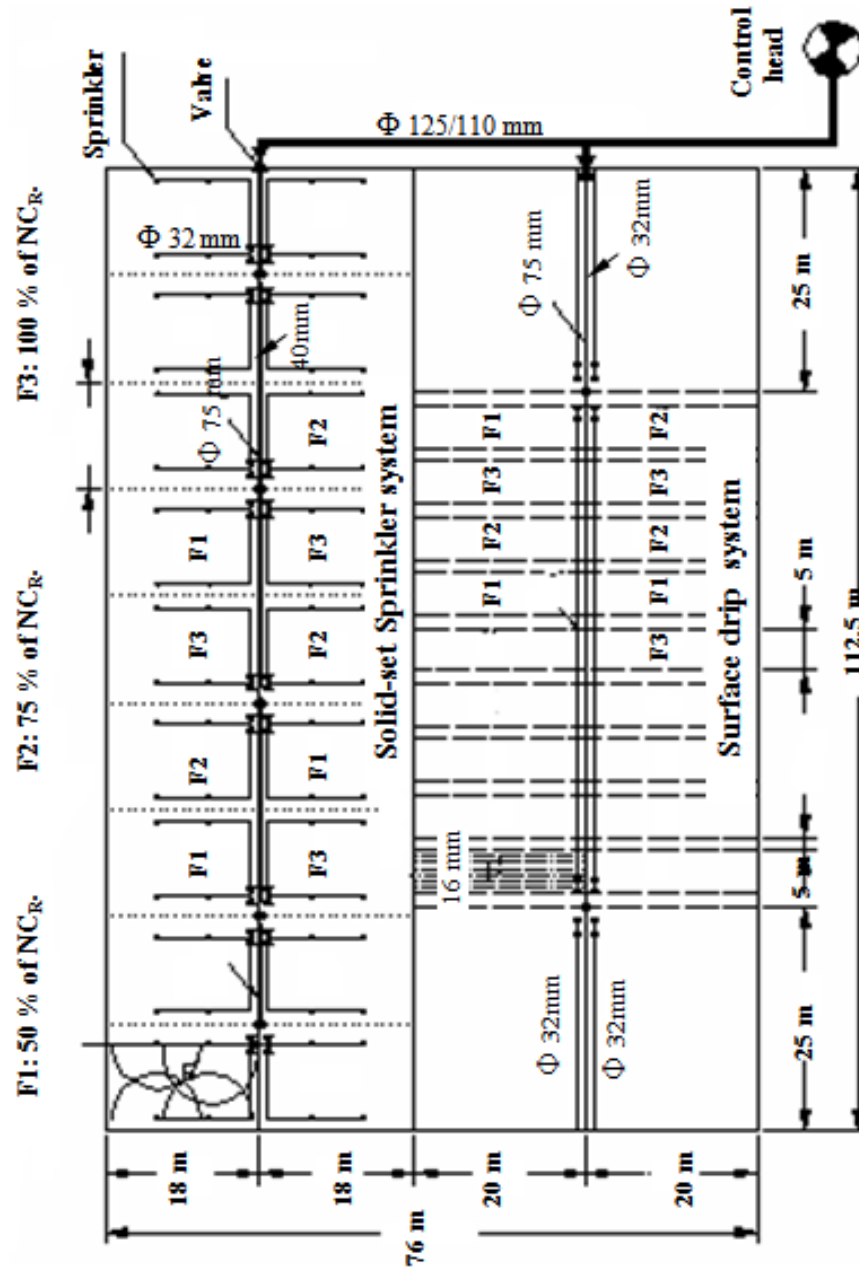


Fig. 1: Layout of the investigated irrigation systems.

d- Costs Analysis:

1 - Irrigation Costs: Capital cost for different irrigation systems and chemical application were calculated using current dealer prices (2008) for equipment and installation according to Worth and Xin, [11].

2- Fertilization Costs: Fertilization of tomato crop carried out by fertigation system through irrigation water or traditional method of fertilization (broadcasting). Fertilization cost was calculated as follows:

$$F_r = (W_f \times P_f) + A_c$$

Where: F_r is the fertilization cost, LE/fed.; W_f is the applied amount of fertilizers, kg/Fed.; P_f is the fertilizer unit price, LE/kg and A_c is the application cost of fertilizers, LE/Fed.

3- Total Costs and Production Cost Unit: Total and production unit costs of tomato crop include irrigation and fertilization costs were calculated according to the current prices 2008.

RESULTS AND DISCUSSION

1- the Response of Irrigation Water and Fertilizer Use Efficiencies to Fertigation Scheduling:

I- the Effect of Pressurized Irrigation Systems: Data illustrated in Table (4) and Fig. (2) indicated that there was small value effect of irrigation method (sprinkler and drip) on the investigated vegetative growth indices: plant height, number of branches/plant and number of fruits /plant. Meanwhile, data indicated that surface drip irrigation system had enhanced the economical tomato yield with about 25.6% compared to solid-set sprinkler irrigation system. This may be due to shorter irrigation intervals in case of drip irrigation which keep higher moisture content of the top soil layer compared by sprinkler irrigation.

With regard to either FWUE or FUE, data illustrated in Figs. (3 and 4) indicated surface drip irrigation system obtained higher values of both indices with about 49.3 and 25.6 percent over solid-set sprinkler one for both WUE and FUE respectively. This may be due to the higher moisture distribution uniform values under in the effective roots zone of tomato plants under drip irrigation, moreover, high frequency application of nutrients under drip irrigation allows splitting of the fertilizers amount, so that the elements availability are fitted to nutritional needs of the crop.

II the Effect of Fertigation Scheduling: Data analysis revealed that there is a positive proportional trend between the fertigation scheduling (fertigation rate) and the observed values of the vegetative growth indices and the maximization indices of irrigation water and fertilizer use efficiencies with corresponded pressurized irrigation systems under drought ecosystems of sandy soils. However, the total economic tomato yields increased from 6.33 to 14.85 and 19.85 Mgram/ha, with increasing fertigation rate from 50 to 75 and 100 percent of the total amounts of the required N of tomato crop, under surface drip irrigation. Meanwhile, the total economic yields were 5.02, 11.23 and 15.8 Mgram/ha, under solid-set sprinkler irrigation system by increasing fertigation rate from 50, 75 and 100 kg-N. Same trend had been observed for either water or fertilizer use efficiencies with respect to the investigated scheduling treatments. These findings may be due to the drip fertigated application gave the chance for mineral nutrients to move into the wetted volume in a manner consistent with the flux of the water in the soil, while applying the fertilizers using conventional method causes non-uniformity distribution of fertilizer through the soil profile and consequently, decreasing fertilizer utilization efficiency and crops productivity.

III- the Effect of Applied Interaction Effect of Irrigation System and Fertigation Scheduling under Sandy Soil Conditions:

Data analysis speculated that economical tomato yields had been increased by 14.24 – 10.11% under drip and sprinkler fertigated respectively, compared with traditional fertilization system (broadcasting). The findings out may be due to the drip fertigated as attractive concept, as it permits application of nutrients directly at the site of a high concentration of active roots and as needed by the crop. However, following application through drip irrigation, mineral nutrients move into the wetted volume in a manner consistent with the flux of the water in the soil, while applying the fertilizers using conventional method causes non-uniformity distribution of fertilizer through the soil profile and consequently, decreasing fertilizer utilization efficiency and crops productivity.

Regarding the maximization indices of either WUE or FUE, data revealed that the average tomato crop-water use efficiency values with using fertigation technique had been enhanced with about 18.18 and 24.39 % under surface drip and solid-set sprinkler irrigation systems compared with traditional fertilization method. This may be due to the high uniformity of fertilizer distribution and fertilizer elements already in

Table 4: Tomato yield and vegetation growth as response to the investigated fertilization methods and pressurized irrigation systems

Irrigation system	Fertilization technique	Fertilization percentage (NC _R), %	Vegetation growth indices			Total economical yield, Mgram/ha
			A*	B*	C*	
Surface drip	Fertigation	100 %	68.5	11.5	14.6	20.02
		75 %	56	8.5	10.7	15
		50 %	49.5	6.3	6.8	6.36
Solid-set sprinkler	Fertigation	100 %	60.5	9.6	12.6	15.94
		75 %	51.5	7.3	9	11.33
		50 %	44	5.7	4.9	5.06
	Broadcasting	100 %	59	9.8	12.5	14.47

* A is the plant height in cm; B is the number of branches per plant and C is the number of fruits per plant

** NC_R is the required amount of Nitrogen of tomato plants under studied area conditions, according to the recommendations of Veg. Res. Inst., ARC (referred to be 238 kg-N per hectare)

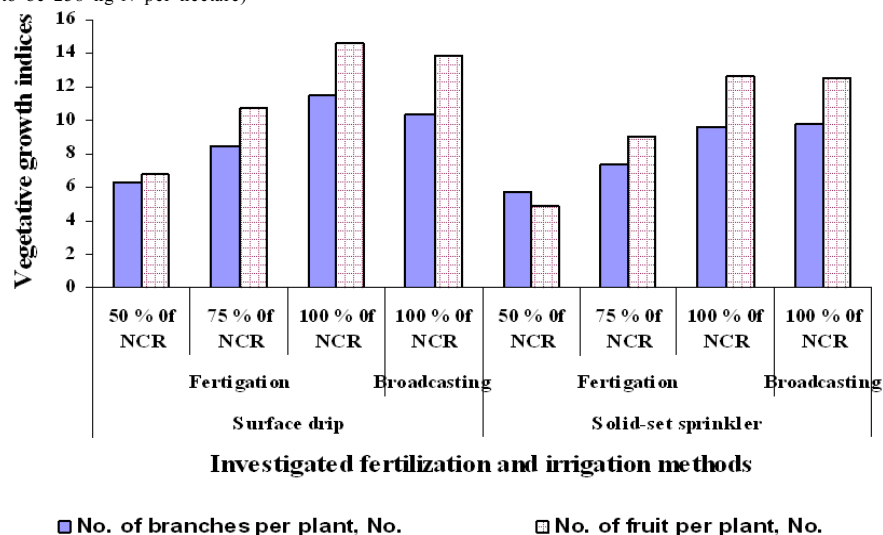


Fig. 2: The response of tomato vegetative growth to fertilization and pressurized irrigation methods

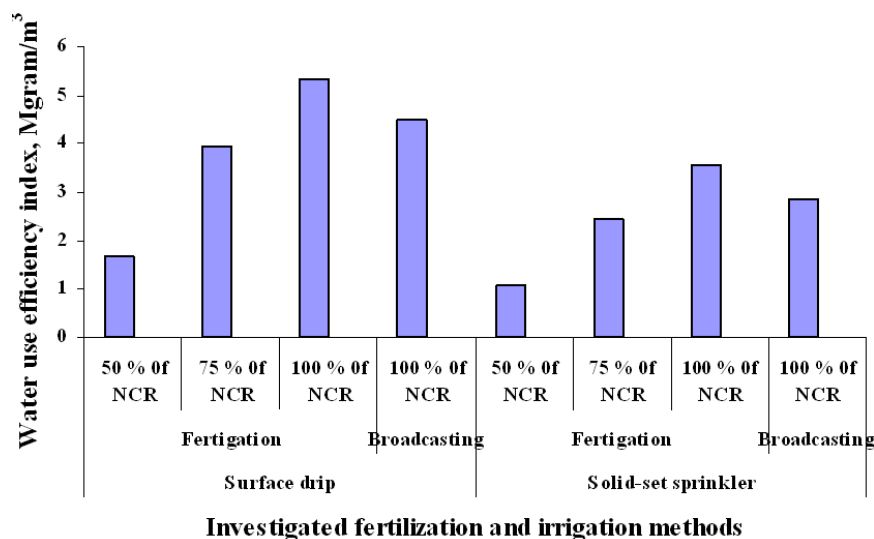


Fig. 3: Effect of fertilization method on water use efficiency under drip and sprinkler irrigation systems

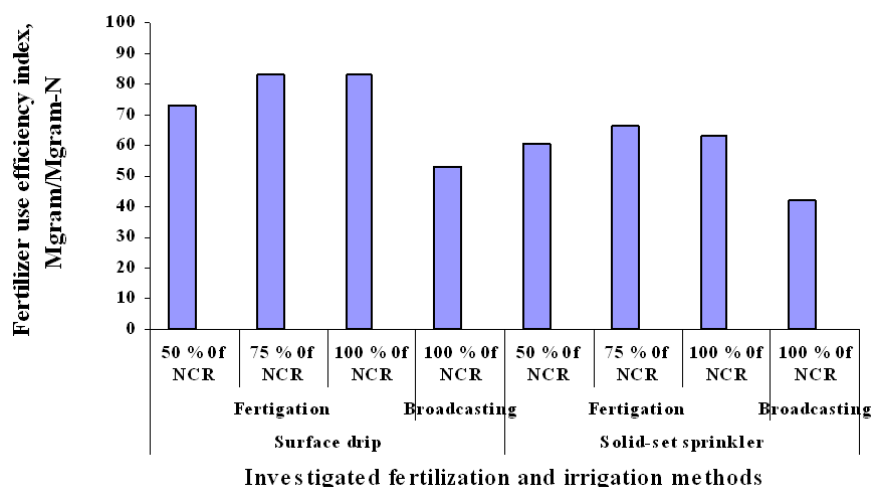


Fig. 4: Effect of fertilization method on Nitrogen fertilizer use efficiency under drip and sprinkler irrigation systems

solution become available to the plant root faster than when placed dry in the soil. Same trend had been obtained for tomato plants-fertilizer use efficiency; however, the increment percent was 14.25% under surface drip and 10.12% under solid-set sprinkler irrigation system compared with the traditional fertilization. This may be due to the high uniformity of fertilizer distribution and fertilizer elements already in solution become available to the plant root faster than when placed dry in the soil.

2- Residues Npk Concentration in Tomato Fruits:

Data tabulated in Table (5) speculated that the residues NPK concentration in tomato fruits had increased by increasing fertigation rate from 50 to 100 % of the total requirements under both surface drip and solid-set sprinkler irrigation systems, but the increase in NPK under surface drip was higher than that under solid-set

sprinkler irrigation. On the other hand, data indicated that the residues nutrients concentration in tomato fruits was higher by using fertigation method than that when using traditional method of fertilization (broadcasting) by 12.4, 1.49 and 26.8 % for N, P and K respectively under surface drip irrigation system, while the increase was 16.7, 4.7 and 20.2 % under solid-set sprinkler irrigation system.

3- Costs Analysis: Data in Table (6) indicate that the lowest cost of tomato production unit was 92.2 LE/Mgram under surface drip irrigation system at fertigation rate of 100 kg-N per unit area, while the highest cost of tomato production unit was 286.1LE/Mgram under sprinkler irrigation system at fertigation rate of 50kg-N per unit area. On the other hand, the cost of tomato production unit under fertigation was lower than that when using traditional

Table 5: Effect of fertigation scheduling on residues NPK concentration in tomato fruits

Irrigation system	Fertilization technique	Fertigation percentage, %	Residues nutrients concentration in tomato fruits, %				
			N	P	K		
Surface drip	Fertigation	50 % of NC _R	1.65	0.58	1.23		
		75 % of NC _R	2.53	0.63	1.95		
		100 % of NC _R	2.66	0.67	2.31		
	Broadcasting	100 % of NC _R	2.33	0.66	1.69		
		Solid-set sprinkler	Fertigation	50 % of NC _R	1.68	0.58	1.37
				75 % of NC _R	2.43	0.6	1.6
100 % of NC _R	2.51			0.63	1.78		
	Broadcasting	100 % of NC _R	2.09	0.60	1.42		

Table 6: Tomato production unit costs under different fertilization methods and pressurized irrigation systems

Irrigation system	Fertilization technique	Fertigation percentage, %	Total cost, LE/ha	Production cost unit, LE/ton
Surface drip	Fertigation	50 % of NC_R	633.6	238.2
		75 % of NC_R	701.1	112.3
		100 % of NC_R	768.6	92.2
	Broadcasting	100 % of NC_R	798.6	109.4
Solid-set sprinkler	Fertigation	50 % of NC_R	603.6	286.1
		75 % of NC_R	671.1	142.2
		100 % of NC_R	738.6	111.2
	Broadcasting	100 % of NC_R	768.6	127.5

fertilization method (broadcasting) by 15.72% and 12.78% under surface drip and solid-set sprinkler irrigation systems at higher rate of fertigation scheduling respectively.

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