

IMPACT OF WATER STRESS DURING DIFFERENT GROWTH STAGES ON TOMATO YIELD UNDER VARIOUS IRRIGATION SYSTEMS

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ABSTRACT

Field experiment was carried out at Maryout Experimental Station Farm, Desert Research Center during summer season 2007. The field experiment aimed to study the impact of water stress levels of 100, 75 and 50 % from crop evapotranspiration, E_{Tc} during development, flowering and harvesting stages on some plant growth parameters and yield of tomatoes (*Lycopersicon esculentum*, mill., cultivator 888) in calcareous sandy clay loam soil. Drip and gated-pipe irrigation systems were used in this investigation. Generally, the obtained results revealed that the plant height values at harvesting growth stage under drip irrigation system were not significantly lower than those obtained under gated pipe irrigation system. The plant height values subjected to irrigation water stress levels 100, 75 and 50 % E_{Tc} during different growth stages were significantly decreased with increasing irrigation water stress levels under the studied irrigation systems. Tomatoes leaf water potential values, -kPa, at harvesting growth stage were significantly increased with increasing irrigation water stress levels subjected during different growth stages under studied irrigation systems. The fruit yield of tomatoes as affected by irrigation water stress levels subjected during different growth stages under drip irrigation system were significantly higher than that obtained under gated pipe irrigation system. Also, fruit yields of tomatoes were significantly decreased with increasing irrigation water stress levels under studied irrigation systems, especially at water stress level of 50 % E_{Tc}. For the fruit yield, the results showed that the flowering growth stage of tomatoes subjected to irrigation water stress levels is more sensitive than other growth stages under studied irrigation systems. Consequently, tomato plants subjected to water stress levels during flowering growth stage achieved the lowest net revenues and invested pound return.

Keywords: water stress, drip irrigation, gated pipe, growth stages, leaf water potential and tomato yield

INTRODUCTION

In arid and semi arid regions, the impact of water stress on plant growth parameters and yield is depending on the quality and amount of irrigation water, crop, plant growth stage, soil type, climate and irrigation system as well as the time of exposure to water stress. Doorenbos and Kassam (1979) reported that the water stress effects on growth and yield are depending on plant species and variety. Moreover, sensitivity to drought varies by the development stage. While, El-Neomani *et al.*, (1990) stated that, for corn, water stress during the rapid vegetative stage restricted plant

growth. On the other hand, Cakir (2004) concluded that sensitive tasselling stage is strongly affected by water stress than other different growth stages.

Yuan *et al.*, (2003) reported that potato is a relatively sensitive plant to water stress and that soil water is one of most important factors affecting the yield and the quality. They tested the effect of different amounts of irrigation water applied to potato crop: 0.25, 0.50, 0.75, 1.0 and 1.25 of water surface pan evaporation, and found that plant height increased with increasing the amount of applied irrigation water. On the other hand, Al-Mohammadi and Al-Zu'bi (2011) conducted an experiment under greenhouse conditions to evaluate the optimum combinations of irrigation and fertilizer levels to attain the best yield and quality of tomato crop, and concluded that the irrigation and fertilizer levels had significant effects on the number of flowers per plant; however, plant height was not affected significantly by any treatment. On the contrary, Incalcaterra, *et al.*, (2003) studied the influence of the volume of irrigation water on winter melon (*Cucumis melo inodorus* Naud) grown under plastic tunnel using three volumes of irrigation water (20, 30, 40 liter / plant). Water was provided by a single application after 50 days from transplanting. The vegetative growth parameters at 60 and 70 days after transplanting were slightly influenced by the treatments tested. After 80 days of transplanting, plant height was positively affected by increasing the amount of irrigation water, but significantly reduced as salinity increased. Katerji *et al.* (1998) studied the effect of tomato growth under both water and salt stresses and they reported that the behavior of the tomato plant under saline conditions appears to be similar to that under drought conditions.

Fisher and Nel (1990) studied the effect of water stress on tomato growth and yield components; they reported a lack of response of tomato leaf growth to water stress, whereas yield and fruit size decreased with the increase of stress. Mathieu *et al.*, (2007) in an experiment conducted in summer of 2003 and 2004 to study the effect of withholding the irrigation on yield of a drip irrigated plants under plastic culture system. Irrigation treatments initiated at tomato planting (S_0), after transplant establishment (S_1), at first flower (S_2), at first fruit (S_3), and at fruit ripening (S_4). In addition treatment received only enough water to apply fertigation with holding drip irrigation for a short period (S_2 – S_3) increased tomato marketable yield by 8–15%, fruit number by 12–14% and reduced amount of irrigation water by 20% compared to the S_0 treatment.

Phene *et al.*, (1987) studied the effect of irrigation frequency and fertigation process under drip irrigation system and demonstrated significant yield increases in tomatoes with the use of high frequency and precise fertility management.

Abdel Gawad *et al.*, (2005) mentioned that irrigating tomato using drip irrigation system produces higher yield than the traditional surface irrigation method.

The objectives of the present study are to investigate the impact of irrigation water stress subjected during different growth stages on some growth parameters and total yield of tomatoes using drip and gated-pipe irrigation systems.

MATERIALS AND METHODS

Field experiment was carried out at Maryout Experimental Station Farm, Desert Research Center during summer season 2007. The station located at 30° 55' 71" N, 29° 51' 67" E and 50 m above sea level. Particle size distribution was determined by pipette method according to Kulte (1986), total carbonate was determined as CaCO₃ % by using Collin's Calcimeter described by Jackson (1967) while the bulk density was determined by core method accordingly, Kulte (1986), the soil was classified as calcareous sandy clay loam (59 % sand, 13 % silt and 28 % clay) with 29.50 % total calcium carbonate and 1370 Mg/m³ bulk density. Soil salinity (ECe) as total soluble salts were determined in the soil saturation extract, Richards (1954). Soil reaction (pH) was measured in soil paste using pH meter according to Page (1982), the electric conductivity of saturated soil paste extract (ECe) was 2.13 dS m⁻¹ and soil reaction, pH, value was 8.2 as well as sodium adsorption ratio (SAR) value was 2.35, the soil is non saline and non alkali. Crop water requirement is calculated using CROPWAT 8.0, for windows, computer program using Penman-Monteith equation using the metrological data of Maryout Experimental Station, Table (1). The duration of stages and the crop factor of tomatoes were used 35, 45 and 30 days and 0.60, 1.15 and 0.80 at development, flowering and harvesting growth stages respectively, according to Allen, *et al.* (1998).

Table(1):Metrological data of Maryout Research Station, Desert Research Center.

Month	Maximum Temperature, °C	Minimum Temperature, °C	Humidity %	Wind speed, km/d	Sunshine H	*ET _o , mm/day
January	17.5	7.5	70.0	343.0	6.6	2.46
February	17.5	7.5	70.0	343.0	7.6	2.70
March	22.5	12.5	60.0	354.2	8.3	4.30
April	25.0	12.5	60.0	334.4	9.2	5.10
May	27.0	15.0	60.0	311.0	10.4	5.73
June	30.0	20.0	60.0	311.0	11.9	6.68
July	30.0	22.5	60.0	338.7	12.0	6.86
August	37.0	25.0	60.0	337.0	11.3	7.73
September	33.0	24.0	60.0	334.4	10.7	6.63
October	28.5	20.0	60.0	337.8	9.2	5.09
November	25.0	19.0	62.0	338.7	7.4	3.92
December	21.0	14.0	70.0	342.1	6.5	2.79

*ET_o, potential Evapotranspiration was calculated according to CROPWAT 8.0, for windows, computer program using Penman-Monteith equation.

Tomato seeds (*Lycopersicon esculentum*, mill., cultivar 888) were planted in seedling plats, filled with mixture of peatmos and vermiculite. Anti-fungi were used to prevent fungus growth in the planting media. The plates were irrigated with fresh water (0.4 dS/m) to have a good establishment. Nutrients solutions were used to encourage seeds growth. Seeds were planted in the plates on 1st April, the seedlings transported to the field

calcareous sandy clay loam soil after 30 days. Different treatments were applied after 5 days from the transporting date. Soil was (before planting) ploughed and mixed with mono calcium phosphate at a rate of 480 kg/ha was also applied. The agronomic practices including weed and pest control followed as recommended for tomato production. Nitrogen fertilizers were applied at a rate of 280 kg N/ha, and K fertilizers at a rate of 175 kg K/ha. Mixer of FeSO₄, MnSO₄, ZnSO₄, and CuSO₄ was applied as foliar spray. Foliar spray of some weeds control and antifungal applied for diseases control. The harvest date was on 23th August.

Drip and gated pipe irrigation systems were used in this investigation. For the irrigation systems, the main irrigation line was 63 mm, and the sub main lines were 16 mm in diameter; the length of sub main lines was 9 m. The space between plants was 0.5 m with distance between rows of 1 m. Water meters installed to measure the amount of applied water for each treatment. For each irrigation system, 3 irrigation water stress levels of 100 (no water stress), 75, and 50% from crop evapotranspiration (ET_c) and 3 growth stages subjected to irrigation water stress levels, during development (d), flowering (f) and harvesting (h). The experiment was irrigated by water having 2.81dSm⁻¹ and 12.15 SAR. The experimental design was completely randomized with three replications. Each irrigation system consisted of 7 treatments with applied irrigation water levels subjected during the different growth stages as follows.

T₁100 (control): the plants were irrigated by the irrigation water depth of 100 % ET_c during the season (no water stress).

T₂ 75 - D: the plants were irrigated by the irrigation water depth of 75 % ET_c subjected during the development growth stage and irrigated by the irrigation water depth of 100 % ET_c during the other growth stages.

T₃ 75 - F: the plants were irrigated by the irrigation water depth of 75 % ET_c subjected during the flowering growth stage and irrigated by the irrigation water depth of 100 % ET_c during the other growth stages.

T₄ 75 - H: the plants were irrigated by the irrigation water depth of 75 % ET_c subjected during the harvesting growth stage and irrigated by the irrigation water depth of 100 % ET_c during the other growth stages.

T₅ 50 - D: the plants were irrigated by the irrigation water depth of 50 % ET_c subjected during the development growth stage and irrigated by the irrigation water depth of 100 % ET_c during the other growth stages.

T₆ 50 - F: the plants were irrigated by the irrigation water depth of 50 % ET_c subjected during the flowering growth stage and irrigated by the irrigation water depth of 100 % ET_c during the other growth stages.

T₇ 50 - H: the plants were irrigated by the irrigation water depth of 50 % ET_c subjected during the harvesting growth stage and irrigated by the irrigation water depth of 100 % ET_c during the other growth stages.

Crop water requirement was calculated using CROPWAT 8.0, for windows, computer program using Penman-Monteith equation using the metrological data of Maryout Experimental Station, Table (1). The length of stages and the crop factor of tomatoes were used 35, 45 and 30 days and 0.60, 1.15 and 0.80 at development, flowering and harvesting growth stages, respectively, according to Allen, *et al.* (1998). The irrigation system

efficiencies are 85 and 65 % for drip and gated pipe irrigation systems, respectively, and the leaching requirements were calculated according to Doorenbos and Pruitt (1984). Data in Table (2) show the depth of irrigation water and the time of water stress levels 100, 75 and 50% from crop evapotranspiration (ET_c) subjected during development (d), flowering (f) and harvesting (h) growth stages.

Table (2):Crop water requirement, ET_c, of tomato plants affected by irrigation water stress levels from % ET_c subjected during development, flowering and harvesting growth stages under studied irrigation systems.

Irrigation water stress levels (% ET _c)	Treatment stage*	ET _c , mm/growth stage		
		Growth stage		
		d	f	h
100	D	125.46	350.66	180.65
	F	125.46	350.66	180.65
	H	125.46	350.66	180.65
75	D	94.10	350.66	180.65
	F	125.46	263.00	180.65
	H	125.46	350.66	135.49
50	D	62.73	350.66	180.65
	F	125.46	175.33	180.65
	H	125.46	350.66	90.33

* The plants subjected to irrigation water stress levels, % ET_c during different growth stages.

Plant height, cm, was measured at harvesting growth stage. Leaf water potential (- kPa) was determined with a portable pressure chamber apparatus (Soil Moisture Equipment Corp, Santa Barbara, CA, USA) for predawn using the fourth leaf in the plant at harvesting growth stage. Total yield, kg/ plant, was determined at harvesting growth stage.

Analysis of variance by 3 Way Completely Randomized was used to test the degree of variability among the obtained data. Least significant difference (LSD) test was used for the comparison among treatments means, Steel and Torrie (1980). Cohort computer program was used for the statistical analysis, version 6.400.

RESULTS AND DISCUSSION

Plant height

Generally, results obtained revealed that plant height values, cm, at harvesting stage under drip irrigation system were not significant and lower than that obtained under gated pipe irrigation system, Table (3) and Fig.(1). Also, the data show that plant height values at the end of harvesting growth stage subjected to irrigation water stress levels 100, 75 and 50 % ETc during development, flowering and harvesting stages were significantly decreased with increasing irrigation water stress levels under studied irrigation systems. This decrease might be attributed to increasing salt accumulation in soil of active root zone with increasing applied irrigation water stress levels. [These results are in agreement with those obtained by Yuan *et al.*, (2003) and Incalcaterra, *et al.*, (2003). Under drip irrigation system, decrease percentage of plant height values relative to control treatment were 18.4, 13.8 & 9.6 % and 33.1, 18.4 & 14.3 % for the plants subjected to irrigation water stress levels 75 and 50 % ETc during the development, flowering and harvesting stages, respectively. Under gated pipe irrigation system, decrease percentage of plant height values relative to control treatment were 11.0, 14.3 & 11.0 % and 33.1, 18.2 & 17.2 % for the plants subjected to irrigation water stress levels 75 and 50 % ETc during the development, flowering and harvesting stages, respectively. Results obtained revealed that the development growth stage of tomatoes subjected to irrigation water stress levels is more affected than other growth stages under studied irrigation systems.

Table(3): Plant growth parameters at harvesting stage and total yield as affected by irrigation water stress levels % ETc subjected during different growth stages under studied irrigation systems.

Irrigation water stress levels, % ETc	Plant height, Cm			Leaf water potential, - kPa			Total yield, kg/plant		
	Treatment stage			Treatment stage			Treatment stage		
	D	F	H	D	F	H	D	F	H
Drip irrigation system									
100%	64.56	64.56	64.56	8.27	8.27	8.27	4.75	4.75	4.75
75%	52.67	55.67	58.33	12.67	14.00	15.17	4.30	3.92	4.24
50%	43.17	52.67	55.33	16.83	17.67	19.03	4.02	3.68	4.09
Average	52.28	57.34	60.89	12.17	13.22	14.68	4.36	4.12	4.36
	56.84			13.36			4.28		
Gated pipe irrigation system									
100%	64.78	64.78	64.78	7.53	7.53	7.53	4.23	4.23	4.23
75%	57.67	55.53	57.67	13.17	13.67	16.67	4.06	3.86	4.04
50%	43.33	53.00	53.67	16.77	16.67	20.17	3.67	3.48	3.71
Average	54.11	57.62	60.00	12.09	12.56	15.28	3.99	3.86	3.99
	57.24			13.31			3.95		
LSD ₀₅ Irrigation system, n = 27	1.31			0.39			0.15*		
LSD ₀₅ Water stress, n = 18	1.60*			0.47*			0.19*		
LSD ₀₅ Treatment stage, n = 18	1.60*			0.47*			0.19		

F1

Leaf water potential

The results demonstrated that tomato leaf water potential values at harvesting stage as affected by irrigation water stress levels 100, 75 and 50 % ETc subjected during development, flowering and harvesting stages under drip irrigation system, were significantly higher than that obtained under gated pipe irrigation system, Table (3) and Fig.(2). This higher values might be attributed to increment of salt accumulation in soil of active root depth under drip irrigation system, consequently, increased tomatoes leaf water potential. The results revealed that tomato leaf water potential values at the end of harvesting stage were significantly increased with increasing irrigation water stress levels 100, 75 and 50 % ETc, subjected during different growth stages under studied irrigation systems. This increase in tomato leaf water potential values might be attributed to increasing soil salinity resulted in deficit of irrigation water. Under drip irrigation system, the leaf water potential values relative to control treatment were increased by 1.53, 1.69, 1.83 times and 2.04, 2.14, 2.30 times for the plants subjected to water stress levels 75 and 50 % ETc during the development, flowering and harvesting stages, respectively. Under gated pipe irrigation system, the leaf water potential values relative to control treatment were increased by 1.75, 1.82 & 2.21 times and 2.23, 2.21& 2.68 times for the plants subjected to water stress levels 75 and 50 % ETc during the development, flowering and harvesting stages, respectively. Consequently, the harvesting stage of tomatoes subjected to irrigation water stress is more affected than other growth stages under studied irrigation system.

Total yield

The fruit yield of tomatoes, kg/plant, subjected to irrigation water stress levels 100, 75 and 50 % ETc during development, flowering and harvesting stages under drip irrigation system were significantly higher than that obtained under gated pipe irrigation system, Table (3) and Fig.(3). Data also revealed that fruit yield of tomatoes were significantly decreased with increasing irrigation water stress levels subjected during different growth stages under studied irrigation systems, especially using irrigation water stress level 50 % ETc. This reduction in fruit yield was mainly attributed to the deficit of irrigation water depth and due to the harmful effect in soil salinity in active root zone. In this respect, many investigators found that increasing irrigation water stress decreased the yield of tomatoes, Fisher and Nel (1990) and Mathieu *et al.*, (2007). Under drip irrigation system, fruit yield reduction percentages relative to control treatment were 9.5, 17.5 & 10.7 and 15.4, 22.5 & 13.9 % for the plants subjected to irrigation water stress levels 75 and 50 % ETc during the development, flowering and harvesting stages, respectively. Under gated pipe irrigation system, fruit yield reduction percentages relative to control treatment were 4.0, 8.7 & 4.5 % and 13.2, 17.7 & 12.3 % for the plants subjected to irrigation water stress levels 75 and 50 % ETc during the development, flowering and harvesting stages, respectively. Consequently, the flowering growth stage of tomatoes subjected to irrigation water stress is more sensitive than other growth stages under studied irrigation systems. These results are confirmed with Al-Mohammadi and Al-Zu'bi (2011).

F2

F3

Economical evaluation

Under studied irrigation systems, the net revenues and invested pound return for tomato yield plant groups D, F and H were decreased with increasing applied irrigation water stress levels 100, 75, 50 % ETc, Table (4). The net revenues and invested pound return for tomatoes under drip irrigation system were higher than gated pipe irrigation system. Also, the tomato yield plants applied deficit irrigation water during flowering stage (group F) achieved the lowest net revenues and invested pound return at applied irrigation water stress levels % ETc.

Table (4): Economical evaluation of tomatoes production, thousand Egyptian pounds per hectare, as affected by applied irrigation water stress levels % ETc under studied irrigation systems.

Irrigation water stress level % ETc	Treatment stage	Average cost, LE	Gross return*	Net revenues	Invested pound return
		Thousand Egyptian pounds			
Drip irrigation system					
100	D	15.71	94.96	79.25	5.05
	F	15.71	94.96	79.25	5.05
	H	15.71	94.96	79.25	5.05
75	D	15.71	85.97	70.26	4.47
	F	15.71	78.35	62.64	3.99
	H	15.71	84.78	69.07	4.40
50	D	15.71	81.97	66.26	4.22
	F	15.71	73.57	57.86	3.68
	H	15.71	81.78	66.07	4.21
Gated pipe irrigation system					
100	D	15.71	84.56	68.85	4.38
	F	15.71	84.56	68.85	4.38
	H	15.71	84.56	68.85	4.38
75	D	15.71	81.16	65.45	4.17
	F	15.71	76.97	61.26	3.90
	H	15.71	80.97	65.26	4.15
50	D	15.71	73.38	57.67	3.67
	F	15.71	69.57	53.86	3.43
	H	15.71	74.16	58.45	3.72

*The price of one kg tomatoes is one Egyptian pound at summer 2007.

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تأثير الإجهاد المائي خلال مراحل النمو المختلفة على محصول الطماطم تحت نظم ري مختلفه

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أجريت تجربة حقلية على محصول الطماطم في المزرعة البحثية لمحطة بحوث مريوط التابعة لمركز بحوث الصحراء – بمنطقة مريوط خلال الموسم الصيفي ٢٠٠٧م. ويهدف البحث إلى دراسة تأثير مستويات من الإجهاد المائي تمثل ١٠٠، ٧٥ و ٥٠ % من البخر – نتج (ETC) أضيفت خلال مراحل النمو المختلفة على بعض عناصر المحصول وكذلك المحصول الكلي. استخدم في البحث صنف طماطم (*Lycopersicon esculentum, mill., cultivator 888*) في تربة جيرية ذات قوام طمي طيني رملي. استخدم في هذا البحث كلا من نظامي الري بالتنقيط والري السطحي المعدل ذو الفتحات. أضيفت مياه الري التي تمثل مستويات الإجهاد المائي خلال مرحلة النمو؛ الإزهار والحصاد باستخدام مياه ري ملوحتها ٢.٨١ ديسيمتر/متر. أظهرت النتائج انخفاض غير معنوي لقيم ارتفاع النبات عند الحصاد تحت نظام الري بالتنقيط عن نظام الري السطحي المعدل ذو الفتحات. النتائج أوضحت انخفاض قيم ارتفاع النبات معنويًا عند الحصاد والتي تعرضت لمستويات الإجهاد المائي (١٠٠، ٧٥ و ٥٠ % من البخر نتج) عند مراحل النمو المختلفة. ازداد الجهد المائي لورقة نبات الطماطم عند الحصاد معنويًا مع زيادة الإجهاد المائي تحت كل من نظامي الري المستخدمين في الدراسة. كان محصول الطماطم (كجم/نبات) متأثرًا بمستويات الإجهاد المائي (١٠٠، ٧٥ و ٥٠ % من البخر نتج) تحت الري بالتنقيط أعلى من الري السطحي المعدل ذو الفتحات. أيضاً إنخفض محصول الطماطم للنبات معنويًا مع زيادة الإجهاد المائي تحت كل من نظامي الري المستخدمين في الدراسة وبصفة خاصة تحت معاملة ٥٠ % من البخر نتج. كذلك اتضح من الدراسة أن محصول الطماطم كان أكثر تأثراً بمستويات الإجهاد المائي عند تعرض مرحلة التزهير للإجهاد المائي تحت كل من نظامي الري المستخدمين في الدراسة .

قام بتحكيم البحث

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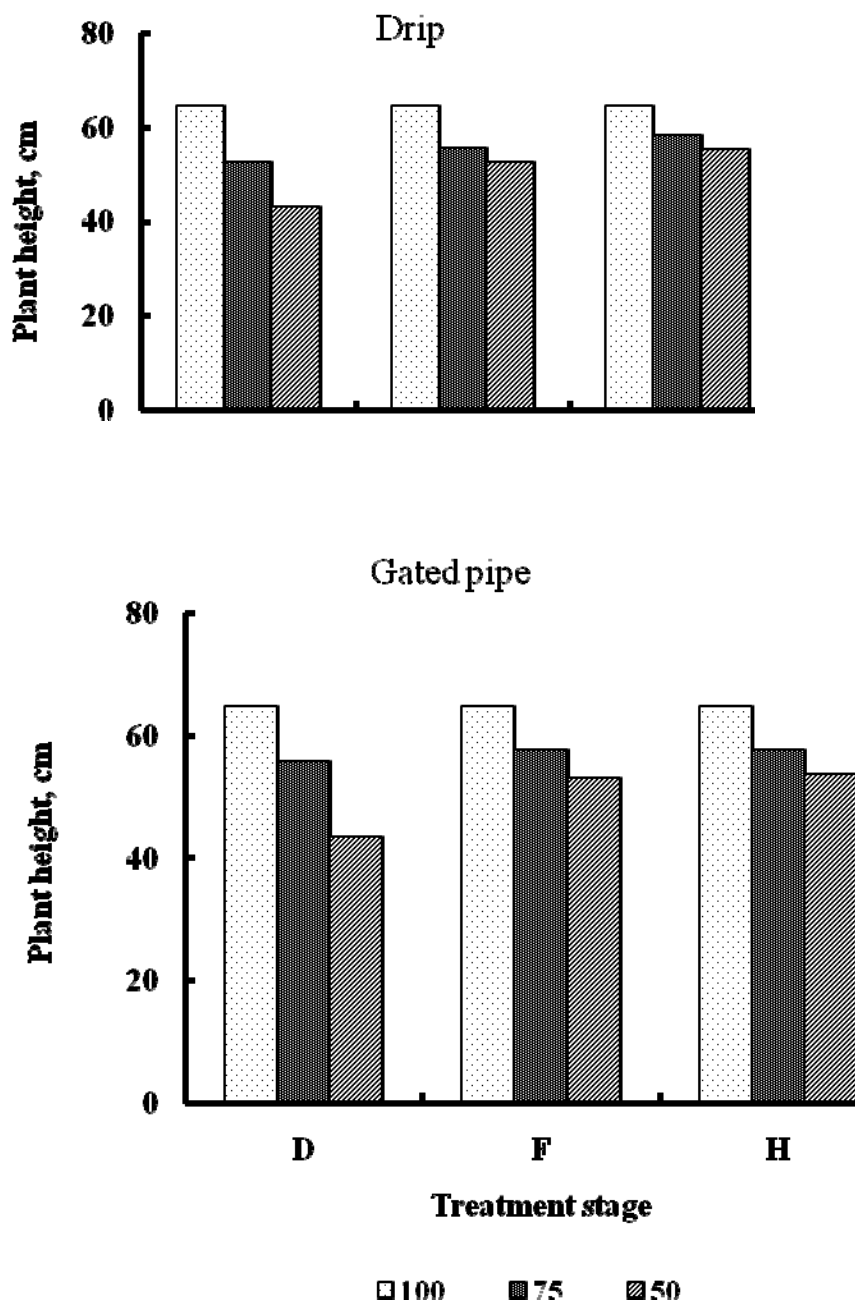
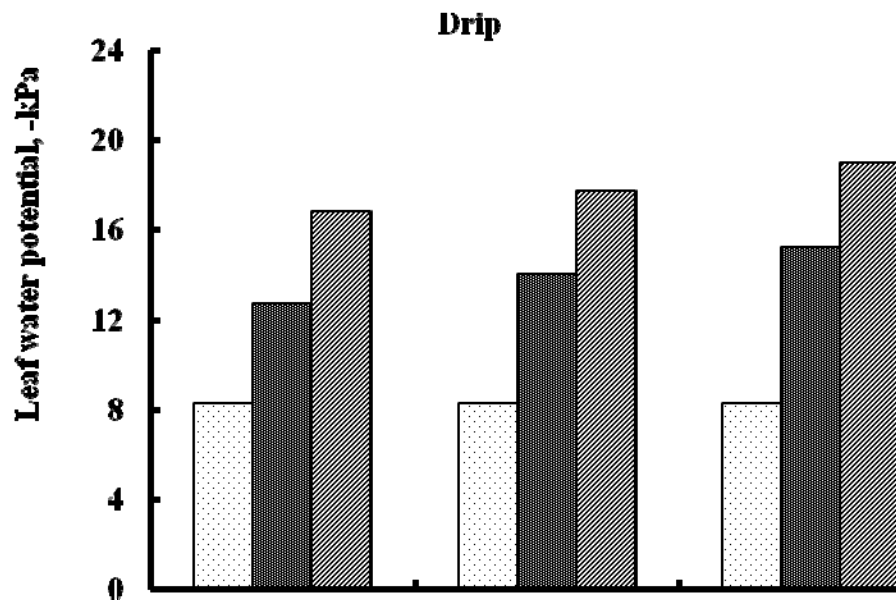


Fig. (1): Plant height at harvesting stage as affected by irrigation water stress levels, % ETC subjected during development, flowering and harvesting stages under studied irrigation systems.



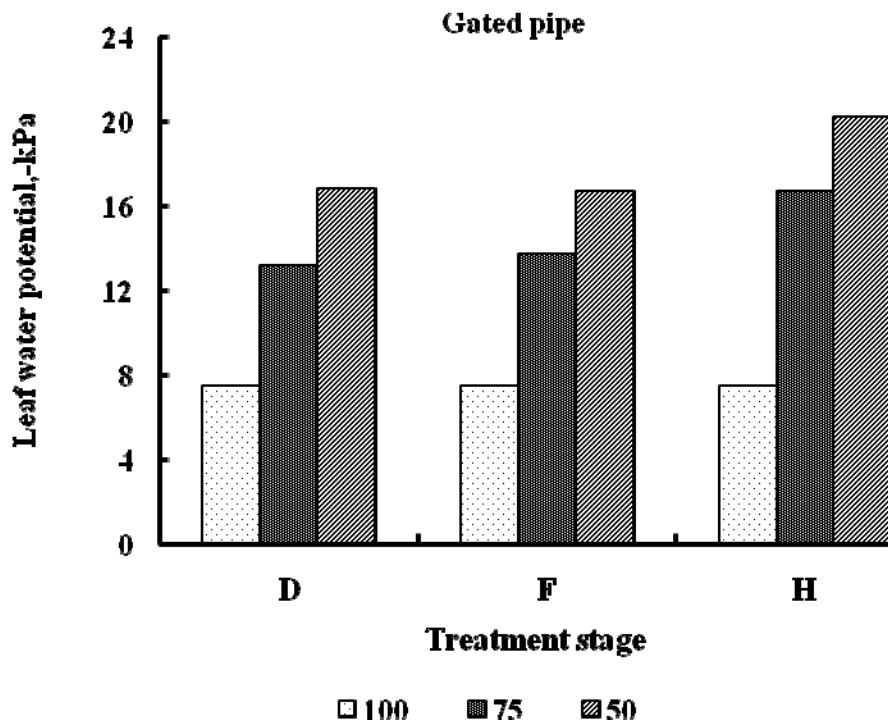
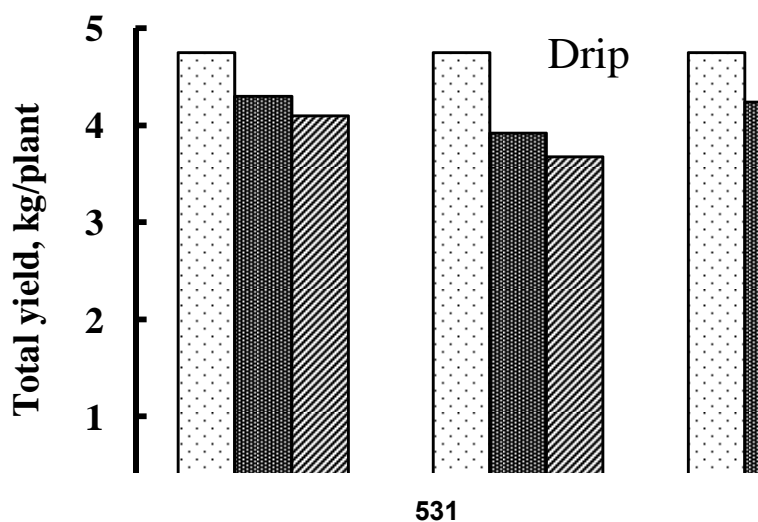


Fig. (2): Plant leaf water potential at harvesting stage as affected by irrigation water stress levels, % ETC subjected during development, flowering and harvesting stages under studied irrigation systems.



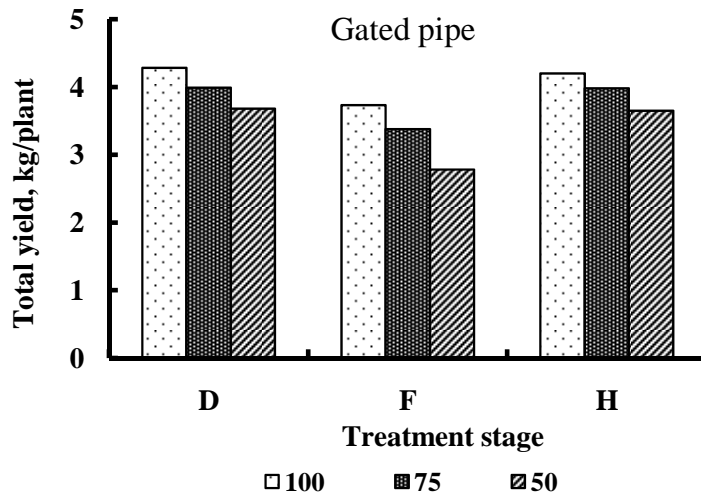


Fig. (3): Plant total yield at harvesting as affected by irrigation water stress levels, % ETC subjected during development, flowering and harvesting stages under studied irrigation systems.

