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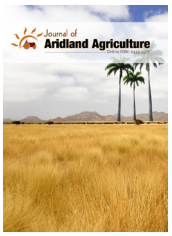
Research Article



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Effect of four irrigation doses and four varieties on agronomical characteristics and yield of cotton cultivation in central Greece

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ABSTRACT

In recent years, reduced irrigation has been applied for the cultivation of cotton. While this strategy remains desirable, it needs to be evaluated as it affects the yields and growth of cotton. During 2015 and 2016, two similar cotton experiments (*Gossypium hirsutum* L.) were performed in Greece, in the area of Karditsa and especially in the location of Palamas. An experiment was established designed according to split-plot design, with main plots four levels of irrigation (IRR. 2, IRR. 4, IRR. 6, IRR. 8) and subplots four varieties of cotton (Dp 419, Campo, Andromeda, Lider) for two growing periods. The results indicated that agronomical characteristics were affected by irrigation dose, while LAI (Leaf Area Index) was affected by irrigation levels and year. LAI higher values were noticed in RR8 level for all varieties. Second year values of LAI were higher than the first year. Irrigation levels affected the number of closed bolls. Closed bolls were ranged from 12 (RR2 with variety Dp 419) to 144.67 (RR8 in same variety). The yield was significantly affected by irrigation levels and variety; the highest value was observed in second year by the Lider variety (3,110 kg ha^{-1}). A strong positive correlation was mentioned between yield and total fresh weight ($r=0.72$, $p=0.001$). On a pooled basis, all varieties responded positively to the largest amount of irrigation (RR8).

KEYWORDS: Cotton, irrigation doses, number of bolls, yield, varieties

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INTRODUCTION

In cotton (*Gossypium hirsutum* L.) irrigation is an important factor during the cultivation and is necessary in all stages, from sowing to the splitting of the bolls. Irrigation season, frequency and quantity of water in each irrigation greatly affect the prematurity, height and quality of production and depend on many factors such as the mechanical composition of the soil, the variety, the early maturity of the plantation and the fertilization.

Water is a critical resource for summer crops in Greece, which usually has hot, dry summers and cool and wet winters that can vary from year to year. So, water conservation is becoming more and more important especially in recent years where the impact of climate change is becoming more intense and the periods of drought are longer. Groundwater is depleted in many areas by over-pumping [1].

The interest for the production with reduced irrigation in the cotton cultivation in Greece is increasing through years. To improve the overall management of irrigation water for the rational use of available water resources, various different irrigation technologies and strategies are discussed [20]. Increased irrigation costs due to declining water availability in the last decade, motivated growers to reduce irrigation water, but this reduction on the amount of water for irrigation, even today, raises doubts that will affect fiber yields and quality [4]. Producers with irrigation potential can irrigate to minimize part of the deficit trend [17]. DeLaune *et al.*[6] note that crops such as cotton (*Gossypium hirsutum* L.) or sorghum (*Sorghum bicolor* L.) can be included in a strategy to reduce irrigated water. Moreover, Karamanos *et al.* [10] emphasize that in Greece there is a need to consider different cultivation practices for soil conservation, since cotton as of great economic importance is cultivated in most cases as monoculture.

For the application of a deficient irrigation program it is necessary to check the yields of the crops before application either during certain stages of development or throughout the season [11]. Also important is the texture of the soil and how much water it can hold. Kirda [12] reports that fine-textured soils have the ability to retain more water. An agricultural practice that is proposed, in addition to reducing the amount of irrigation, in a range of crops, drip irrigation has been proposed as a means of irrigation [2].

Well, management practices that lead to efficient water use are imperative for the sustainability of irrigated cotton production. The objectives of this study were to evaluate the yield potential and accuracy of four commercial varieties in Greece with four levels of irrigation. Most studies focus on crop yields under reduced irrigation. It is certainly the central point of interest for the producer and in this study the performance is presented. But it is important to consider from the total yield weight what part the shoot, leaves and fruiting bodies occupy. Thus, in this study, the individual elements of the above ground part of the plant are investigated in detail. Also, for the evaluation of the growth of the plant, the development of the leaf surface is noted using the LAI index and the number of closed bolls.

MATERIAL AND METHODS

Location and Experimental Design

During 2015 and 2016, two similar cotton experiments (*Gossypium hirsutum* L.) were performed in Greece, in area of Karditsa and especially in the location of Palamas. (N 39 ° 33'-39 ° 03 ', E 21 ° 22'-22 ° 15'). The experiments were designed according to split-plot design, having 4 main plots and 16 subplots. Main plots had different irrigations (IRR. 2, IRR. 4, IRR. 6, IRR. 8) (Table 1) and the subplots different varieties of cotton (Dp 419, Campo, Andromeda, Lider) (Table 2). The soil properties in the experimental field are presented in Table 3.

Moreover, the total experimental area was 1,920 m^2 (4 x 120m^2). The mean temperature and precipitation during the experimental periods for both experiments are shown in Figure 1.

Cultivation Practices

Sowing for the first experiment took place on 11 May 2015 and for the second on 13 May 2016. The row spacing was 96 cm (conventional row). The plants emerged on 9 DAS for the year 2015 and on 11 DAS for 2016.

The crops were fertilized using 400 kg ha^{-1} (20-10-10) pre sowing and 100 kg ha^{-1} potassium nitrate (KNO_3) (13-0- 46) post sowing. In addition, a drip irrigation system was used in order to irrigate the crops.

Harvesting was done manually on two different dates per experiment. For the first experiment the first harvest was performed at 133 DAP and the second, 18 days later, on 151 DAP. In terms of the second experiment, the first harvest done on 134 DAP and the second one, after 19 days, on 154 DAP.

Measurements and Methods

In order to perform the measurements, one hundred bolls were randomly selected per plot. All measurements concerned plant agronomic characteristics. The leaf area index (LAI) was determined using the SunScan devices (Delta-T Devices Ltd). Additionally, there were measured the fresh weight of leaves (g $plant^{-1}$), shoots (g $plant^{-1}$), upper parts (g $plant^{-1}$),

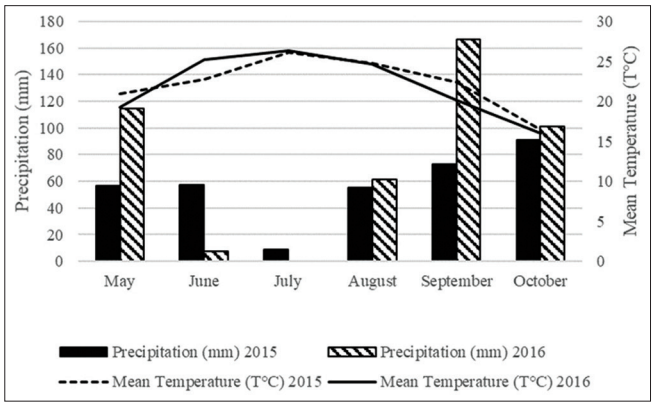

Figure 1: Meteorological data, mean temperature (°C) and precipitation (mm), during the experimental period, for both the years (2015-2016).

Table 1: The irrigation program for the two years (2015-2016)

				Irrigation Dose (mm³ ha^{-1})			
2015	41 DAS Bud	65 DAS Flowering	71 DAS Fruiting	108 DAS ball development	119 DAS Physiological maturity	129 DAS Inception of ball opening	Total
IRR. 2	-	-	-	400	600	-	1000
IRR. 4	400	-	-	400	600	-	1400
IRR. 6	400	400	-	600	600	-	2100
IRR. 8	400	400	500	600	500	500	2900
2016	73 DAS Bud	95 DAS Flowering	111 DAS Fruiting	129 DAS Ball Development	144 DAS Physiological Maturity	163 DAS Inception of Ball Opening	Total
IRR. 2	-	-	-	400	600	-	1000
IRR. 4	400	-	-	400	600	-	1400
IRR. 6	400	400	-	600	600	-	2100
IRR. 8	400	400	500	600	500	500	2900

DAS: days after sown

Table 2: Main characteristics of cotton varieties Dp 419, Campo, Andromeda and Lider

Variety	Characteristics
Dp 419	• Medium-early variety • Excellent production potential of first growth • Adaptability to all environmental conditions • Yield stability • High lint yield • Exceptional technological lint characteristics
Campo	• Medium late variety • Ideal production potential • High yields • High lint quality • Deep root system • Excellent drought resistance • High adaptability to different soil and climatic conditions • Variety for early sowing
Andromeda	• Medium-early variety • Excellent production potential • High resistance to arid conditions • Adaptability to all the soil types
Lider	• Medium-early variety • Highly adaptable to different soil types

Table 3: Soil properties of the experimental field

Depth soil (layer cm)	$CaCO_3$ %	pH	P ppm	K_2O 100g^{-1} soil	Mechanical analysis		
					Sand%	Silt %	Clay %
0-30	1.26	8.2	17.5	5.1	39	45	16
30-60	3.36	8.4	5.5	0.7	35	51	14
60-90	4.62	8.3	4.0	0.4	19	51	30

fruiting bodies (g plant^{-1}) and the total weight of them (kg ha^{-1}) in 129 DAS. Moreover, there were estimated the dry matter of leaves (g plant^{-1}), shoots (g plant^{-1}), upper parts (g plant^{-1}), fruiting sites (g plant^{-1}) and the total weight of them (kg ha^{-1}) in 129 DAS. Yield was estimated 150 DAS. For all parts studied, dry weights were determined after drying for 48 hours at 70°C.

Another agronomic characteristic, that was measured, was the number of closed bolls per 10m. Finally, the total yield (kg ha^{-1}) as well as the ratios between the total dry weight with the total fresh weight, the yield with the total fresh weight and the yield with the total dry weight (%) were determined.

Statistical Analysis

Analysis of variance was carried out on data using the STATISTICA (Stat Soft, 2011) logistic package as a split-plot design. For the significance of differences between treatments estimation, Tukey's test in significant 5% level (p=0.05) was used.

RESULTS

In the Table 4 presented the agronomic characteristics as well as the fresh weight of leaves per plant. In all varieties the IRR.2 had not statistically significant difference with the IRR.4 but the IRR.6 and the IRR.8 had statistically significant difference with the other treatments in the 2015. On the other hand, in the 2016, IRR.8 had statistically significant difference with the other treatments in the four varieties. The highest value was 202.90 g plant^{-1} in the IRR.8 in the Lider variety in the 2015. The lowest values are showed in the Andromeda variety in the 2016 from 88.75 g plant^{-1} to 121.93 g plant^{-1}. It was observed that different irrigation was affect in the fresh weight of leaves in the both years of the experiment (Table 4). Whiles water quantities were increased, fresh weight of leaves were increased as shown in the Table 4. In the fresh weight of stems per plant in the 2015 all treatments had statistically significant difference between them in all varieties but in the 2016 the IRR.2 had not statistically significant difference with the IRR.4. The Lider variety had the highest values in the both years of experiment and the Campo had the lowest values. In all varieties as increased the irrigation, the fresh weight of stems increased (Table 4). Also, in the fresh weight of upper parts, in the 2015 the IRR.2 had not statistically significant difference with the IRR.4 in the four varieties. Hence in the 2016 the IRR.2 had not statistically significant difference with the IRR.6 and the IRR.4 had not statistically significant difference with the IRR.8. The highest value was 458.23 g plant^{-1} in the Andromeda and Lider variety in the IRR.8 in 2015. In the first year of experiment the values were higher. It is worth noting that the varieties did not have any statistically significant differences between them.

Moreover, in the dry matter of leaves per plant in the 2015 the IRR.2 had not statistically significant difference with the IIR.4 but in the 2016 the IRR.4 had not statistically significant difference with the IRR.8 in all varieties (Table 5). The Lider variety had the highest values in the both years and the Campo and Andromeda had the lowest values. The highest value was 54.66 g per plant in the Lider, in the IRR.8. However, it seems that the increase in irrigation causes a increase in the dry matter of the leaves. Also, in the dry matter of stems in the 2015 the IRR.6 had not statistically significant difference with the IRR.8 but in the 2016 the IRR.4 had not statistically significant difference with the IRR.2 and with the IRR.8 in all varieties (Table 5).

The highest value was 135.41 g per plant in the Campo variety in the IRR.8 and the lowest was 45.30 g per plant in the Lider in IRR.2 in second year. Furthermore, in the dry matter of upper parts in 2015 all treatments had statistically significant difference between them in all varieties. On the other hand, in the 2016 the IRR.2 had not statistically significant difference with the IRR.4 and the IRR.6 had not statistically significant difference with the IRR.8. The highest value was 173.18 g per plant in the Campo in IRR.8 in the first year of experiment and the lowest was 71.30 g per plant in the Lider variety in IRR.2 in the second year (Table 5). The varieties did not have a statistically significant difference between them in comparison to Table 4.

Concerning the dry matter of fruiting sites per plant in the 2015 the IRR.2 had not statistically significant difference with the IRR.4 and the IRR.6 had not statistically significant difference with the IRR.8 in all varieties (Table 6). But in the 2016 there were no statistically significant differences between

Table 4: Fresh weight of leaves (g plant $^{-1}$), fresh weight of stems (g plant $^{-1}$) and fresh weight of upper parts (g plant $^{-1}$) of four cotton varieties as affected by different irrigation levels

2015	Fresh weight of leaves g plant^{-1}				Fresh weight of stems g plant^{-1}				Fresh weight of upper parts g plant^{-1}			
	Dp 419	Campo	Andromeda	Lider	Dp 419	Campo	Andromeda	Lider	Dp 419	Campo	Andromeda	Lider
IRR. 2	135.26^{a}	107.15^{a}	107.15^{a}	145.46^{a}	137.63^{a}	137.56^{a}	146.63^{a}	239.33^{a}	272.89^{a}	244.71^{a}	253.78^{a}	384.79^{a}
IRR. 4	162.87^{a}	110.45^{a}	127.08^{a}	157.43^{a}	153.66^{b}	141.82^{b}	152.10^{b}	232.50^{b}	316.53^{a}	252.27^{a}	279.18^{a}	389.93^{a}
IRR. 6	174.20^{b}	120.35^{b}	138.75^{b}	177.00^{b}	173.43^{c}	142.79^{c}	159.37^{c}	260.17^{c}	347.63^{b}	263.14^{b}	398.12^{b}	437.17^{b}
IRR. 8	181.59^{c}	135.26^{c}	145.46^{c}	202.90^{c}	175.63^{d}	146.63^{d}	160.87^{d}	255.33^{d}	357.22^{c}	281.89^{c}	306.33^{c}	458.23^{c}
2016												
IRR. 2	108.40^{a}	100.40^{a}	91.13^{a}	91.13^{a}	140.33^{a}	114.10^{a}	114.10^{a}	130.53^{a}	248.73^{a}	214.50^{a}	205.23^{a}	221.66^{a}
IRR. 4	131.73^{ab}	101.03^{ab}	88.57^{ab}	109.03^{ab}	146.37^{a}	117.57^{a}	125.47^{a}	125.07^{a}	278.10^{b}	215.60^{b}	214.04^{b}	234.10^{b}
IRR. 6	134.13^{b}	124.10^{b}	89.97^{b}	133.63^{b}	142.37^{b}	131.90^{b}	128.67^{b}	145.27^{b}	276.50^{a}	256.00^{a}	218.64^{a}	278.90^{a}
IRR. 8	121.93^{c}	111.63^{c}	121.93^{c}	153.10^{c}	152.07^{c}	140.33^{c}	130.53^{c}	162.20^{c}	274.00^{b}	251.96^{b}	252.46^{b}	315.30^{b}
F_{irrig}		*45.95****				*52.48****				*50.93****		
$F_{variety}$		*ns*				*ns*				*ns*		
F_{year}		*133.52****				*110.59****				*117.66****		
$F_{irrig\ x\ variety}$		*ns*				*ns*				*ns*		
$F_{irrig\ x\ year}$		*20.59****				*13.65****				*17.70****		
$F_{variety\ x\ year}$		*2.39****				*ns*				*ns*		
$F_{irrig\ x\ variety\ x\ year}$		*ns*				*ns*				*ns*		

Table 5: Dry matter of leaves (g plant $^{-1}$), Dry matter of stems (g plant $^{-1}$) and dry matter of upper parts (g plant $^{-1}$) of four cotton varieties as affected by different irrigation levels

2015	Dry matter of leaves (g plant^{-1})				Dry matter of stems (g plant^{-1})				Dry matter of upper parts (g plant^{-1})			
	Dp 419	Campo	Andromeda	Lider	Dp 419	Campo	Andromeda	Lider	Dp 419	Campo	Andromeda	Lider
IRR. 2	37.77^{a}	31.85^{a}	36.90^{a}	41.08^{a}	60.47^{a}	48.93^{a}	55.25^{a}	56.88^{a}	98.24^{a}	80.78^{a}	92.15^{a}	97.96^{a}
IRR. 4	43.50^{a}	32.15^{a}	39.58^{a}	44.75^{a}	65.00^{b}	74.34^{b}	75.27^{b}	74.67^{b}	108.50^{b}	106.49^{b}	114.85^{b}	119.42^{b}
IRR. 6	47.00^{b}	34.35^{b}	41.08^{b}	48.78^{b}	85.38^{c}	88.03^{c}	109.66^{c}	99.50^{c}	132.38^{c}	122.38^{c}	150.74^{c}	148.28^{c}
IRR. 8	48.40^{c}	37.77^{b}	44.75^{b}	54.66^{b}	93.24^{c}	135.41^{c}	114.58^{c}	98.77^{c}	141.24^{d}	173.18^{d}	189.33^{d}	153.43^{d}
2016												
IRR. 2	33.13^{a}	28.60^{a}	26.10^{a}	26.10^{a}	55.43^{a}	49.37^{a}	49.07^{a}	45.30^{a}	88.57^{a}	77.97^{a}	75.17^{a}	71.30^{a}
IRR. 4	31.57^{b}	34.27^{b}	27.43^{b}	30.63^{b}	70.80^{ab}	70.80^{ab}	59.30^{ab}	49.13^{ab}	114.27^{a}	105.07^{a}	86.73^{a}	79.76^{a}
IRR. 6	30.93^{c}	35.83^{c}	28.33^{c}	36.67^{c}	47.10^{c}	56.83^{c}	56.90^{c}	62.07^{c}	78.23^{b}	92.66^{b}	85.23^{b}	98.74^{b}
IRR. 8	35.33^{b}	35.33^{b}	28.10^{b}	44.17^{b}	76.10^{b}	85.83^{b}	68.17^{b}	72.17^{b}	117.07^{b}	121.16^{b}	96.27^{b}	116.34^{b}
F_{irrig}		*42.60****				*35.75****				*43.263****		
$F_{variety}$		*ns*				*ns*				*ns*		
F_{year}		*114.08****				*65.24****				*94.241****		
$F_{irrig\ x\ variety}$		*2.41**				*ns*				*ns*		
$F_{irrig\ x\ year}$		*12.32****				*9.09****				*11.139****		
$F_{variety\ x\ year}$		*ns*				*ns*				*ns*		
$F_{irrig\ x\ variety\ x\ year}$		*ns*				*ns*				*ns*		

the treatments. The highest value was 63.27 g per plant in the Lider in the IRR.8 and the lowest was 30.93 g per plant in the Dp 419 in the IRR.2. Also, in the fresh weight of fruiting sites in the first year of experiment the IRR.8 had not statistically significant difference with the IRR.4 and with the IRR.6. In the 2016 the IRR.2 had statistically significant difference with the other treatments in all varieties. The highest value was 185.89 g per plant in the Lider in the IRR.6 in 2015 and the lowest was 65.27 g per plant in the IRR.2 in Lider variety in 2016. The varieties did not have a statistically significant difference between them.

Furthermore, in the total fresh weight the IRR.2 had not statistically significant different with the IRR.4 and the IRR.6 had not statistically with the IRR.8 in the 2015 in all varieties. In the 2016 there were no statistically significant differences between the treatments (Table 7). The highest value was 1197.6 kg ha^{-1} in the Dp 419 in the IRR.8 in 2015 and the lowest was 628.5 kg ha^{-1} in the Campo variety in the IRR.2 in 2016. Also, in the total dry weight in 2015 the IRR.8 had not statistically significant difference with the IRR.4 and with the IRR.6. In the 2016 there were no statistically significant differences between the treatments (Table 7). The highest value was 36,270 kg ha^{-1} in the Dp 41,9 in the IRR.8 and the lowest was 20,481 kg ha^{-1} in the IRR.2 in the 2016. Moreover, in the Leaf Area Index (LAI), in the both years of experiment all treatments had statistically significant difference between them. The fact was that as long as irrigation increases, LAI follows a similar course of development. The highest value was 5.54 in IRR.8 in 2016 and the lowest was 2.37 in IRR.2 in Andromeda variety in 2015 (Table 7). The varieties did not have a statistically significant difference between them.

Moreover, in the closed bolls the IRR.4 had not statistically significant difference with the IRR.6 in all varieties in 2015

Table 6: Fresh weight of fruiting sites (g plant $^{-1}$) and dry matter of fruiting sites (g plant $^{-1}$) of four cotton varieties as affected by different irrigation levels

2015	Dry matter of fruiting sites (g plant^{-1})				Fresh weight of fruiting sites (g plant^{-1})			
	Dp 419	Campo	Andromeda	Lider	Dp 419	Campo	Andromeda	Lider
IRR. 2	32.15^{a}	32.15^{a}	39.58^{a}	54.42^{a}	118.83^{a}	98.33^{a}	123.57^{a}	106.08^{a}
IRR. 4	34.35^{a}	31.85^{a}	41.08^{a}	59.92^{a}	156.65^{b}	134.12^{b}	126.19^{b}	163.69^{b}
IRR. 6	37.77^{b}	36.90^{b}	44.75^{b}	60.65^{b}	182.61^{c}	158.16^{c}	175.79^{c}	185.89^{c}
IRR. 8	43.50^{b}	39.58^{b}	48.78^{b}	63.27^{b}	179.71^{bc}	169.97^{bc}	132.39^{bc}	152.94^{bc}
2016								
IRR. 2	30.93^{a}	34.27^{a}	27.43^{a}	36.67^{a}	78.83^{a}	94.80^{a}	74.17^{a}	65.27^{a}
IRR. 4	35.33^{a}	28.60^{a}	26.10^{a}	44.17^{a}	118.60^{b}	117.90^{b}	83.37^{b}	93^{b}
IRR. 6	35.83^{a}	28.33^{a}	30.63^{a}	43.37^{a}	105.17^{b}	131.47^{b}	123.33^{b}	121.93^{b}
IRR. 8	34.27^{a}	27.43^{a}	36.67^{a}	40.93^{a}	106.63^{b}	95.33^{b}	107.20^{b}	130.07^{b}
F_{irrig}		*14.05****				*15.79****		
$F_{variety}$		*ns*				*ns*		
F_{year}		*55.28****				*65.23****		
$F_{irrig\ x\ variety}$		*ns*				*ns*		
$F_{irrig\ x\ year}$		*8.66****				*ns*		
$F_{variety\ x\ year}$		*ns*				*ns*		
$F_{irrig\ x\ variety\ x\ year}$		*ns*				*ns*		

F-test ratios are from ANOVA. Different letters within a column indicate significant differences according to Tukey's test . Significance levels: *p < 0.05; **p < 0.01; ***p < 0.001; ns, not significant (p > 0.05). IRR: irrigation

Table 7: Total fresh weight (kg ha^{-1}), total dry weight (kg ha^{-1}) and LAI of four cotton varieties as affected by different irrigation levels

2015	Total Fresh weight kg.ha^{-1}				Total Dry weight kg.ha^{-1}				LAI			
	Dp 419	Campo	Andromeda	Lider	Dp 419	Campo	Andromeda	Lider	Dp 419	Campo	Andromeda	Lider
IRR. 2	799.0^{a}	799.0^{a}	872.6^{a}	942.4^{a}	235.6^{a}	235.6^{a}	291.8^{a}	281.0^{a}	3.36^{a}	2.53^{a}	2.37^{a}	2.73^{a}
IRR. 4	115.7^{a}	793.8^{a}	899.1^{a}	1055.2^{a}	290.7^{b}	243.2^{b}	286.5^{b}	320.6^{b}	3.99^{b}	3.48^{b}	3.12^{b}	3.71^{b}
IRR. 6	1244.3^{b}	798.6^{b}	953.3^{b}	1135.2^{b}	354.5^{c}	257.1^{c}	302.9^{c}	327.7^{c}	4^{c}	4.23^{c}	4.47^{c}	4.81^{c}
IRR. 8	1197.6^{b}	872.6^{b}	942.4^{b}	1179.6^{b}	334.3^{bc}	291.8^{bc}	281.0^{bc}	337.7^{bc}	4.74^{d}	5.10^{d}	5.37^{d}	5.14^{d}
2016												
IRR. 2	704.8^{a}	628.5^{a}	725.9^{a}	859.3^{a}	204.8^{a}	362.7^{a}	259.8^{a}	241.4^{a}	3.27^{a}	2.87^{a}	2.48^{a}	2.64^{a}
IRR. 4	648.7^{a}	727.4^{a}	776.1^{a}	931.1^{a}	348.7^{a}	261.0^{a}	291.5^{a}	266.7^{a}	3.58^{b}	3.57^{b}	3.46^{b}	3.58^{b}
IRR. 6	651.9^{a}	825.8^{a}	877.3^{a}	1030.1^{a}	351.9^{a}	276.5^{a}	242.4^{a}	292.8^{a}	4.19^{c}	4.32^{c}	4.59^{c}	4.64^{c}
IRR. 8	762.7^{a}	925.9^{a}	959.3^{a}	1128.6^{a}	362.7^{a}	259.8^{a}	241.4^{a}	305.2^{a}	4.91^{d}	5.30^{d}	5.54^{d}	5.44^{d}
F_{irrig}		*9.82****				*14.61****				*451.34****		
$F_{variety}$		*ns*				*ns*				*ns*		
F_{year}		*77.24****				*56.13****				*1.15****		
$F_{irrig\ x\ variety}$		*ns*				*ns*				*ns*		
$F_{irrig\ x\ year}$		*10.69****				*ns*				*ns*		
$F_{variety\ x\ year}$		*ns*				*ns*				*ns*		
$F_{irrig\ x\ variety\ x\ year}$		*ns*				*ns*				*ns*		

(Table 8). Hence, in the 2016 the IRR.4 had not statistically significant difference with the IRR.2 and with the IRR.6. The highest value was 144.67 closed bolls per 10 m in IRR.8 and the lowest was 12 closed bolls per 10 m in the DP 419, in 2016. It was worth noting that the number of closed bolls was increasing rapidly IRR.8 in both years of the experiment but also in all varieties, on the other hand in IRR.2 and IRR.4 had the lowest values (Table 8). In the yield the IRR.6 had not statistically significant difference with the IRR.8 but in the 2016 the IRR.2 had not statistically significant difference with the IRR.4 and the IRR.6 had not statistically difference with the IRR.8 in all varieties. The Lider variety had the highest values in the both years of experiment and the Dp 419 and Campo had the lowest values (Table 8). It was observed that as the increased the irrigation the yield is also increased. There was no statistically significant difference between the varieties (Table 8).

Additional, in the total dry weight/total fresh weight there was no statistically significant difference between the treatments in the 2015 (Table 9). In the 2016 the IRR.2 had not statistically significant difference with the IRR.8. The highest value was 33.41 in the Campo variety in the IRR.8 in 2015 and the lowest was 25.44 in the Andromeda and Lider in the IRR.8 and IRR.2 respectively. Also, in the yield/total dry weight in the both years there was no statistically significant difference between the treatments (Table 9). The highest value was 16.12 in the Andromeda and in the Lider (IRR.8, IRR.2) respectively in 2016. Moreover, in the yield/total fresh weight in the 2015 there was no statistically significant difference between the treatments but in the 2016 the IRR.2 had not statistically significant difference with the IRR.8. The highest value was 4.37 in the IRR.6 in the 2016 and the lowest was 2.68 in the IRR.4 in 2015 in the Dp 419 (Table 9).

Table 8: Agronomic characteristics of cotton as affected by different irrigation levels

2015	Closed bolls/10 m line				Yield (kg.ha^{-1})			
	Dp 419	Campo	Andromeda	Lider	Dp 419	Campo	Andromeda	Lider
IRR. 2	17.00^{a}	15.67^{a}	19.67^{a}	19.67^{a}	2,820^{a}	2,881^{a}	2,948^{a}	3,018^{a}
IRR. 4	10.67^{b}	20.67^{b}	15.33^{b}	16.33^{b}	2,835^{b}	2,897^{b}	2,927^{b}	3,092^{b}
IRR. 6	15.67^{b}	22.00^{b}	53.33^{b}	44.67^{b}	2,916^{c}	2,888^{c}	2,949^{c}	3,171^{c}
IRR. 8	83.00^{c}	128.33^{c}	123.33^{c}	65.33^{c}	2,881^{c}	2,948^{c}	3,018^{c}	3,007^{c}
2016								
IRR. 2	12.00^{a}	14.67^{a}	18.67^{a}	12.67^{a}	2,452^{a}	2,851^{a}	2,597^{a}	2,930^{a}
IRR. 4	19.33^{ab}	11.33^{ab}	16.00^{ab}	27.33^{ab}	2,574^{a}	2,747^{a}	2,611^{a}	3,110^{a}
IRR. 6	24.67^{b}	40.00^{b}	24.67^{b}	48.00^{b}	2,693^{b}	2,585^{b}	2,736^{b}	3,016^{b}
IRR. 8	144.67^{c}	82.67^{c}	140.67^{c}	137.33^{c}	2,851^{b}	2,597^{b}	2,930^{b}	2,864^{b}
F_{irrig}		110.09***				56.64***		
$F_{variety}$		*ns*				*4.64***		
F_{year}		*ns*				*27.16****		
$F_{irrig\ x\ variety}$		*ns*				*ns*		
$F_{irrig\ x\ year}$		*ns*				*ns*		
$F_{variety\ x\ year}$		*ns*				*ns*		
$F_{irrig\ x\ variety\ x\ year}$		*2.84***				*3.07***		

F-test ratios are from ANOVA. Different letters within a column indicate significant differences according to Tukey's

Table 9: The ratio of total dry, fresh weight and yield of cotton as affected by different irrigation

2015	Total Dry weight/Total fresh weight (%)				Yield/Total dry weight (%)				Yield/Total fresh weight (%)			
	Dp 419	Campo	Andromeda	Lider	Dp 419	Campo	Andromeda	Lider	Dp 419	Campo	Andromeda	Lider
IRR. 2	28.46^{a}	29.45^{a}	28.46^{a}	29.75^{a}	10.78^{a}	12.48^{a}	10.58^{a}	11^{a}	3.01^{a}	3.66^{a}	3.53^{a}	3.26^{a}
IRR. 4	29.57^{a}	30.84^{a}	29.57^{a}	30.42^{a}	8.99^{a}	12.10^{a}	10.80^{a}	9.65^{a}	2.68^{a}	3.71^{a}	3.35^{a}	2.93^{a}
IRR. 6	27.12^{a}	32.38^{a}	27.12^{a}	28.95^{a}	11.33^{a}	11.32^{a}	10.26^{a}	9.68^{a}	3.14^{a}	3.68^{a}	3.17^{a}	2.80^{a}
IRR. 8	29.45^{a}	33.41^{a}	29.45^{a}	28.71^{a}	12.48^{a}	10.58^{a}	11^{a}	8.93^{a}	3.66^{a}	3.53^{a}	3.26^{a}	2.56^{a}
2016												
IRR. 2	28.31^{a}	30.73^{a}	29.08^{a}	25.44^{a}	13.41^{a}	13.62^{a}	14.11^{a}	16.12^{a}	3.86^{a}	4.14^{a}	3.82^{a}	4.15^{a}
IRR. 4	30.73^{b}	28.40^{b}	32.26^{b}	29.27^{b}	14.68^{a}	13.65^{a}	12.57^{a}	15.08^{a}	4.17^{b}	3.75^{b}	4^{b}	4.26^{b}
IRR. 6	30.75^{c}	25.24^{c}	29.55^{c}	31.35^{c}	14.39^{a}	13.63^{a}	13.53^{a}	11.26^{a}	4.37^{c}	3.27^{c}	3.82^{c}	3.49^{c}
IRR. 8	28.71^{a}	29.08^{a}	25.44^{a}	32.41^{a}	13.62^{a}	14.11^{a}	16.12^{a}	9.62^{a}	4.14^{b}	3.82^{b}	4.15^{b}	3.14^{b}
F_{irrig}		*6.59****				*ns*				*4.02**		
$F_{variety}$		*ns*				*ns*				*ns*		
F_{year}		*8.67***				*25.14****				*42.62****		
$F_{irrig\ x\ variety}$		*ns*				*ns*				*ns*		
$F_{irrig\ x\ year}$		*6.41****				*ns*				*9.94****		
$F_{variety\ x\ year}$		*ns*				*ns*				*ns*		
$F_{irrig\ x\ variety\ x\ year}$		*ns*				*ns*				*ns*		

F-test ratios are from ANOVA. Different letters within a column indicate significant differences according to Tukey's test. Significance levels: *p < 0.05; **p < 0.01; ***p < 0.001; ns, not significant (p > 0.05). IRR: irrigation

DISCUSSION

Ünlü *et al.* [21] said that dry matter yields increased as water use increased. Furthermore, Dadgale *et al.* [3] noted that the dry matter production increased as the frequency of irrigation increased. This was also observed in our study where leaf dry matter and stem dry matter increased as irrigation regimes increased and as the frequency increased, although lower values were shown in IRR.2 and IRR.4 treatments. A similar course was followed by fresh weight where from minimum irrigation regime to over-irrigation it increased. The dry matter of the upper parts consists of the leaves and shoots, which means that as the dry and fresh weight of the leaves and shoots increases with irrigation, so does the total weight.

Regarding fruiting sites, Reddell *et al.* [18] reported that early flowering is water sensitive. Also, Lashin *et al.* [13] observed that there was an increase in the number of flowers and bolls per plant and therefore in yield, as a result of the water stress that appeared in the stage before flowering. Thus, as the number of flowers increases, this has resulted in an increase in the fresh and dry weight of the fruiting sites. In our study, as the level of irrigation increased the dry and the fresh weight increased. The fresh and dry weight of upper parts had positive correlation with the LAI (r= 0.59, p=0.001) and with the number of closed bolls (r= 0.43, p= 0.001) as shown in Table 10. This means that increased irrigation results in increased LAI as well as higher number of closed bolls and therefore due to the positive correlation that exists there was an increase in both fresh and dry weight of upper parts.

The ratio between total dry weight and total fresh weight seems to be directly affected by irrigation. The highest values were observed mainly at the lowest irrigation doses. In addition, according to Table 10, there was a strongly positive correlation between this ratio and the ratio between yield and total fresh weight (r=0.72, p=0.001). In terms of the ratio between yield and total dry and total fresh weight, only the latter was affected

Table 10: Pearson's correlation coefficient (r) of agronomic characteristics and ratio in the cotton cultivation

	Fresh weight of upper parts (g plant^{-1})	Dry matter of upper parts (g plant^{-1})	LAI	Closed bolls (Per 10 m)	Total Fresh weight (kg.ha^{-1})	Total Dry weight (kg.ha^{-1})	Total dry weight/Total fresh weight (%)	Yield/Total dry weight (%)	Yield/ Total fresh weight (%)
Fresh weight of upper parts (g plant^{-1})	1	0.86***	0.59***	0.43***	0.84***	0.73***	-0.35***	-0.40***	-0.54***
Dry matter of upper parts (g plant^{-1})	0.86***	1	0.59***	0.43***	0.70***	0.84***	-0.01^{ns}	-0.57***	-0.38***
LAI	0.59***	0.59***	1	0.72**	0.34***	0.41***	0.06^{ns}	-0.10^{ns}	0.01^{ns}
Closed bolls (per 10 m)	0.43***	0.43***	0.72***	1	0.26*	0.21*	-0.13^{ns}	-0.01^{ns}	-0.09^{ns}
Total Fresh weight (kg.ha^{-1})	0.84***	0.70***	0.34**	0.26**	1	0.78***	-0.50***	-0.57***	-0.76***
Total Dry weight (kg.ha^{-1})	0.73***	0.84***	0.41***	0.21*	0.78***	1	0.08ns	-0.80***	-0.47***
Total dry weight/Total fresh weight (%)	-0.35**	-0.01^{ns}	0.06^{ns}	-0.13^{ns}	-0.50***	0.08^{ns}	1	-0.11^{ns}	0.72***
Yield/Total dry weight (%)	-0.40***	-0.57***	-0.10^{ns}	-0.01^{ns}	-0.57***	-0.80***	-0.11^{ns}	1	0.57***
Yield/Total fresh weight (%)	-0.54***	-0.38***	0.01^{ns}	-0.09^{ns}	-0.76***	-0.47***	0.72***	0.57***	1

Correlation coefficients are significant at the 0.05 probability level; ('ns': not statistically significant; *: statistically significant for a significance level of $p < 0.05$; **statistically significant for a significance level of $p < 0.01$; ***: statistically significant for a significance level of $p < 0.001$

by irrigation, while there was a positive correlation between them (Table 10) ($r=0.57$, $p=0.001$). Their highest values are presented in the irrigation regimes with the lowest quantities of irrigation water. These ratios inform us whether irrigation affects biomass production at the expense of yield. Therefore, it is observed that the higher the amount of irrigation is, as well as the higher its frequency is, it favors the crop production not necessarily yield.

In general, irrigation and genotype affect the evolution of the leaf area index [16]. Zhang *et al.* [22] stated that LAI had appeared reduced in deficit irrigation while it was high as irrigation increased. According to our results, the leaf area index LAI, was affected significantly by irrigation treatment. This is explained by the fact that irrigation leads to an increase in biomass production [5]. In addition, an increase in the irrigation dose led to an increase in LAI, up to 100 days after plant emergence, after which fruit production is promoted [9].

Moreover, the number of closed bolls per 10 m, was affected only by irrigation treatments. More specifically, as irrigation doses increased, the number of closed bolls also increased. Similar results were presented in a study by [15], in which it was reported that irrigation treatment negatively affected the number of closed bolls per plants. Mahadevappa *et al.* [14] said that the number of bolls per plant increased as such the irrigation increased.

Regarding yield, according to the results of the present study, it was affected by irrigation, variety as well as by year. The yield was positively affected by the irrigation treatment. In terms of variety, the highest yield value was observed in the Lider, in the IRR. 6 treatment. Onder *et al.* [15] reported that the yield of cotton seed was correlated with the number and weight of green bolls per plant. In addition, the number of closed bolls was strongly correlated with yield [7]. In contrast, Kang *et al.* [8] reported that the higher irrigation regime did not lead to an increase in yield. On the other hand Shinde *et al.* [19] observed that the higher dry matter production increased number of bolls per plant and as a result there was an increased in seed yield.

In terms of varieties, Lider recorded the highest yield values in the IRR. 6 treatment, presenting at the same time high values in all agronomic characteristics and low number of closed bolls. On the other hand, the lowest value of yield presented in Dp 419, although it had the fewest closed bolls.

CONCLUSION

The high production potential of cotton in relation to irrigation water remains a major issue today that can establish the future of the crop. By evaluating the agronomic characteristics, we can conclude that different irrigation regime had effect on them (LAI, yield, closed bolls) in cotton varieties. More specifically, higher irrigation regime treatment, the highest yields were recorded in all varieties in both years, while at the same level the highest values of closed bolls were recorded. According to varieties, no differences were presented in either of the two experimental years. Varieties Andromeda and Lider presented the best agronomic characteristics. A basic knowledge is structured while further research is needed on quality fiber and bolls.

REFERENCES

1. Aeschbach-Hertig W, Gleeson T. Regional strategies for the accelerating global problem of groundwater depletion. Nature Geoscience. 2012;5(12):853-861.
2. Cetin O, Bilgel L. Effects of different irrigation methods on shedding and yield of cotton. Agricultural Water Management. 2002;54(1): 1-15.

3. Dadgale PR, Chavan DA, Gudade BA, Jadhav SG, Deshmukh VA, Suresh Pal. Productivity and quality of Bt cotton (*Gossypium hirsutum*) as influenced by planting geometry and nitrogen levels under irrigated and rainfed conditions. Indian Journal of Agricultural Sciences. 2014; 84 (9): 1069–1072
4. Darawsheh MK. Cotton fiber quality parameters response to cultivation system as influenced by limited and normal irrigation. Journal of Food, Agriculture & Environment. 2010;8(2): 527-530.
5. Darawsheh MK, Kakabouki I, Roussis I, Bilalis DJ. Cotton Response to Planting Patterns under Effect of Typical and Limited Irrigation Regime. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 2019;47(4): 1206–1214. doi:10.15835/nbha47411712.
6. DeLaune PB, Mubvumba P, Ale S, Kimura E. Impact of no-till, cover crop, and irrigation on Cotton yield. Agricultural Water Management. 2020;232:106038.
7. Ertek A, Kanber R. Effects of different drip irrigation programs on the boll number and shedding percentage and yield of cotton. Agricultural Water Management. 2003;60(1): 1-11.
8. Kang Y, Wang R, Wan S, Hu W, Jiang S, Liu S. Effects of different water levels on cotton growth and water use through drip irrigation in an arid region with saline ground water of Northwest China. Agricultural Water Management. 2012;109:117–126. doi:10.1016/j.agwat.2012.02.01.
9. Karam F, Lahoud R, Masaad R, Daccache A, Mounzer O, Rouphael Y. Water use and lint yield response of drip irrigated cotton to the length of irrigation season. Agricultural Water Management. 2006;85(3):287-295.
10. Karamanos AJ, Bilalis D, Sidiras N. Effects of reduced tillage and fertilization practices on soil characteristics, plant water status, growth and yield of upland cotton. Journal of Agronomy and Crop Science. 2004;190(4):262-276.
11. Kirda C, Kanber R, Tulucu K, Gungor H. Yield response of cotton, maize, soybean, sugar beet, sunflower and wheat to deficit irrigation. Crop Yield Response to Deficit Irrigation. Kluwer Academic Publishers, Dordrecht, Boston, London. 1999;21-38.
12. Kirda C. Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Food and Agricultural Organization of the United Nations, Deficit Irrigation Practices, Water Reports. 2002;22:102.
13. Lashin H, Raafat A, Elkadi M. Fruiting and shedding of cotton as influenced by irrigation frequency and nitrogen level. Zeitschrift fur Acker und Pflanzenbau. 1970;131:128-140.
14. Mahadevappa SG, Sreenivas G, Raji Reddy D, Madhavi A, Rao SS. Effect of Different Levels of Irrigation and Nitrogen on Growth and Yield of Bt Cotton. International Journal of Current Microbiology and Applied Sciences.2018; 7(8): 4599-4604
15. Onder D, Akiscan Y, Onder S, Mert M. Effect of different irrigation water level on cotton yield and yield components. African Journal of Biotechnology. 2009;8 (8):1536-1544.
16. Papastylianou PT, Argyrokastritis IG. Effect of limited drip irrigation regime on yield, yield components, and fiber quality of cotton under Mediterranean conditions. Agricultural Water Management. 2014;142:127–134. doi:10.1016/j.agwat.2014.05.005.
17. Pettigrew WT. Impact of varying planting dates and irrigation regimes on cotton growth and lint yield production. Agronomy Journal. 2010;102(5):1379-1387.
18. Reddell DL, Prochaska JF, Cudrak AJ. Sequential water stress in cotton: a stress day index model. American Society of Agricultural Engineers. 1987;87-2080.
19. Shinde VS, Deshmukh LS, Raskar SK. Response of cotton (*Gossypium arboreum* L.) to protective irrigation at different critical growth stages. Journal of cotton Research and Development. 2009; 23 (1): 93–95.
20. Tsakmakis ID, Zoidou M, Gikas GD, Sylaios GK. Impact of irrigation technologies and strategies on cotton water footprint using AquaCrop and CROPWAT models. Environmental Processes. 2018;5(1):181-199.
21. Ünlü M, Kanber R, Levent Koc D¸ Tekin S, Kapur B. Effects of deficit irrigation on the yield and yield components of drip irrigated cotton in a mediterranean environment. Agricultural Water Management. 2011;98:597–605.
22. Zhang D, Dongmei L, Luo Z, Liu S, Suhua L, Li W, WeiTang, Dong H. Effects of deficit irrigation and plant density on the growth, yield and fiber quality of irrigated cotton. Field Crops Research. 2016; 197:1-9 doi:10.1016/j.fcr.2016.06.003