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CROP – WATER RELATIONS AND YIELD OF COTTON AS AFFECTED BY IRRIGATION WATER AND NITROGEN FERTILIZATION MANAGEMENT

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ABSTRACT: *A field experiment was carried out at Tameia Agric, Res. Station, Fayoum Governorate during 2011 and 2012 summer seasons. The study aiming at determining the effect of different irrigation regimes, i.e. irrigation at 30, 50 and 70% available soil moisture depletion (ASMD) and three nitrogen fertilization levels (55, 70 and 85 kg N/fed) and interaction on seed cotton yield , yield components and some crop - water relations. The adopted treatments were assessed in a split –plot design with four replicates where irrigation regimes were represented in the main plots while the sub ones were assigned to N levels. The main obtained results could be as follows:*

- *Seed cotton yield was significantly affected by irrigation regimes, N fertilization levels and interaction, while most studied yield components exhibited similar trend in both seasons of study.*
- *The highest values of seed cotton yield were recorded under irrigating at 30 ASMD% regime. In addition, the highest N level resulted in the highest seed cotton yield. The highest seed cotton yields(1140.65 and 1090.74 kg / fed in 2011 and 2012 seasons, respectively) were obtained with 30 ASMD% regime as interacted with 85 kg N/fed level. Irrigating at 30 ASMD% regime and / or 85 kg N/fed level exhibited the highest values of yield components in the two seasons of study..*
- *Seasonal evapotranspiration (ET_C), as a function of irrigation regimes and N fertilization levels averaged 92.54 and 90.96 cm in 2011 and 2012 seasons, respectively. Either Irrigation at 30% ASMD regime or 85 kg N/ fed level gave the highest ET_C values which amounted to 96.81 and 95.04cm and 95.0 and 93.76cm in 2011 and 2012 seasons, respectively. Interaction of irrigating at 30% ASMD regime and 85 kg N/ fed level exhibited the highest ET_C values which reached to 99.05 and 97.78cm in 2011 and 2012 seasons, respectively.*
- *The daily mean of ET_C ($mm day^{-1}$) increased from march and reached its peak values during June and July, then declined during August. The crop coefficient (Kc) as a mean of the two seasons were 0.57, 0.84, 0.91 .1.04, 1.14 and 0.80 during March, April, May, June, July and August, respectively.*
- *The highest water use efficiency values (0.247 and 0.266 kg seed cotton / m^3 water consumed in 2011 and 2012 seasons, respectively) were recorded under irrigating cotton crop at 30 % ASMD and applying 85 kg N/fed level interaction.*
- *Based on the obtained WUE results, it is advisable to irrigate cotton crop at 50% ASMD regime and applying N - fertilizer at 75 or 85 $kg fed^{-1}$ levels in order to accomplish acceptable water productivity and cotton seed yield figures under Fayoum Governorate conditions.*

Key words : *Irrigation regimes, N- fertilization levels, cotton crop – water relations, Water use efficiency, crop coefficient*

INTRODUCTION

Cotton (*Gossypium barbadense* L.) is one of the most important crops for fiber and oil production and considered as a major crop in the Egyptian agriculture. Thus, a great attention must be paid towards it's adaptability to various Egyptian conditions and to proper water and fertilization management that lead to higher yield and reasonable water productivity.

Concerning the response of cotton crop to irrigation water management , Dagdelen *et al.* (2009) with drip – irrigated cotton, found that full irrigation regime (received 100% of the soil water depletion) exhibited the highest cotton yield, while 25% of full irrigation regime resulted in the highest WUE. In connection, Yudhveer Singh *et al.* (2010) found that, under drip irrigation, irrigation at 0.8 Etc regime resulted in reduction in seed cotton yield reached 9.3% of the maximum yield under full irrigation, and further increase in deficit irrigation from 0.7 Etc to 0.5 Etc significantly decreased seed cotton yield. In this sense, Oweis *et al.*(2011) reported that drip – irrigated cotton yield (lint plus seed, or lintseed) and water productivity were reduced by 56.1 and 18.0%,respectively, under 40% irrigation regime, comparable with 100% irrigation one. Mustafa Ünlü *et al.* (2011) found that Etc for drip irrigated cotton ranged from 477 to 671 mm in full irrigation and from 376 to 398 mm in the severe water stress treatments and the highest both seed cotton yield (3397 kg ha^{-1}) and WUE (6.0 kg ha^{-1} mm^{-1}) were obtained from full irrigation regime. Under center pivot (LEPA) system, Wen *et al.* (2013) found that the actual total water consumption by cotton crop ranged from 560 and 594 mm (the sum of irrigation and precipitation that was actually used).The author also reported reductions in cotton lint yield ranged from 5.3 to 25.4% and from 32.0 to 34.0% under Etc - based 80 and 70% traditional deficit irrigation schemes, respectively, comparable with control (100%). With respect to cotton crop response to water management under the Egyptian circumstances, Eid and Hosny (1995) showed that the largest number of open bolls / plant and seed cotton yield were obtained by 94.5 cm at Sakha and Gimmeza, 105 cm at Beni Sueif. Mohamed *et al.* (1995) reported that the highest seed cotton yield, fruiting branches, boll weight/plant and WUE (0.56 kg seed cotton/m^3 water consumed) were detected from irrigation every 10 days until flowering and every 20 days till picking. In addition, the maximum plant height and ETc (75.9 cm) were attained from irrigation every 10 days along the growing season. Ibrahim (2007) stated that irrigation according to 1.4 Cumulative Pan Evaporation (CPE) regime exhibited higher values of seasonal evapotranspiration (ET_C) and seed cotton yield besides the yield attributes such as plant high, number of fruiting branches / plant, number of flower buds / plant, number of green bolls/ plant, total bolls/ plant, number of open bolls / plant, boll weight , as compared to 0.8 CPE regime. The author added that the crop coefficient values were 0.60 , 0.86, 0.95 , 1.10 , 1.25 and 0.79 for March , April, May, June, July and August, respectively. Water use efficiency was the highest due to irrigation at 1.2 CPE regime (0.304kg seed cotton/ m^3 water consumed)

Regarding the effect of N fertilization on cotton crop, Thind *et al.* (2008) reported that the decrease in N applied, irrespective of methods of planting, caused a significant decline in seed cotton yield. In addition, Parajulee *et al.* (2010) found that cotton lint yield increased curvilinearly with added N, but the yield did not significantly increase beyond 100 lb N/acre with additional N. Under the Egyptian conditions, El-Shahawy and Hamoda (2010) indicated that plant height, No. of opened bolls/plant, boll weight, seed index and seed cotton yield were increased due to increasing nitrogen level. Moreover, Emara, and El-Gammaal (2012) reported that plant height, No. of opened bolls/plant, seed cotton yield/plant, lint percentage and seed index were increased by increasing nitrogen level.

The herein research trial aiming at finding how both different irrigation regimes (irrigating at 30, 50 and 70% of Available Soil Moisture Depletion) and 55, 70 and 85 kgNfed^{-1} levels and interaction affected cotton seed yield, yield components and some crop – water relationships in order to distinguish the most efficient interaction exhibiting higher water productivity and cotton seed yield as well under Fayoum Governorate circumstances.

MATERIALS AND METHODS

A field experiment was carried out at Tameia Agric. Res. Station Fayoum Governorate during 2011 and 2012 summer seasons to study the effect of irrigation water and nitrogen fertilization management and their interaction on seed cotton yield, yield components and some crop - water relations. To achieve these objectives, three irrigation regimes i.e. irrigation as 30, 50 and 70% of the available soil moisture were depleted (ASMD%) were combined with three N- fertilization levels, i.e. 55, 70 and 85 kg N fed^{-1} (as ammonium nitrate 33.5%N) in a split plot design with four replicates. The main plots were occupied by irrigation regime treatments, whereas nitrogen levels were assigned to sub-plots. The sub –plot area was 21.0 m^2 (3×7m) which contained five ridges of 7.0 m length and 0.6 m width. Calcium super phosphate (15.5% P_2 O_5) at the rate of 150 kg fed^{-1} and potassium sulphate (46% k_2O) at the rate of 50 kg fed^{-1} were added during the field preparation. The assessed nitrogen levels were applied in two equal doses just before the 1^{st} and 2^{nd} irrigations. Cotton Seeds (Giza 90 cv.) at the rate of 30 kg/fed were planted on March 15^{th} in hills 20 cm apart and thinned to leave two plants/hill just before the first irrigation in both seasons. Cotton picking was executed on August 21^{st} and August 24^{th} in 2011 and 2012 seasons, respectively. Particle size distribution and some soil chemical characteristics of the experimental site were determined according to klute (1986) and Page *et al.* (1982) and data are recorded in Table 1.

It is worthy to mention that, under the adopted irrigation regimes, the soil was sampled regularly and watering was practiced to refill the root zone as the average of predetermined soil moisture depletion attained (mean of 60 cm depth). The furrow – irrigated cotton crop under 30. 50 and 70% ASMD regimes received 10, 8 and 7 irrigation events, respectively, in the two seasons of study and irrigation date and irrigation cycles are reported in Table 2.

Crop - water relationships

1. Seasonal consumptive use (ETc)

The crop water consumptive use (ETc) was determined via soil sampling of each sub-plot, just before and after 48 hours from each irrigation, as well as at harvesting time. The soil samples were taken in 15 cm increment system to 60 cm depth of the soil profile. Bulk density and some soil moisture constants are recorded in Table 3 .The crop water consumptive use, between each two successive irrigations, was calculated according to Israelsen and Hansen, (1962) as follows :-

$$Cu\ (ETc) = \{ (Q_2 - Q_1) / 100\} \times Bd \times D$$

Where:

Cu = Crop water consumptive use (cm).

Q_2= Soil moisture percentage by weight, 48 hours after irrigation.

Q_1= Soil moisture percentage by weight, just before the next irrigation.

Bd = Soil bulk density (g cm^{-3}).

D = Soil layer depth (cm).

Table 1: Particle size distribution and some soil chemical analyses of the experimental field at 2011 and 2012 seasons (two seasons average)

<table>
<tr><td colspan="8">Particle size distribution</td><td colspan="3" rowspan="2">Organic matter %</td><td colspan="4" rowspan="2">$CaCo_3$ %</td></tr>
<tr><td colspan="2">Sand%</td><td>Silt%</td><td colspan="2">Clay%</td><td colspan="3">Textural class</td></tr>
<tr><td colspan="2">49.80</td><td>21.2</td><td colspan="2">38.00</td><td colspan="3">Clay loam</td><td colspan="3">1.59</td><td colspan="4">5.18</td></tr>
<tr><td colspan="4">Soluble cations, meq/L</td><td colspan="4">Soluble anions, meq/L</td><td>EC dS/m</td><td>pH 1:2.5 Extract</td><td>CEC meq/ 100 g soil</td><td colspan="4">Exchangeable Cations meq/100 g soil</td></tr>
<tr><td>Ca^{++}</td><td>Mg^{+}</td><td>Na^{+}</td><td>K^{+}</td><td>Cl^{-}</td><td>HCO_3^{-}</td><td>CO_3^{--}</td><td>SO_4^{--}</td><td rowspan="2">4.0</td><td rowspan="2">7.9</td><td rowspan="2">32.47</td><td>Ca^{++}</td><td>Mg^{++}</td><td>K^{+}</td><td>Na+</td></tr>
<tr><td>8.18</td><td>7.69</td><td>24.67</td><td>0.33</td><td>20.37</td><td>3.06</td><td>-</td><td>17.08</td><td>16.29</td><td>10.29</td><td>4.05</td><td>1.2</td></tr>
</table>

Table 2 : Irrigation event, dates of irrigation and irrigation cycle under different irrigation regime treatments in 2011 and 2012 seasons

Irrigation event	2011 Season						2012 Season					
	Irrigation regimes (ASMD %)						Irrigation regimes (ASMD %)					
	30		50		70		30		50		70	
	Date	Irrigation Cycle (days)	Date	Irrigation Cycle (days)	Date	Irrigation Cycle (days)	Date	Irrigation Cycle (days)	Date	Irrigation Cycle (days)	Date	Irrigation Cycle (days)
Planting	15/3	-	15/3	-	15/3	-	15/3	-	15/3	-	15/3	-
First	4/4	20	4/4	20	4/4	20	3/4	19	3/4	19	3/4	19
Second	20/4	16	24/4	20	29/4	25	20/4	17	24/4	21	30/4	27
Third	4/5	14	13/5	19	22/5	23	5/5	15	14/5	20	24/5	24
Fourth	17/5	13	30/5	18	12/6	21	18/5	13	1/6	18	15/6	22
Fifth	28/5	11	15/6	16	2/7	20	29/5	12	18/6	18	5/7	20
Sixth	10/6	13	3/7	18	22/7	20	10/6	12	4/7	16	25/7	20
Seventh	21/6	12	20/7	17	11/8	20	22/6	12	19/7	15	13/8	19
Eighth	4/7	13	3/8	14	-	-	6/7	14	4/8	16	-	-
Ninth	22/7	18	-	-	-	-	20/7	14	-	-	-	-
Tenth	6/8	15	-	-	-	-	7/8	18	-	-	-	-
Picking	21/8	16	21/8	19	21/8	11	24/8	18	24/8	21	24/8	12
Irrigations count		10		8		7		10		8		7

Table 3 : Bulk density and some soil moisture constants of the experimental field (average of two seasons)

Soil depth (cm)	Field capacity (%, wt/wt)	Wilting point (%, wt/wt)	Available moisture (%, wt/wt)	Bulk density ($gmcm^{-3}$)	Available moisture (mm)
00 - 15	42.46	21.06	21-40	1.41	45.26
15 - 30	40.73	20.81	19.92	1.40	41.83
30 - 45	37.12	18.55	18.57	1.31	36.49
45 - 60	36.55	18.32	18.23	1.34	36.64
Mean	39.22	19.66	19.53	1.37	Total 160.22

2. Daily ETc rate ($mmday^{-1}$)

was calculated from the ETc between each two successive irrigations divided by the number of days.

3. Reference evapotranspiration (ET_0)

Was estimated as a monthly rate ($mmday^{-1}$) using the monthly averages of weather factors of Fayoum Governorate (Table 4) and the procedures of the FAO - Penman Monteith equation (Allen *et al.* 1998).

4. Crop Coefficient (Kc).

The crop coefficient was calculated as follows :-

$$Kc = ETc/ET_0$$

Where:

ETc = Actual crop evapotranspiration ($mm\ day^{-1}$)

ET_0 = Reference evapotranspiration ($mm\ day^{-1}$)

5. Water Use Efficiency (WUE)

The water use efficiency or the productivity of consumed water unit , as kg seed cotton yield/m^3 water consumed, was calculated as outlined by Vites (1965) as follows :-

WUE, kg seed cotton yield m^{-3} = seed cotton yield ($kgfed^{-1}$)/ seasonal ETc (m^3fed^{-1})

Table 4 : Monthly averages of weather factors for Fayoum Governorate during 2011 and 2012 growing seasons

Month	season	Temperature C°			Relative Humidity (%)	Wind speed ($msec^{-1}$)	Pan evaporation ($mmday^{-1}$)	Total solar radiation ($MJ\ m^{-2}\ day^{-1}$)
		Min	Max	Mean				
March	2011	31.8	14.3	23.00	46	2.4	5.9	459
	2012	32.4	11.8	18.6	52	2.4	5.8	450
April	2011	28.5	13.7	21.1	47	2.4	5.9	545
	2012	29.1	13.6	21.3	49	2.5	5.6	540
May	2011	32.8	17.4	25.1	44	2.8	6.5	584
	2012	34.1	18.3	26.2	45	2.7	6.7	570
June	2011	35.7	20.6	28.2	48	3.0	8.1	643
	2012	38.4	21.8	30.1	44	2.6	8.6	635
July	2011	38.7	22.5	30.6	50	2.6	7.9	630
	2012	39.8	23.6	31.7	45	2.2	8.1	625
August	2011	38.6	22.9	30.8	49	2.4	7.2	598
	2012	38.0	25.2	31.6	49	2.1	6.9	580

RESULTS AND DISCUSSION

I.Seed cotton yield and yield components :

The results in Table 5 reveal that seed cotton yield and its components were significantly affected by the adopted irrigation regime treatments in both seasons. Irrigation at 30% ASMD gave the highest seed cotton yield amounted to 975.29 and 921.71kgfed^{-1} in 2011 and 2012 seasons, respectively. Further increasing of ASMD% regime to be 50 and 70 caused significant reductions in cotton seed yield reached 14.16 and 13.78% and 30.29 and 30.49% in 2011 and 2012 seasons, respectively, comparable with 30% ASMD regime. The present results are in harmony with those of Yudhveer Singh *et al.* (2010) who found that, under drip irrigation, reduction in seed cotton yield reached 9.3%, as the crop was irrigated at 0.8 Etc regime compared with the yield under full irrigation. The author added that further increase in deficit irrigation from 0.7 Etc to 0.5 Etc significantly decreased seed cotton yield . In addition, Oweis *et al.*(2011) reported that drip – irrigated cotton yield (lint plus seed, or lintseed) was reduced by 56.1%, under 40% irrigation regime, comparable with 100% irrigation one. Furthermore, Wen *et al.* (2013) reported reductions in cotton lint yield ranged from 5.3 to 25.4% and from 32.0 to 34.0% under Etc - based 80 and 70% traditional deficit irrigation schemes, respectively, comparable with control (100% Etc).

All of the measured yield components tended to reduce as ASMD% increased and such trend was true in 2011 and 2012 seasons. With irrigating at 50% ASMD the reductions in number of boll/plant amounted to 10.92 and 9.91%, number of open bolls/plant 10.68 and10.88% and seed cotton yield /plant 7.86 and 7.57%. in 2011 and 2012 seasons, respectively, comparing with 30% ASMD regime. Further increasing of ASMD regime to 70%, the corresponding reductions in the above mentioned yield components were (20.0 and 20.06%), (17.08 and 17.68%) and (12.93 and 13.02%) in the order, respectively, as compared with 30% ASMD regime. It could be concluded that increasing the available soil moisture depletion caused remarkable decreases in seed cotton yield and yield components. In addition, these results may be attributed to the negative effect of soil moisture deficit on plant photosynthesis which in turn reduced vegetative growth and dry matter accumulation in plant organs during the reproductive stage. These results are in full agreement with those obtained by Eid and Hosny (1995), Mohamed *et al.* (1995), Mohamed *et al.* (1999) and Ibrahim (2007).

Table 5 : Effect of irrigation regime, N- level and their interaction on seed cotton yield and yield components in 2011 and 2012 seasons

Irrigation regime	N - levels (kg $Nfed^{-1}$)	bolls No /plant	open bolls No /plant	Seed cotton yield $plant^{-1}$ (g)	Seed cotton Yield ($kgfed^{-1}$)
2011 season					
30% (ASMD)	55	22.60	16.80	30.84	804.50
	70	25.20	18.90	35.91	980.71
	85	27.20	20.50	40.16	1140.65
Mean		25.00	18.73	35.64	975.29
50% (ASMD)	55	20.20	15.10	27.97	711.22
	70	22.60	16.80	33.12	860.34
	85	24.00	18.30	37.44	940.08
Mean		22.27	16.73	32.84	837.21
70% (ASMD)	55	18.10	14.10	25.69	580.62
	70	20.00	15.30	31.51	690.84
	85	21.90	17.20	35.89	768.15
Mean		20.00	15.53	31.03	679.87
N - fertilization mean					
55 (kg $Nfed^{-1}$)		20.30	15.33	28.17	698.78
70 (kg $Nfed^{-1}$)		22.60	17.00	33.51	843.96
85 (kg $Nfed^{-1}$)		24.37	18.67	37.83	949.63
LSD, 05					
Irrigation regimes		2.13	1.23	2.03	13.48
N- levels		1.23	0.91	0.97	12.45
Interaction		NS	NS	NS	21.56
2012 season					
30% (ASMD)	55	21.90	16.10	30.10	770.94
	70	24.00	18.00	34.80	903.46
	85	26.80	20.20	39.72	1090.74
Mean		24.23	18.10	34.87	921.71
50% (ASMD)	55	19.90	14.60	27.50	680.36
	70	22.10	16.20	32.00	806.45
	85	23.50	17.60	37.20	896.16
Mean		21.83	16.13	32.23	794.32
70% (ASMD)	55	17.70	13.70	25.07	560.55
	70	19.30	14.10	30.81	640.80
	85	21.10	16.90	35.12	720.75
Mean		19.37	14.90	30.33	640.70
N- fertilization mean					
55 (kg $Nfed^{-1}$)		19.83	14.80	27.56	670.62
70 (kg $Nfed^{-1}$)		21.80	16.10	32.54	783.57
85 (kg $Nfed^{-1}$)		23.80	18.23	37.35	902.55
LSD, 05					
Irrigation regimes		0.63	0.57	0.31	13.96
N- levels		1.14	0.34	0.37	9.20
Interaction		NS	0.59	0.63	15.94

Regarding the effect of N fertilization level, data in Table (5) show that seed cotton yield and its component were significantly affected by different N levels in both seasons. Increasing N level from 55 to 70 or 85 kg N/fed significantly increased seed cotton yield/fed by 20.78 and 35.90% and by 16.84 and 34.58% in 2011 and 2012 seasons, respectively. The yield components under study i.e. number of boll, number of open bolls/plant, seed cotton yield /plant exhibited gradual increases, in the two seasons of study, as N level gradually increased. These results may be referred to N role in enhancing cotton growth and dry matter accumulation in plant organs. These results are in harmony with those reported by El-Shahawy and Hamoda (2010) and Emara, and El-Gammaal (2012) who indicated that No. of opened bolls/plant, boll weight, seed index and seed cotton yield were increased due to increasing nitrogen levels.

With respect to the effect of irrigation regimes and N fertilization levels interaction, results in Table (5) show that seed cotton yield was significantly affected in the two seasons of study. Irrigation at 30% ASMD as interacted with 85kg $Nfed^{-1}$ level gave the highest average of seed cotton yield (amounted to 1140.65 and 1090.74 kg fed^{-1} in 2011 and 2012 seasons, respectively) , bolls No./plant , open bolls No. / plant and seed cotton yield/ plant. On the contrary, the lowest averages of seed cotton yield (580.62 and 560.55 kg/fed in 2011 and 2012 season, respectively) and the above mentioned yield components were obtained under irrigation at 70% ASMD and applying 55 kg $Nfed^{-1}$ level.

II. Crop - water relations

1. Seasonal evapotranspiration (ET_C)

The results in Table (6) show that seasonal ET of cotton crop, as a function of the adopted irrigation regimes and N fertilization levels interaction, were 92.54 and 90.96cm in 2011 and 2012 seasons, respectively. The highest ETc values (96.81 and 95.04 cm) were obtained from irrigating at 30% ASMD. Irrigating according to 50 or 70% ASMD regimes resulted in lower ETc figures amounted to 4.14 and 9.09% in 2011season and 4.32 and 8.56% in 2012 one, respectively, comparable with 30% ASMD regime. These results may be referred to that increasing moisture depletion in the root zone will decrease transpiration from plant^{s} foliage and evaporation from soil surface, which in turn reduced ETc. Such findings are in agreement with those reported by Eid and Hosny (1995), Mohamed *et al.* (1995), and Ibrahim (2007).

Regarding the effect of N fertilization levels on ETc , data in Table (6) indicate that 85 kg N/fed level gave the highest ETc values which comprised 95.0 and 93.76 cm in 2011 and 2012 seasons respectively. Decreasing N fertilization level to 70 or 55 kg N/fed resulted in lower ETc values amounted to 2.29 and 5.48% in 2011 season and 2.87 and 6.10% in 2012 one, respectively, comparing with 85 kg N/fed level. These results indicate that increasing N level caused an increase in ETc to match both higher seed cotton yield and yield components.

With respect to the interaction effect of the adopted irrigation regimes and N fertilization levels treatments , results in Table (6) show that the highest ETc values (99.05 and 97.78 cm in 2011 and 2012 seasons, respectively) were recorded under irrigation at 30% ASMD (short irrigation cycle) and 85 kg N/fed level interaction. On the contrary, the lowest ETc values (85.27 and 83.75 cm in the two successive seasons) were noticed due to irrigation at 70% ASMD (extended irrigation cycle) and 55 kg N/fed level interaction.

Table 6 : Effect of irrigation regime, N - fertilization level and their interaction on cotton seasonal evapotranspiration (ETc, mm) in 2011 and 2012 seasons.

Irrigation regime (ASMD%)	2011 season				2012 season			
	N - fertilization level (kg/fed)				N - fertilization level (kg/fed)			
	55	70	85	Mean	55	70	85	Mean
30	94.16	97.21	99.05	96.81	92.24	95.09	97.78	95.04
50	89.94	93.09	95.36	92.80	88.14	91.00	93.66	90.93
70	85.27	88.15	90.61	88.01	83.75	87.12	89.84	86.90
Mean	89.79	92.82	95.00	92.54	88.04	91.07	93.76	90.96

2. Reference evapotransportation (ET_0)

Reference evapotranspiration (ETo, mmday^{-1}) values during cotton growing season were estimated using weather data of Fyoum Governorate and the FAO-Penman Monteith equation (Allen *et al.*,1998). The ET_0 values Table (7) indicate that the daily ET_0 started with low values during March, then increased during April and May to reach its highest values during June and July, thereafter decreased again during August. These results are mainly attributed to the changes in the weather factors from month to the other. In this respect, Allen *et al.* (1998) reported that the reference ET values depend mainly on crop characteristics and the evaporative power e.g. air temperature, solar radiation, air relative humidity and wind speed which prevailing during the crop growing period.

3. Crop coefficient (Kc).

The crop coefficient (K_C) is a function of both Etc and ET_0 values and mainly affected by the crop vegetation and ground cover. The Kc values in the present investigation were estimated from average daily evapotranspiration of cotton plants for each month (mmday^{-1}) of the highest yielding interaction e.g. irrigation at 30% ASMD and addition of 85 kg Nfed^{-1}. The results in Table (7) show that, in 2011 and 2012 seasons, respectively, Kc values started low (0.57 and 0.56) at the initial stage during March which may be referred to higher diffusive resistance of the bare soil after planting and during germination stage. Thereafter, the Kc values tended to increase during April (0.85 and 0.83), May (0.91 and 0.91) and June (1.06 and 1.01) as the crop cover percentage increased and the crop reached the maximum flowering period. At July, Kc reached the maximum values (1.18 and 1.09) which matched bolls formation stage and the peak of crop water requirement. At August Kc values were reduced and reached (0.81 and 0.79) at late season stage. These result are in accordance with those reported by Doorenbos *et al*. (1979) who reported that the Kc for different cotton growth stages are 0.4 - 05 for initial stage , 0.7- 0.8 for development stage , 1.05 - 1.25 for mid- season stage , 0.8 - 0.9 for late season and 0.65 - 0.7 at picking . Under the Egyptian conditions, Ibrahim (2007) reported similar results.

4. Water use efficiency (WUE) .

The efficient management of limited water resources is an important concern in the irrigation commands in order to attain high WUE figures. Water use efficiency can be improved by proper irrigation scheduling and other agricultural practices. In the herein research trail, WUE parameter has been used to evaluate cotton production per the unit of water consumed by the crop under the adopted experimental treatments

Table 7: Reference evapotranspiration (ET_0, mmday^{-1}), cotton daily ET (ET_C, mmday^{-1}) and crop coefficient (Kc) of the highest yielding interaction* in 2011 and 2012 seasons

	2011 season						2012 season					
	March	April	May	June	July	August	March	April	May	June	July	August
ET_0 (mmday^{-1})	4.51	5.30	6.80	7.7	7.0	7.0	4.50	5.43	6.60	7.50	7.50	6.50
ET_C (mmday^{-1})	2.57	4.50	6.19	8.16	8.26	5.67	2.52	4.51	6.00	7.58	8.18	5.53
K_C	0.57	0.85	0.91	1.06	1.18	0.81	0.56	0.83	0.91	1.01	1.09	0.79

* irrigation at 30% ASMD and addition of 85 kg Nfed^{-1}

The results in Table 8 point out that mean of water use efficiency values, as influenced by the adopted irrigation regimes and N fertilization levels were 0.209 and 0.204 kg seed cotton / m^{3}water consumed in 2011 and 2012 seasons , respectively. The highest WUE values (0.230 and 0.230 kg seeds cotton/m^3 water consumed) were detected from irrigation at 30% ASMD in 2011 and 2012 seasons, respectively. Such results are in accordance with Mohamed *et al* (1995), Oweis *et al*. (2011) and Mustafa Ünlü *et al*.(2011) who found that higher WUE values for cotton crop were recorded under full irrigation scheme. Nevertheless, Dagdelen *et al*.(2009) found that 25% of full irrigation regime resulted in the highest WUE, comparing with 100% regime. Such different trends may be due to differed experimental circumstances e.g. cotton variety, soil type, irrigation system, prevailing weather elements. Irrigating cotton plants at 70% ASMD gave the lowest WUE values which reached to 0.184 and 0.175 kg seed cotton / m^3 water consumed, respectively, in 2011 and 2012 seasons which could be attributed to drastic seed yield reduction under such irrigation regime.

Date in Table 8 clear out that as N fertilization level increased from 55 to be 70 and 85 kg N / fed , WUE values were increased from 0.184 to be 0.216 and 0.228 and from 0.181 to be 0.204 and 0.228 kg seed cotton/ m^3 water consumed in 2011and 2012 seasons, respectively. These results may be referred to that seed cotton yield was increased proportionally more than Etc due to increasing N level.

Regarding interaction effect of the tested irrigation regimes and N fertilization levels, data in Table 8 show that irrigating cotton plants at 30% ASMD and addition 85 kg N/fed gave the highest WUE values which comprised 0.247 and 0.266 kg seed cotton / m^3 water consumed in 2011 and 2012 seasons, respectively. On the contrary, the lowest WUE values e.g. 0.162 and 0.159 kg seed cotton / m^3 water consumed in 2011 and 2012 seasons, respectively , were attained from irrigation at 70% ASMD as interacted with 55 kg Nfed^{-1} level.

It is well known that under limited irrigation water resources, the crop productivity is preferable to determine based on the quantity of irrigation water (consumed or applied) required to obtain the unity of the marketable yield. So, based on the herein WUE results, it is advisable to irrigate cotton crop based on 50% ASMD regime and applying N - fertilizer at 75 or 85 kgfed^{-1} levels in order to accomplish both acceptable water productivity and cotton seed yield figures under Fayoum Governorate conditions.

Table 8: Effect of irrigation regime, N - fertilization level and their interaction on water use efficiency (kg seed cotton / m^3 water consumed) in 2011 and 2012 seasons

Irrigation regime (ASMD%)	2011season				2012 season			
	N - fertilization level (kgfed^{-1})				N - fertilization level (kgfed^{-1})			
	55	70	85	Mean	55	70	85	Mean
30	0.203	0.240	0.247	0.230	0.199	0.226	0.266	0.230
50	0.188	0.220	0.235	0.214	0.184	0.211	0.228	0.207
70	0.162	0.187	0.202	0.184	0.159	0.175	0.191	0.175
Mean	0.184	0.216	0.228	0.209	0.181	0.204	0.228	0.204

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العلاقات المائية ومحصول القطن وتأثرهم بإدارة مياه الري والتسميد النيتروجيني

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الملخص العربي

أقيمت تجربتان حقليتان بمحطة البحوث الزراعية بطامية – محافظة الفيوم خلال موسمي 2012/2011 لدراسة تأثير معاملات الري (الري عند فقد نسب مختلفة من الماء الميسر بالتربة) ومستويات التسميد النيتروجيني على محصل القطن الزهر، مكونات المحصول، وبعض العلاقات المائية للمحصول، ولتحقيق هذه الأهداف توافقت 3 معاملات للري وهي: الري عند I_1: 30%، I_2: 50%، I_3: 70%، فقد من ماء التربة الميسر مع 3 مستويات للتسميد النيتروجيني وهي N_1: 55، N_2: 70، N_3: 85 كجم ن/ف، وذلك في تصميم القطع المنشقة مرة واحدة في 3 مكررات، وكانت أهم النتائج المتحصل عليها كما يلي:

- تأثر محصول القطن الزهر ومكوناته معنوياً بمعاملات الري، مستويات التسميد النيتروجيني والتفاعل بينهما في كلا الموسمين.
- نتجت أعلى متوسطات لارتفاع النبات، عدد اللوز/نبات، عدد اللوز المتفتح/نبات، محصول النبات من القطن الزهر، محصول الفدان من القطن الزهر (1140,65 ، 1090,74 كجم في 2012/2011 على الترتيب) من الري عند فقد 30% من ماء التربة الميسر وإضافة 85 كجم ن/ف، زيادة الإجهاد المائي بالري عند فقد 70% من

ماء التربة الميسر ونقص النيتروجين المضاف إلى 55 كجم ن/ف أعطى أقل متوسطات لمكونات المحصول ومحصول الفدان من القطن الزهر (580,62 / 560,55 كجم في موسمي 2012/2011 على التوالي) .

- كانت قيم الاستهلاك المائي الموسمي الناتجة عن تفاعل معاملات الري مع معاملات التسميد هي: 92,54 / 90,96 سم في 2012/2011 على الترتيب، أدى الري عند فقد 30% من الماء الميسر وإضافة 85 كجم ن/ف للحصول على أعلى قيم للاستهلاك المائي الموسمي والتي كانت 99,05 / 97,87 سم في 2012/2011 على الترتيب بينما كانت أقل قيم الاستهلاك المائي الموسمي الناتجة عن تفاعل معاملات الري مع معاملات التسميد هي 85,27 / 83,75 في الموسمين المتعاقبين، قد نتجت من الري عند فقد 70% من ماء التربة الميسر وإضافة 55 كجم ن/ف، وقد ازداد متوسط الاستهلاك المائي اليومي (مم/يوم) من شهر مارس ووصل إلى قمة الاستهلاك خلال يونيو ويوليو (8,16 ، 8,26 مم/يوم في 2011، 7,58، 8,18 مم/يوم في 2012)، ثم انخفض مرة أخرى خلال أغسطس، وكان ثابت المحصول KC هو 0,57، 0,84، 0,91, 1,04، 1,14، 0,80 (متوسط الموسمين) خلال مارس، أبريل، مايو، يونيه، يوليو، أغسطس على الترتيب.
- نتجت أعلى قيم لكفاءة استهلاك الماء وهي 0,247، 0,266 كجم قطن زهر/ م3 ماء مستهلك في 2012/2011 على الترتيب من الري عند فقد 30% من الماء الميسر وإضافة 85 كجم ن/ف.