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Optimum Irrigation Schedules for Cotton under Deficit Irrigation Conditions

Coordinated Research Project of the use of nuclear and related techniques in assesment of irrigation schedules of field crops to increase effective use of water in irrigation projects.

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SUMMARY

The study aimed at determining the followings; water consumptions, irrigation water requirements of new cotton variety N84; specific growth stages of cotton which are less sensitive to stress so that the irrigation could be avoided without significant yield decrease; and interactions between deficit irrigation and nitrogen fertilizer use.

The experiment was set up with 6 irrigation and three nitrogen fertilizer (0, 60 , 120 kg.ha^{-1}) treatments. The irrigation treatments employed single stress at vegetative, flowering and boll formation stages, in addition to full irrigation, continuous stress and the traditional practice. In stress conditions available soil water depleted to 75 - 80 %, whereas in normal irrigation the depletion was 40 % in 0.90 m. of root zone.

In full irrigation treatment 8 irrigations were applied, whereas 3 or 4 irrigations were needed in continuous stress conditions. The number of irrigations were 6 or 7 for other stress treatments.

Irrigation water applications varied from 424 to 751 mm. Seasonal ET were ranged between 659 and 899 mm. The highest monthly ET was in August for all of the treatments. Daily ET were found to vary from 2.2 to 12.1 mm.day^{-1}.

The seed cotton yields, ky values and yield - N indices have indicated that the vegetative stage was more sensitive to water stress. The stress at boll formation stage had slight effects on these parameters. Under limited water resource conditions, vegetative growth period of cotton should be given preference for irrigation, followed by flowering period. Omitting irrigation in boll formation period would result in 4.3 to 9.1 % water savings.

Yield changes with respect to N rates showed that high N doses are accompained by high yields. Nitrogen recoveries either from fertilizers or soil revealed high uptakes in full irrigation conditions. Nitrogen use efficiencies were also high in these conditions. Average of three years put forth that 19 % of N in stress conditions and 29 % in full irrigation were efficient. The distribution of N uptake in different plant parts showed that seeds are the first superiority order.

1. INTRODUCTION

Irrigation should be practiced in the majority of Turkey since rainfall is insufficient to meet the plant water requirements for optimum crop growth and yield. Investments for irrigation projects are of top priority like other arid and semi-arid regions of the world. The total irrigated area is app. 4 x 10^6 ha. A new irrigation project, aimed at irrigating 1.8 x 10^6 ha. of agricultural land in Southeast Anatolia is under construction.

Although the promising improvements have been achieved, major problems confront the future of irrigation development in Turkey. Chief among these are; rapidly decreasing surface and ground-water resources due to drought climatological conditions occured particularly in the western regions, escalating cost of pumping and intensified competition for water from expanding urban areas and industry.

The impact of progressive drought on the water resources of irrigation schemes in Western part of Turkey has of vital importance for the last 5 years. For example, in the Lower Gediz Irrigation Project which covers an area of 107725 ha., the reservoir storages were decreased up to 16 % - 35 % of those available in normal years since 1988. Water shortages limited irrigation deliveries to a great extend and usually water distribution was performed for 3 or 4 weeks at the peak demand period of the major crops.

Limited availability of irrigation water requires fundamental changes in irrigation management or urges the application of water saving methods. Generally applicable procedure is to assess the benefits of changing irrigation water management based on deficit-partial irrigation which is the practice of deliberately underirrigating crops. In order to implement deficit irrigation successfully, specific growth stages of the major crops at which they can withstand water stress with no significant effect on plant growth and yield need to be well identified. Thus, it will be possible to develop optimum schedules for implementing deficit irrigation programmes.

In Aegean Region, cotton is one of the main crops with approximately 240.000 ha. of planted area.

The objectives of the study were to improve solutions to problems as the following;

- -Assessing the water consumptions, irrigation water requirements, irrigation intervals and thus developing irrigation schedules for new cotton variety of N84,
- -Developing reliable crop production function that relate water use to crop yield,
- -Relations between high nitrogen fertilization and improved water stress tolerance of plants. Nitrogen recoveries and use efficiencies under full irrigation and stress conditions.
- -Identifying specific growth stages of cotton during

which it is less sensitive to water stress so that the irrigation can be omitted without significant yield decrease and thereby considerable saving can be achieved in total irrigation water application.

2. MATERIAL AND METHODS

The experiment was conducted in Bornova -Izmir (38° 24' N, 27° 10' E). In the experiment a local new cotton variety N 84 was used.

The climate is of the Mediterranean type which is characterized by rainy and warm winters and dry and hot summers. Long term average annual precipitation is 524.8 mm. During the experiment years in 1992, 1993 and 1994 annual rainfall values were recorded as 293.5 mm, 554.1 mm and 484.6 mm, respectively. Precipitation is concentrated mostly between October and May. Mean annual temperature and relative humidity are 17.1 °C and 61 %, respectively. Annual class A pan evaporation is about 1569 mm. with daily maximum of 9.0 mm. in July.

The experiment soil on which the trial was conducted is alluvial. Some physical and chemical properties of the soil is given in table 1 and 2.

TABLE 1. PHYSICAL PROPERTIES OF THE EXPERIMENTAL SOILS.

Soil depth (cm)	Texture	F.C. (%)	P.W.P. (%)	Bulk density ($gr.cm^{-3}$)
0 - 30	clay loam	28.90	12.13	1.40
30 - 60	clay loam	25.00	13.68	1.62
60 - 90	clay loam	23.88	13.03	1.69
90 - 120	clay loam	20.79	11.68	1.70

TABLE 2. CHEMICAL PROPERTIES OF THE EXPERIMENTAL SOILS.

Soil depth (cm)	pH	T.S.S (%)	$CaCO_3$ (%)	O.M (%)	C.E.C. $me.100^{-1}gr$
0 - 20	7.05	0.085	10.85	1.90	32.08
20 - 40	7.15	0.059	13.85	2.00	28.25

Soil was found clay loam in texture. Water content at field capacity varied from 20.79 to 28.90 %, whereas that at permanent wilting point varied from 11.68 to 13.68 % on dry weight basis. Soil bulk density values were found between 1.40 - 1.70 $gr.cm^{-3}$. Available water holding capacity for 0.90 m. soil depth was 180.5 mm.

The soil was neutral in reaction and low inorganic matter. $CaCO_3$ and cation exchange capacities changed between 10.85 - 13.85 % and 28.25 - 32.08 $me.100^{-1}gr$, respectively. Total soluble salts changed between 0.059 - 0.085 %. The available phosphorus and total nitrogen in soil were 0.25 ppm and 0.13 %, respectively.

Seeding was done on 13th of May in 1992 and 18th of May in 1993 and 1994. A row spacing of 0.70 m. and within - row spacing of 0.25 m.- population density of 57000 plants per hectare - were used.

The experiment was set up in split plot design with six irrigation treatments as main plots and three nitrogen fertilizer rates (0 - 60 - 120 $kg.ha^{-1}$) as subplots, with four replications.

Since vegetative growth is continued during flowering and boll formation, and flowering is continued during boll formation, the distinction of cotton growth stages is difficult. Therefore, the growth stages were divided into three phases following Doorenbos and Kassam [1]:

1. Vegetative stage from 25 days after emergence until 5 % of flowering opening,
2. Flowering stage from 5 % until 70 - 80 % flowering opening,
3. Boll formation stage from 70 - 80 % flower opening until opening fist bolls (Table 3).

TABLE 3. IRRIGATION TREATMENTS.

Treat.	Vegetative	Flowering	Boll forma.	Description
		controls		
111	1	1	1	Full irrigation
TR	---	---	---	Trad. practice
000	0	0	0	Continu. stress
		One stress		
011	0	1	1	Stress at vege.
101	1	0	1	Flowering
110	1	1	0	Boll formation

(1) Normal watering; (0) Water stress

In full irrigation the soil water content was allowed to deplete to 60 % of available water content of the plant root zone (0.90 m.), whereas in the stress conditions it was depleted to 20 - 25 % during the spesific growth stage.

The traditional irrigation, generally adopted by the farmers in the region is to apply irrigation 4 or 5 times with 15 - 25 days interval particularly during the flowering period.

As for the nitrogen fertilizer rates, 120 kg.ha^{-1} -high input- and 60 kg.ha^{-1} -low input-were applied. For reliable statistical analysis, control plots which didn't receive nitrogen fertilizer were considered as well. In order to determine fertilizer N recovery and fertilizer use efficiency, ^{15}N labelled fertilizers were applied to microplots in full irrigation (111) and continuous stress (000) treatments and in the high input i.e. 120 kg per ha applications. Morever, the other fertilizers were dressed for each plot at constant amounts as 80 kg.ha^{-1} P_2O_5 and 100 kg.ha^{-1} K_2O.

At planting the plot sizes were 4.2 m.x 6.0 m. = 25.2 m^2, whereas the basic plot sizes harvested were 2.8 m.x 4.0 m. = 11.2 m^2. The soil water was at field capacity on all plots at sowing. Irrigation water was applied to furrows by perforated pipes.

Soil moisture status down to a depth of 1.50 m. was frequently monitored for each treatment with gravimetric (0-0.20 m.) and neutron probe (0.20-1.50 m.). Neutron probe was calibrated in situ. Within one replication, each of the irrigation treatments was equipped with two access tubes for determining soil water content in 0.15 m. increments. Around one of the access tubes, tensiometers were installed at each of the depths 45, 60, 80 and 110 cm. for determining soil water potential. Measurements of soil water content and water potential were taken frequently throughout the growing season, in order to calculate crop actual seasonal evapotranspiration using water balance equation as:

$$ET = I + P + C - D \mp \Delta S$$

where

ET is the evapotranspiration (mm),
I is the irrigation (mm),
P is the precipitation (mm),
C is the capillary (upward) rise (mm),
D is the downward drainage (percolation) (mm),
ΔS is the change in soil water storage (mm).

The amount of irrigation water to be applied for each irrigation was determined as the amount necessary to replenish a 0 to 0.90 m. soil profile to field capacity.

Cotton yields were harvested by hand in two pickings (October and November) after removing border effects. At harvest seed cotton yields were determined.

Water use efficiencies were calculated based on total depth of irrigation water (WUE_f) and seasonal evapotranspiration (WUE_a).

In order to evaluate the sensitivity to water stress, yield response factor ky was calculated for each irrigation *treatment. ky is defined as ratio of relative yield decrease* to relative evapotranspiration deficit. This relation can be writen as:

$$\left(1 - \frac{Ya}{Ym}\right) = ky \times \left(1 - \frac{ETa}{ETm}\right)$$

where

Ya	is the actual yield ($kg.ha^{-1}$),
Ym	is the maximum yield ($kg.ha^{-1}$),
ETa	is the actual evapotranspiration (mm),
ETm	is the maximum evapotranspiration (mm).

Yield - N index which is defined as the ratio of kg seed cotton production to kg of applied N was calculated, for all treatments. Total N and ^{15}N contents of the cotton parts (leaf, stem, burs, seed, lint) were measured and the same procedure was repeated for the soil samples taken from the labelled microplots. The data was used to determine the total N yield (uptake), fertilizer N yield, soil N yield and nitrogen use efficiency.

3. RESULTS AND DISCUSSION

3.1. WATER REQUIREMENT AND CONSUMPTIVE USE

Rainfall during the growing seasons of experiment was extremely low, allowing the desirable stress to be applied. May through October the rainfall totaled in 1992, 1993 and 1994 growing seasons, 7.6 mm., 2.5 mm. and 6.2 mm., respectively. June, July and August were almost completely dry.

Number of irrigations, seasonal evapotranspiration and depth of irrigation water applied to different treatments are given in Table 4.

TABLE 4. IRRIGATION TREATMENT EFFECTS ON NUMBER OF IRRIGATIONS, SEASONAL ET AND IRRIGATION WATER APPLIED.

Year	Treat.	Number of irr.	Seasonal ET(mm)	Irrigation water (mm)	Relative ET (%)	Relative irrigation water (%)
1992	111	8	---	576	---	100.0
	110	7	---	552	---	95.7
	101	6	---	515	---	89.3
	011	6	---	521	---	90.3
	000	4	---	471	---	81.7
	Tr.	4	---	462	---	80.2
1993	111	8	834	647	100.0	100.0
	110	7	763	588	91.5	90.9
	101	6	701	544	84.1	84.1
	011	6	734	574	88.0	88.7
	000	4	659	476	79.0	73.6
	Tr.	5	702	553	84.2	85.5
1994	111	8	899	751	100.0	100.0
	110	7	828	703	92.1	93.6
	101	6	718	564	79.9	75.1
	011	6	748	640	83.2	85.2
	000	3	680	424	75.6	56.5
	Tr.	5	844	626	93.9	83.4

In full irrigation treatments 8 irrigations were applied, as for the continuous stress condition 3 or 4 irrigations were needed throughout the growing period.Total number of irrigations were 6 or 7 for other treatments. In traditional irrigation treatment 4 or 5 irrigations were applied as the normal application adopted by the farmers. Although, in the experimental years drought conditions were very severe and the available water distributed within the irrigation schemes of Aegean Region was sufficient to apply 2 times in July and August, i.e. peak water consumption period of cotton.

ET in the first year of the experiment, 1992, is not given because of problems in obtaining some water balance components. Seasonal ET increased with increased number and depth of irrigation water applied (Table 4). The highest seasonal ET occured in the full irrigation treatment obviously due to adequate soil moisture during entire growth period. As was expected the lowest occured in continuous stress treatment. On the other hand, the values have been found close together in the treatments of 101 and 011.

Seasonal ET varied between 659 and 834 mm in 1993 and between 680 and 899 mm in 1994. Similar ET values have been reported by several researchers under the climatic conditions similar to those of the experiment [2,3].

The variations of cumulative and daily evapotranspiration with time are shown in Figs.1, 2 and 3. The cumulative and daily ET values were also influenced by stress treatments which changed the number and depth of irrigations. Daily ET values were found to vary from 2.2 to 11.4 mm.day^{-1} and 2.4 to 12.1 mm.day^{-1} in 1993 and 1994 respectively. The maximum ET rates were generally obtained in mid August, i.e. peak blooming stage of crop growth. The period of peak ET rate was almost the same in both of the experiment years.

The seasonal and daily ET in 1993 was lower than in 1994. Some climatic factors may have caused this,particularly that the temperature was higher in 1994. Average monthly temperatures were continuously higher during growth period, except June (Fig.4). The temperature variations in July, August, September and October were 0.6, 1.2, 3.2 and 1.4 °C, respectively.

Irrigation water amounts, determined on the basis of soil water storage depletion within the 0.90 m. of plant root zone were found within the range of 462 - 576 mm. in 1992, 476 - 647 mm. in 1993 and 424 - 751 mm. in 1994. 18.3 %, 26.4 % and 43.5 % of irrigation water was saved in continuous stress conditions in 1992, 1993 and 1994, respectively. In the treatments where water stress was created at different growth stages the irrigation water savings were ranged between 4.3 % - 24.9 % (Table 4).

The results of the soil water balance calculation have shown that, downward drainage below the crop root zone (0.90 m.) and upward flow from this zone were particularly higher in stress created treatments. Following an irrigation initially downward flow occured and several days after irrigation the flow reversed to the upward direction for almost all of the treatments. However, the upward flow amounts of the water balance component were totaly higher than the amounts of percolation in all treatments. In continuous stress treatment the highest percolation and upward flow amounts were obtained, whereas these amounts were at minimum in full irrigation treatment. Contributions of upward flow to the seasonal ET were 11.2 % in 1993 and 15.0 % in 1994 for 000 treatment and 4.5 % in 1993 and 3.0 % in 1994 for 111 treatment. Similar ratios of upward flow have been reported by Van Bavel et. al. [4] for sorghum. The researchers attributed some part of this contribution to direct root absorption from deeper zone rather than capillary rise.

3.2. SEED COTTON YIELD

Results concerning seed cotton yields are shown in Table 5.

TABLE 5. SEED COTTON YIELDS UNDER DIFFERENT IRRIGATION AND NITROGEN TREATMENTS.

Year	Treat.	Seed Cotton Yield ($kg.ha^{-1}$)				Relative yield(%)
		N0	N60	N120	Average	
1992	111	2379	3055	3228	2888	100.0
	110	2326	2905	3219	2817	97.5
	101	2310	2545	2884	2580	89.3
	011	1906	2464	2705	2359	81.7
	000	1759	2331	2410	2166	75.0
	Tr.	1674	2420	2241	2112	73.1
Sx 0.05					93.6	
1993	111	2985	3553	3647	3312	100.0
	110	2680	3021	3452	3051	92.1
	101	2677	3096	3263	3012	90.9
	011	2598	3439	3366	3134	94.6
	000	1951	2401	2503	2285	69.0
	Tr.	2305	2824	2898	2676	80.8
Sx 0.05					177.2	
1994	111	3067	3442	3851	3453	100.0
	110	2803	3135	3765	3234	93.7
	101	2462	3141	3313	2972	86.1
	011	2629	2830	3111	2856	82.7
	000	2455	2636	2765	2618	75.8
	Tr.	2742	3419	3468	3210	92.9
Sx 0.05					157.6	

Statistically nonsignificant interactions were determined between irrigation and nitrogen treatments for seed cotton yield. On the average, the hignest seed cotton yield was obtained in full irrigation treatment and the lowest in cotinuous stress treatment. In comparison with the 111 treatment, the yield decrease ratios in 000 were varied between 24.2 and 31.0 %. The seed cotton yields in the treatments of 111 and 110 were recorded to be close to each other, with low (2.5 - 7.9 %) yield decrease ratios.

The yield decreases in 011 were higher than 110 and 101 treatments in 1992 and 1994. However, yield differences were not found significant between these treatments in 1993 (Fig 5).

The seed cotton yields were consistently higher in high nitrogen application for all irrigation treatments.

These results reveal that, the cotton is more sensitive to water stress at vegetative stage and flowering stage follows it. On the other hand, nonsignificant differences have been found between full irrigation and the treatment which stress created at boll formation stage.

In design and management of irrigation systems for deficit irrigation, the irrigation planners must rely upon water production functions that relate water consumption to crop yields. Based on average seed cotton yield and ET, linear functions have been derived (Fig.6) and described for 1993 and 1994, respectively by the equations;

$$Y = -852.64 + 5.14\,ET \quad ; \quad R^2 = 0.71^{*}$$

$$Y = -354.61 + 3.44\,ET \quad ; \quad R^2 = 0.92^{**}$$

where

Y is the seed cotton yield ($kg.ha^{-1}$),
ET is the seasonal evapotranspiration (mm).

Bilgel and Kanber [5], Baştuğ and Tekinel [6] and Sammis [7] reported linear production functions for cotton. Linear functions are almost likely when ET deficits are distributed over several growth periods or when irrigation applications achieve programmed depletions of root zone water [8].

The water production function results indicate the strong relationship between seed cotton yield and ET. When such relationship between yield and ET occurs, the sensitivity to water stress at different growth stages are close to each other.

3.3. EFFECT OF N RATES

Significant responses were observed between N rates and seed cotton yields and increasing trends were apparent.

Excluding the first year of study, second and third year results showed similar tendencies statistically (Table 6).

TABLE 6. SEED COTTON YIELDS, N RATES AND YEARS.

N rates,(kg.ha^{-1})	Seed cotton yield, (kg.ha^{-1})		
	1992	1993	1994
0	2059	2533	2692
60	2619	3014	3100
120	2781	3188	3378
Sx 0.05	56.59	54.13	68.22

With respect to years, yields ranged from 2059 - 2781, 2570 - 3188 and 2692 - 3378 kg.ha^{-1}, respectively. Results also revealed that second and third year yields were higher than the first year which may be attributed to the increased availability of soil N in the fertilizer added plots [9] of 1993 and 1994 study years. However, in the preceeding year of 1992, the experimental field was empty and infertilized. Therefore, N uptake by the first year crop might have been low.

An overall evaluation of 3 year results put forth that N rates had quadratic effects on yield particularly in 000, 011 and Tr. irrigations which are notified as ˜ low yielding treatments ˜. Significant quadratic relations pointed out 100 kg.ha^{-1} of N as the optimum fertilization dose for such irrigation managements similar to above cases.

Current results were also evaluated with respect to yield increases achieved by per unit of added fertilizer and was identified as ˜ yield - N index ˜. In every study year and generally almost in every irrigation treatment, the index decreased implying that there is a fall in crop production with the addition of high N doses (Table 7).

Table 7 shows the yearly and average indices where the declines were much more typical. The 011, 000 and Tr. - low yielding treatments - generally had the low index which confirms the N rate - yield relations in the present study. Similar results are reported by Lathwal et al. [10] in a paper on wheat.

In the study, total N yields (uptake), fertilizer N yields, soil N yields and nitrogen use efficiencies of cotton were also examined under full irrigation and continuous stress conditions but only at high N application dose i.e. 120 kg.ha^{-1} N.

TABLE 7. YIELD - N INDEX AND IRRIGATION TREATMENTS.

Irrig. treat.	Yield - N index							
	1992		1993		1994		Average	
	N60	N120	N60	N120	N60	N120	N60	N120
111	11.3	7.1	9.5	5.5	6.3	6.5	9.0	6.4
110	9.7	7.4	5.6	5.2	5.5	8.0	6.9	6.8
101	3.9	4.8	6.9	4.8	11.3	7.1	7.4	5.6
011	9.3	6.7	14.0	6.4	3.4	4.0	8.9	5.7
000	9.5	5.4	7.5	4.6	3.0	2.6	6.7	4.2
Tr.	12.4	4.7	8.9	4.9	11.2	6.0	10.8	5.2

Before proceeding any further, if average total N concentration (%) of plant tissues and total dry matter productions (kg.ha^{-1}) are examined in relation to irrigation, apparent slight decreases in N concentrations and increases in dry matter are seen which resulted in higher total N yields (uptakes) at full irrigation conditions (Table 8). The average of three years data shows that 166 and 225 kg of N were taken up by per hectar of cotton with respect to 000 and 111 irrigation conditions, respectively. Similar effects of irrigation have also been reported by Doss and Scarsbrook [11] for cotton.

TABLE 8. NITROGEN CONCENTRATIONS (%) IN PLANT TISSUE AND TOTAL DRY MATTER PRODUCTION (kg.ha^{-1}).

	1992		1993		1994	
	000	111	000	111	000	111
Average total N concentration(%)	1.87	1.80	1.83	1.60	1.81	1.75
Total dry matter product.(kg.ha^{-1})	8824	11377	9235	13572	9060	14514

Fertilizer N yield and soil N yield results revealed that recoveries were always greater in full irrigation conditions. It is also put forth that N derived from soil was always higher than N from fertilizers. The situation is very distinct at the final year where 23 kg.ha^{-1} N was taken up from the fertilizer and 141 kg.ha^{-1} N from the soil in 000 irrigation treatment and 40 and 214 kg.ha^{-1} N in 111 treatment respectivelly (Table 9). The apparent increase in the uptake of soil N with and without stress conditions could be attributed to the stimulation of microbial activity by the addition of N fertilizers, mineralization of organic matter, increased availability by the water [12,9].

TABLE 9. TOTAL **N** YIELD, FERTILIZER **N** YIELD, SOIL **N** YIELD AND **N** USE EFFICIENCY OF COTTON.

		Irrigation	treatments
		000	111
	1992	165	203
	1993	169	217
Total **N** yield(kg.ha^{-1})	1994	164	254
	Average	166	225
	1992	20	25
	1993	25	38
Fertilizer **N** yield(kg.ha^{-1})	1994	23	40
	Average	23	34
	1992	145	178
	1993	144	179
Soil **N** yield(kg.ha^{-1})	1994	141	214
	Average	143	190
	1992	17	21
	1993	21	32
Nitrogen use efficiency(%)	1994	19	33
	Average	19	29

As for the N use efficiencies, average results pointed out that 19 % of nitrogen in stress conditions and 29 % in full irrigation were found efficient. Results were relatively low compared to previous findings [9] for wheat and corn [12], higher than reported by Atta and Van Cleemput [13] for sesame and sunflower and confirmed by Hearn and Constable [14] for cotton imposed to stress conditions. The conflicting data could be mainly due to crop variety, rooting system and other cultural managements.

The distribution of N uptake in different plant parts e.i. leaves, stems, burs, seed and lint revealed that 45 % of the total uptake in 000 conditions and 39 % in 111 conditions are recovered by the seeds. The second highest recovery was achieved in the leaves. A parallel trend was also observed in the partitioning of labelled N in various plant parts. The current results are in agreement with other investigations [13].

3.4. WATER USE EFFICIENCY AND YIELD RESPONSE FACTOR

Water use efficiencies were calculated based on irrigation water (WUE_r) and on seasonal evapotranspiration of crop (WUE_o) (Table 10). Crop water use efficiency indicates the yield produced per unit amount of water consumption. WUE_o values were the lowest in continuous stress conditions. The values have been found close to each other under the treatments which stress imposed at different growth stages. Consequently, no clear distinction can be made between these stress treatments. In 1994, however value was the lowest in 011 treatment.

TABLE 10. IRRIGATION TREATMENT EFFECTS ON WUE_r, WUE_o AND YIELD RESPONSE (ky) FACTOR.

Year	Treat.	WUE_r kg.(ha.mm)$^{-1}$	WUE_o kg.(ha.mm)$^{-1}$	ky
1993	111	5.64	4.37	----
	110	5.87	4.52	0.63
	101	6.00	4.65	0.66
	011	5.86	4.59	0.64
	000	5.26	3.80	1.49
	Tr.	5.24	4.13	1.30
1994	111	5.13	4.28	----
	110	5.36	4.55	0.28
	101	5.87	4.61	0.69
	011	4.86	4.16	1.11
	000	6.52	4.07	1.15
	Tr.	5.54	4.11	1.63

The lowest yield response factor (ky) was obtained from the treatment 110, as 0.63 in 1993 and 0.28 in 1994 (Table 10). The yield responses to water deficit in whole growth period were 1.49 and 1.15 in 1993 and 1994, respectively. Althought scattering ky values were obtained in stress created treatments, the highest yield response factor was found for 011 in 1994 as 1.11 (Fig 7). The ky values of 0.50 for flowering and 0.85 for total growing period have been reported by Doorenbos and Kassam [1]. They also explained the differences in ky values with variations in climate, level of ET and soil.

Differences can be attributed to the variations in above factors and also varying response to water stress of new cotton variety, N 84 used in the experiment.

4.CONCLUSION

The results of the experiment have indicated that, the sensitivity of cotton plant to water stress at different growth stages are close to each other. This situation might be attributed to the high water holding capacity [15] of experimental soils and to the water moved in from soil outside the depleted root zone to alleviate stress [16]. On the other hand, Ayars et al.,[17] and Taylor and Klepper [18] emphasize the adaptive mechanisms of cotton plant by adjusting root and shoot growth which can alleviate water stress impact. Neverthless, the seed cotton yields, ky values of 1994 and yield - N indices have revealed that the vegetative stage was more sensitive to stress conditions. On the other hand, stress at boll formation stage had slightly affected the above parameters. Therefore, under limited water resource conditions which exist in most of the irrigation projects of Turkey, the vegetative growth period of cotton should be given priority for irrigation, followed by flowering period. Under such conditions, best option as irrigating cotton during only in vegetative and flowering stages would result 2.5 to 7.9 % yield reduction but 4.3 to 9.1 % water savings.

Seed cotton yield results showed that high N rates are accompained by high yields. Fertilizer N yields (uptake) and soil N yields revealed that recoveries were always higher in full irrigation conditions at high nitrogen rates. Apparent increases in soil N uptake with and without stress conditions were determined. The highest recovery was achieved by the seed in both full and continuous stress condition followed by the leaves.

Nitrogen use efficiencies were always higher in full irrigation treatments. It is concluded that irrigation has an important effect on the efficiency of fertilizers and that even high N doses can not improve the efficiency in stress conditions.

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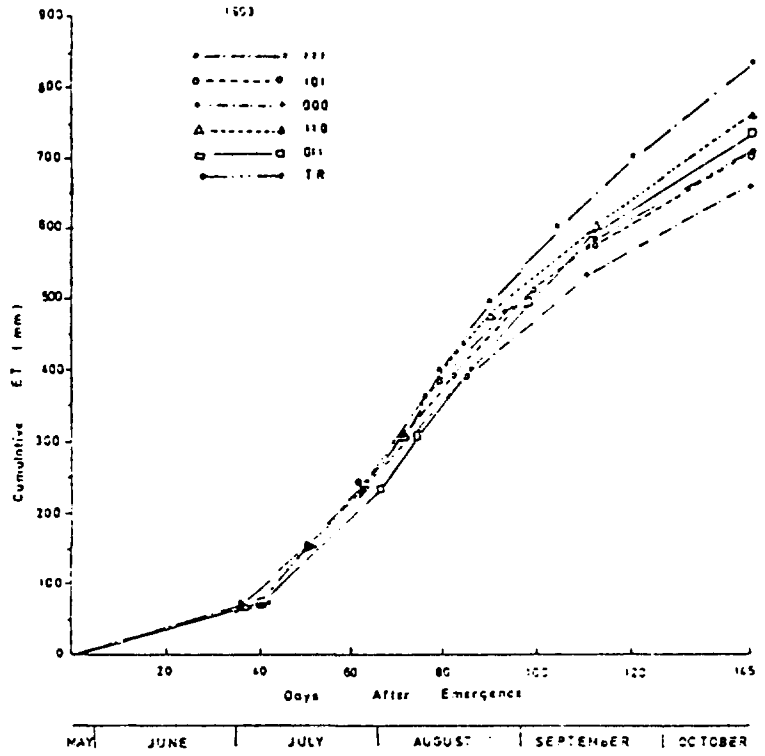

Fig.1. Cumulative ET in the different irrigation treatments (1993).

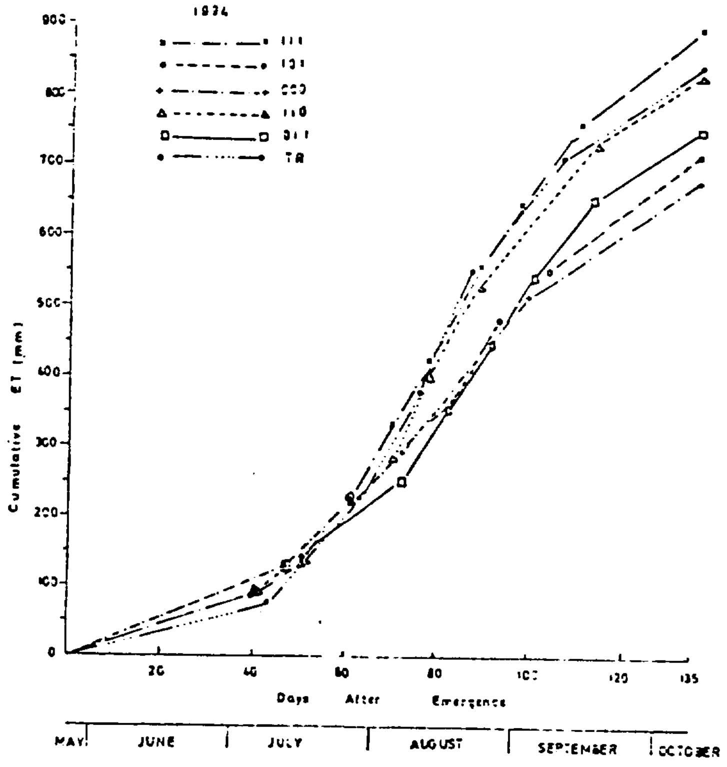

Fig. 2. Cumulative ET in the different irrigation treatments (1994).

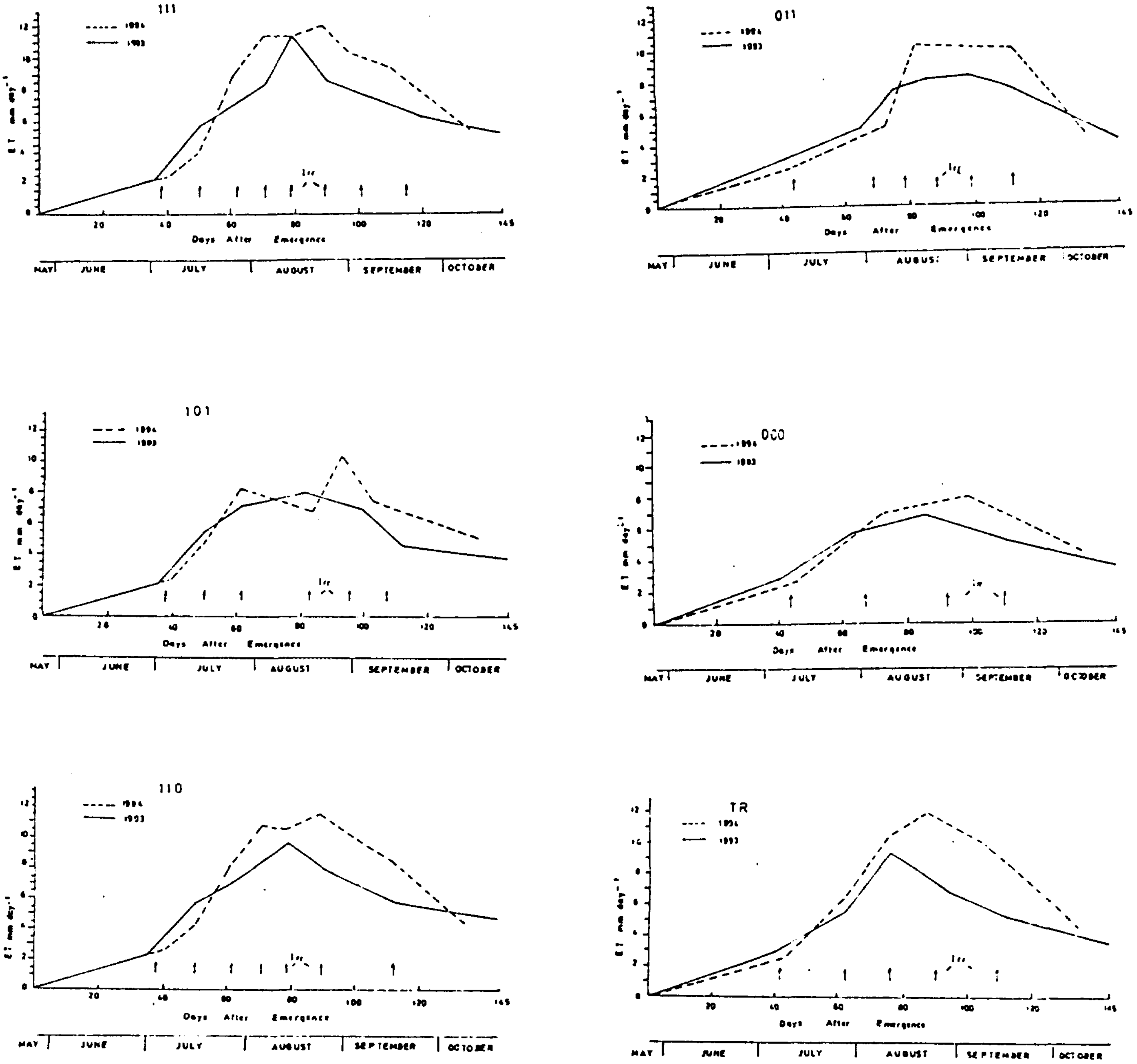

Fig. 3. Variation of daily ET in the different irrigation treatments.

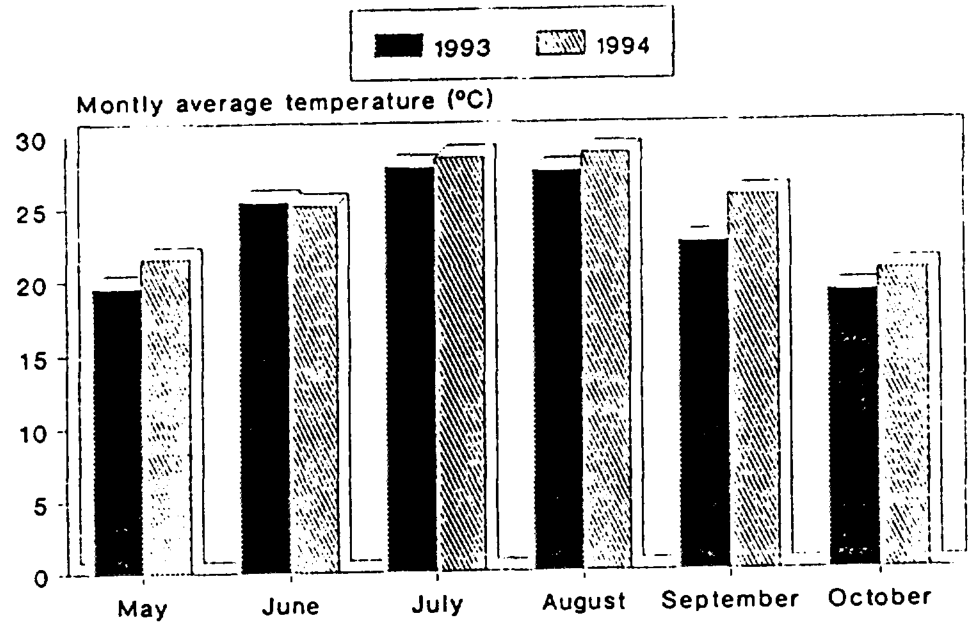

Fig.4.Monthly temperatures (°C) during growth periods.

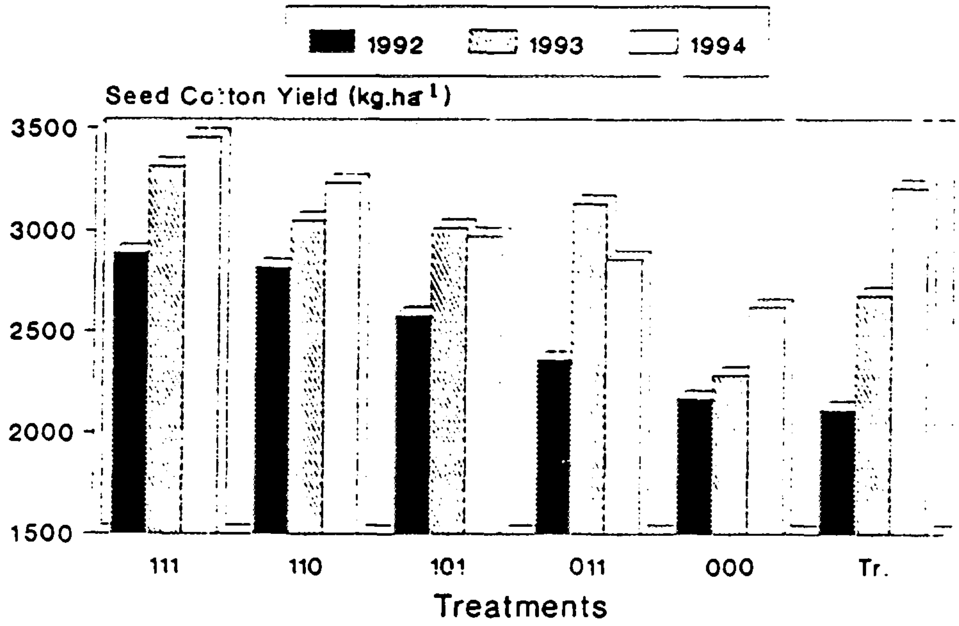

Fig.5.Seed cotton yields in the different irrigation treatments.

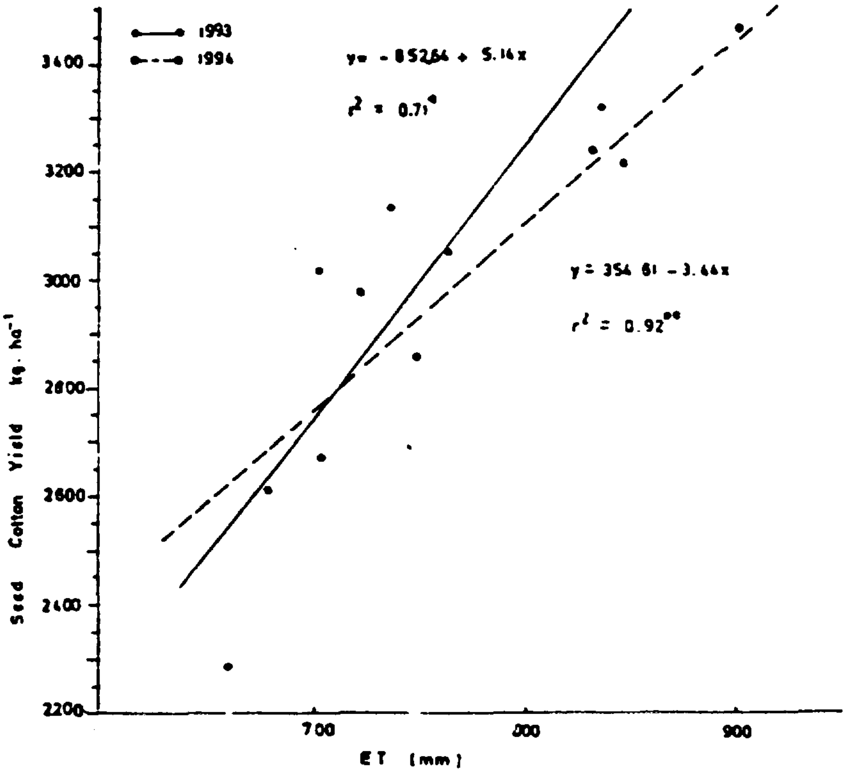

Fig.6.Seasonal ET - seed cotton yield relationships.

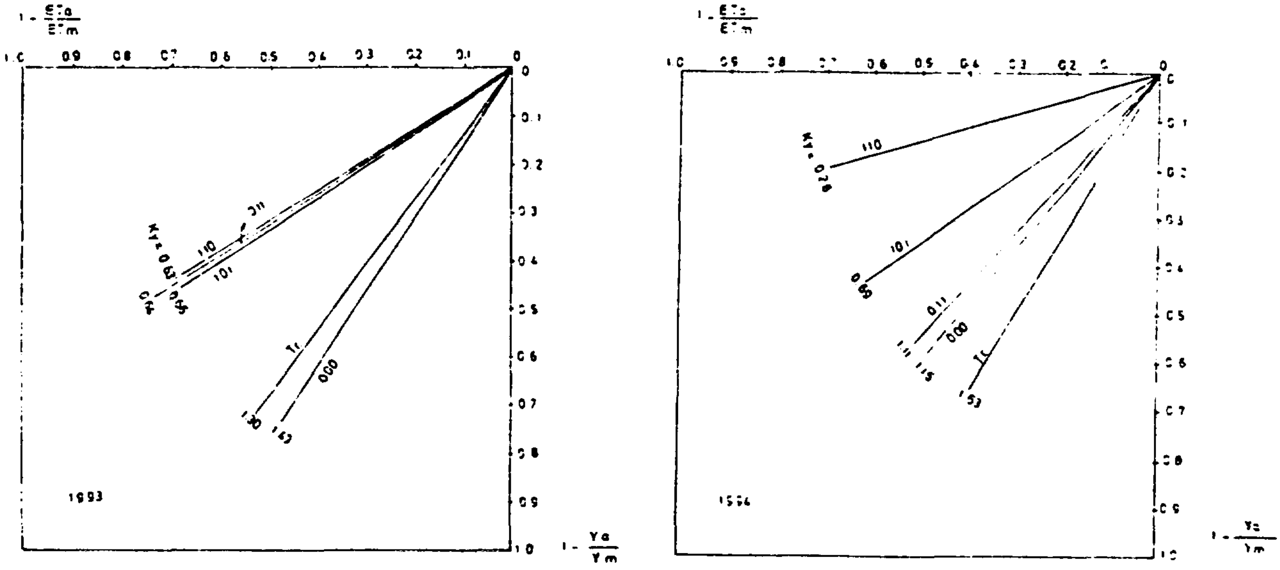

Fig.7.Relationships between relative yield decrease and relative ET deficit.