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Effects of Different Irrigation Programs on Fruit, Trunk Growth Rates, Quality and Yield of Grapefruit Trees

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Abstract: Long-term field experiments were carried out between 1985 and 1988 to determine the effect of different irrigation intervals and pan coefficients on the fruit and trunk growth rates and yield of mature grapefruit trees grown in the Eastern Mediterranean Region of Turkey in a medium-light textured soil. Two different irrigation intervals (I_1=15 and I_2=25 days), and pan coefficients (k_1=0.60 and k_2=1.00) were used.

Higher evapotranspiration values were obtained from the treatments with k_2 coefficient in the two irrigation regimes. The average irrigation water (IR) and evapotranspiration (Et) values were 796 mm and 1039 mm for I_1k_2, and 782 mm and 988 mm for I_2k_2, respectively. The grapefruit trees exhibited periodicity during the period of study. Results indicate that the effects of the irrigaiton programs on grapefruit yield were not significantly different. However, slightly higher yields were obtained from the frequently irrigated trees with an average of 67.3±0.164 t/ha for I_1k_1. In periodicity years, the yield and the number of fruits harvested decreased by 45-52% and 77-85% with respect to irrigation treatments. In normal-yield years, the average fruit weight and diameter were nearly 32% and 20% lower than in the periodicity years, and the seed number was two to four times greater than in the periodicity years. It was found that there was an inverse relationship between fruit extract and TSS (total soluble solid percentage). The fruit extract content increased to 41.9%, whereas TSS decreased to 11.1% in normal-yield years. Fruit extract and peel thickness varied during the experimental period. In the periodicity years, the average fruit extract was about 17% lower and the peel thickness was 18% higher than in normal-yield years. Both the fruit and trunk-diameter growth rates were higher in treatment I_1k_1 than the o†hers. The maximum development in trunk diameters was observed in I_1k_1, with 23% (above the graft) and 28% (below the graft), and 35% in terms of fruit diameter. The relationship between yield and some quality characteristics in the estimation of the yield was analyzed. The effects of various factors on the yield were determined using multiple regression analysis. The equation Y=-141.518+0.058FN-10.359NS can be used to estimate the final yield o*f* grapefruit where FN is the fruit number, and NS is the number of segments. However, it was shown that measurement of fruit diameter during certain periods of the year can be used to predict grapefruit yield. For this purpose, the equation Y=162.681+56.819(X_{16})-17.650(X_{19})-41.100(X_{20}) can be used, where X16, X19, and X20 are the fruit diameters observed on August 15, September 30, and October 15, respectively.

Farklı Sulama Programlarının Altıntop Bitkisinde Meyve, Gövde Gelişim Oranları, Kalite ve Verim Üzerine Etkileri

Özet: Deneme, Doğu Akdeniz Bölgesi'nde, farklı sulama aralıkları ve pan katsayılarının meyve ve gövde gelişim ile verim üzerine etkilerini belirlemek amacıyla, kumlu-tınlı topraklarda, 1985-1988 yılları arasında, yürütülmüştür. İki farklı sulama aralığı (I_1=15 ve I_2= 25 gün) ve pan katsayıları (k_1=0.60 ve K_2=1.00) kullanılmıştır.

Sulama aralıklarında en yüksek evapotranspirasyon değerleri, k_2 katsayısının kullanıldığı konudan elde edilmiştir. Konulara uygulanan ortalama sulama suyu miktarı (IR) ve evapotranspirasyon (Et) değerleri, I_1k_2 konusunda, 796 mm ve 1039 mm, I_2k_2 konusunda ise 782 mm ve 988 mm olarak saptanmıştır. Deneme yıllarında altıntop ağaçlarında peryodisite görülmüştür. Sulama programlarının altıntop verimi üzerine istatistiksel anlamda etkisi olmamıştır. Bununla birlikte, I_1k_1 konusundan elde edilen verim değerleri, 67.3±0.164 t/ha, diğer konulardan daha yüksektir. Peryodisite yıllarında verim ve meyve sayısı deneme konularına bağlı olarak sırasıyla 45-52% ve 77-85% oranında azalmıştır. Ortalama meyve ağırlığı ve çapı, normal verim yıllarında peryodisite yılına oranla, sırasıyla, 32% ve 20% düzeylerinde daha düşük bulunmuştur. Çekirdek sayısı ise peryodisite yıllarında 2-4 kat artmıştır. Usare miktarları ile toplam kuru madde miktarları arasında önemli ilişki saptanmıştır. Normal verim yıllarında, toplam kuru madde miktarları, %11.1 düzeyinde azalırken, usare miktarları %41.9 oranında artmıştır. Usare miktarları ve kabuk kalınlıkları normal ve peryodisite yıllarına bağlı olarak değişim göstermiştir. Peryodisite yıllarında, ortalama usare miktarı yaklaşık %17, düşük kabuk kalınlığı ise %18 daha yüksek bulunmuştur. Meyve ve ağaç gövde çap gelişimi, diğer konulara kıyasla, I_1k_1 konusunda daha hızlı olmuştur. Maksimum gövde çapının olduğu I_1k_1 konusunda, aşı yerinin üzerinde %23; aşı yerinin altında %28 ve meyva çapında %35 gelişme olduğu belirlenmiştir. Verim ve kimi kalite özellikleri ilişkileri, toplam verim kestiriminde kullanılmıştır. Farklı öğelerin verim üzerine etkileri, çoklu doğrusal analizlerle belirlenmiştir. Hasattaki verim değerlerinin belirlenmesinde meyve ve dilim sayısı ilişkilerini veren Y=-141.518+0.058FN-10.359NS eşitliği elde edilmiştir. Diğer yandan, gelişme dönemi boyunca ölçülen meyve çap gelişimi de, verimin kestiriminde kullanılmıştır. Sonuçta farklı zamanlarda, (X_{16}: 15 Ağustos; X_{19}:30 Eylül ve X_{20}: 15 Ekim), ölçülen meyve çapı-verim ilişkisini veren $Y=162.681+56.819(X_{16})-17.650(X_{19}) -41.100(X_{20})$, eşitliği bulunmuştur.

Introduction

Recent increases in citrus acreage in Turkey have resulted in the need for more research on irrigation of citrus crops. Summers in the Mediterranean region, where citrus are grown intensively, are very dry; therefore, irrigation is essential to obtain higher yields and better quality. One of the major problems in irrigating crops is finding practical measures for determining the frequency and amount of water application. Such measures may also help evaluate crop response to a seasonal irrigation regime and thus improve the irrigation program for subsequent seasons (1).

The total growth rate of a tree is a function of the growth of various tree organs during each season. The number of fruits and their final size are dependent on the growth of other organs such as the root, shoots, and trunk. It is, therefore, important to study the growth patterns and growth rates of the various tree organs and to investigate the effect of water potential at different stages. The daily growth of the trunk and fruits were found to be the net result of shrinkage during the day and swelling during the night, when there is little water loss (2). Daily shrinkage has also been used to determine water potential and irrigation needs (3).

The vegetative development of citrus trees is dependent on the irrigation regime applied (4). In long-term experiments, a good correlation has been found between canopy volume and yield (5). However, as trees reach full size, excessive growth as a consequence of intensive irrigation can lead to decreased yield, mainly because of shading and the need for severe hedging. Controlled water stress is used to limit canopy development (2).

For measurements of wood growth, either the trunk or main branches may be used to compare the response of trees to different irrigation treatments at the same location (2, 5, 6-7). Nevertheless, fruit size is considered to be the major fruit characteristic influenced by irrigation (8,9). It has been shown that harvest yield can be predicted from fruit-size measurements taken at different development stages of the tree (10).

The main objective of this study was to evaluate the effects of different irrigation regimes on the seasonal pattern of trunk and fruit growth, fruit drop, and other quality characteristics. The other objective of this experiment was to determine whether fruit characteristics can be used in the estimation of the final yield of grapefruit.

Material and Method

This study was carried out on grapefruit (variety: Marsh Seedless) trees located in Yeşilkent, near Dörtyol in the eastern Mediterranean region of Turkey, between 1985 and 1989. The yields of trees were evaluated and a total of 56 trees with similar yields were selected prior to commencement of the study. Tree spacing was 8x6 m.

The soil at the experimental site is fine sandy-loam and clay-loam (typical-Xerofluevent) with 162 mm available water capacity in a 1.50-m depth of profile. Trees received the same fertilization treatments in February and May. The amount of fertilizer was 0.7 kg N, 0.4 kg P_2O_5, and 0.4 kg K_2O applied to each tree each year.

Two irrigation intervals of 15 days (I_1) and 25 days (I_2) and two pan coefficients of 0.60 (k_1) and 1.00 (k_2) were used. Water which had C_2S_1 quality-class was applied using the basin-irrigation method. The experiment was a factorial randomized complete block design with 14 replications. Each plot contained one tree.

The volume of irrigation water was calculated using open water surface evaporation. Daily pan evaporation was determined from an unscreened Class A pan at a nearby weather station. In the first applications, the same amount of water, equal to the soil water deficit, was given to all the trees. Soil water content were measured at one or two weeks intervals, jost before irrigation during the whole year and also at harvest. A water balance equation was used for the calculation of evapotranspiration. Detailed information about irrigation applications, estimation of evapotranspiration, rainfall, and other factors relevant to this experiment can be found in Kanber et al. (11).

In order to determine fruit growth rates, 10 fruits were carefully selected from nearly equal-sized spurs well distributed around the tree canopy from eight replications (80 fruits per treatment). Fruit diameter measurements were carried out weekly. Fruits that dropped during the season (ca. %15) were discarded. Measurements began when the fruit diameter was about 1.0 cm. The diameter of the fruits was taken as the largest perimeter, measured with a wooden compass.

During the experiment, measurement of the circumference of each tree trunk were taken at 7.5 cm above and below the graft with a plastic tape. Measurements were made at the end of winter and in the spring months, especially before the irrigation seasons in the experiment al years.

Eight randomly selected trees in each treatment were designated for the measurement of fruit drop. Fabric (8x10 m) was placed under the trees to measure fruit shedding. Measurements were taken daily from the end of May until harvest. The dropped fruits were collected from the trees and counted.

The fruit was harvested according to fruit maturity and potential for export. At the end of each growing season (usually the middle of December), the quantity and pomological properties of 50 fruits from each treatment were determined using the methods described by Özsan and Bahçecioğlu (12). All the fruits of four labeled trees in each treatment were counted during the harvest.

Statistical analyses were carried out in order to determine the effects of irrigation treatments on the yield, Et, and certain qualities of the fruit (13). To determine the relationships between yield and fruit growth and other qualities of the fruit, step-wise multiple regression analysis was used.

Result and Discussion

Irrigation Regimes, Yield, Fruit and Trunk Growth and Fruit Drop

The amount of irrigation water applied, evapotranspiration values, fruit yield and some characteristics of the fruit are presented in Table 1. The greatest irrigation water and evapotranspiration were observed in the treatments with a pan coefficient of 1.0 with both irrigation intervals. The seasonal average irrigation water and evapotranspiration for treatments I_1k_2 and I_2k_2 were calculated to be 796 mm and 782 mm; 1039 mm and 988 mm, respectively. The amount of water applied was not necessarily related to the frequency of irrigation. The quantity of irrigation water required and seasonal evapotranspiration increased with an increase in the pan coefficient. The total evapotranspiration was similar for different irrigation intervals with the same coefficient. In 1985, irrigation water for treatment I_1k_2 somewhat exceeded the amount of total evapotranspiration. The difference was due to deep percolation losses of irrigation water, as explained by Kanber et al. (11). During the fall and winter months, evapotranspiration values partially increased. This increase, which had little effect on the yield and development of the plants was probably due to winter rains. Increased rainfall constitutes a proportion of evapotranspiration together with evaporation and deep percolation. A similar finding was reported by English et

Table 1 .Water regimes, and fruit and yield characteristics of grapefruit according to irrigation and year(1)

Year	Treatment	No.of irr.	Water app. mm	Et. mm.	Fruit/tree at harvest	Fruit yield total fruit	t/ha	Fruit weight g	Fruit dia.at harves, cm	Fruit drop %
1985(2)	I_1k_1	7	484	570			50.4a	535	13.7	
	I_1k_2	7	753	676			42.4a	545	13.3	
	I_2k_1	5	531	615			45.0a	557	13.9	
	I_2k_2	5	831	779			45.8a	573	13.3	
1986	I_1k_1	12	594	760	1410 a	2436 a	100.4a	380	10.2	42
	I_1k_2	12	962	1106	1156 b	2178 b	91.4ab	367	10.4	47
	I_2k_1	7	559	709	1220 b	2518 b	90.8 ab	366	10.4	51
	I_2k_2	7	904	1006	1329 a	2566 a	89.0ab	384	10.2	48
1987	I_1k_1	10	486	852	272 a	527 b	37.8a	420	10.2	48
	I_1k_2	10	793	1023	400 a	634 b	40.2a	402	11.2	37
	I_2k_1	6	471	818	362 a	631 b	42.6a	405	10.9	43
	I_2k_2	6	734	1000	578 a	884 a	45.0a	386	10.9	35
1988	I_1k_1	8	406	843	1641 a	4856 a	80.6a	273	9.8	66
	I_1k_2	8	677	988	1440 b	4579 a	76.6a	285	9.7	69
	I_2k_1	5	430	863	1469 b	5122 a	77.8a	288	9.3	71
	I_2k_2	5	661	958	1438 b	4997 a	76.6a	280	9.2	71
SD					61.7-112.3	86.4-75.9	16.3-19.9	n.s.	n.s.	n.s.

(1) Values of treatment for each year marked with the same letters are significantly different at P<0.05

(2) July to December

al. (14) in relation to field and horticultural crops. Results obtained from grapefruit yield and water consumption studies by Doorenbos and Kassam (15), Prathapar et al. (6) and Çevik et al. (17) agreed with those of this study. However, studies carried out by Dinçer et al. (18) and Eylen et al. (19) produced different results. The difference is probably due to different calculation methods for determining plant water comsumption (11).

The treatments resulted in similar yields, except in 1986, when the yields were significantly different at a significance level of 5%. The grapefruit trees did exhibit periodicity during the study years. 1985 and 1987 were periodicity years, while 1986 and 1988 were years of normal yield. In the periodicity years, the yields from I_1k_1 and I_1k_2 treatments were 52% and %51 lower than those in normal years. The corresponding values for I_2k_1 and I_2k_2 treatments were 48% and 45%, respectively. Generally, it is assumed that frequent irrigation increases grapefruit yield. However, statistics have proved this claim to be meaningless.

The number of harvested fruit per tree showed significant differences with respect to treatment and year. The maximum number of fruits was obtained from treatment I_1k_1 with an average of 1526 fruits in the years of normal yield. In the periodicity years, the number of fruits decreased by 77-85% in all tretments. As has been previously reported (11), the differences in yield were mainly due to the fruit number. Similar results were observed by various researchers such as Levy et al. (20) and Finkel (21). However, Stylianou (22) reported that the number of fruit per tree was largely unaffected by irrigation regimes.

The final fruit weight after harvest varied from treatment to treatment and year to year. The highest fruit weight was obtained from treatment with k_1 coefficient with an average of 480 g per fruit in the periodicity years. The fruit weights decreased by an average of 32 % for all the treatments in the normal-yield years. There was an inverse relationship between fruit weight and the number of fruit harvested.

The conclusions drawn from the fruit diameter measurements were similar to those based on the number of fruit harvested per tree. The overall diameter of fruits at the harvest was found to differ according to treatment and was different in the experimental years. In the normal-yield years, fruit diameters were smaller than fruit diameters in the periodicity years. The maximum fruit diameter was observed in the I_2k_1 treatment with an average of 12.4 cm in the periodicity years. The results show that the fruit diameters decreased by 16.5% for irrigation interval I_1 and 20% for I_2 in the normal-yield years. Larger diameters found during the periodicity years were usually attributed to the fact that the trees had fewer fruits during these years. Hilgeman (3) and

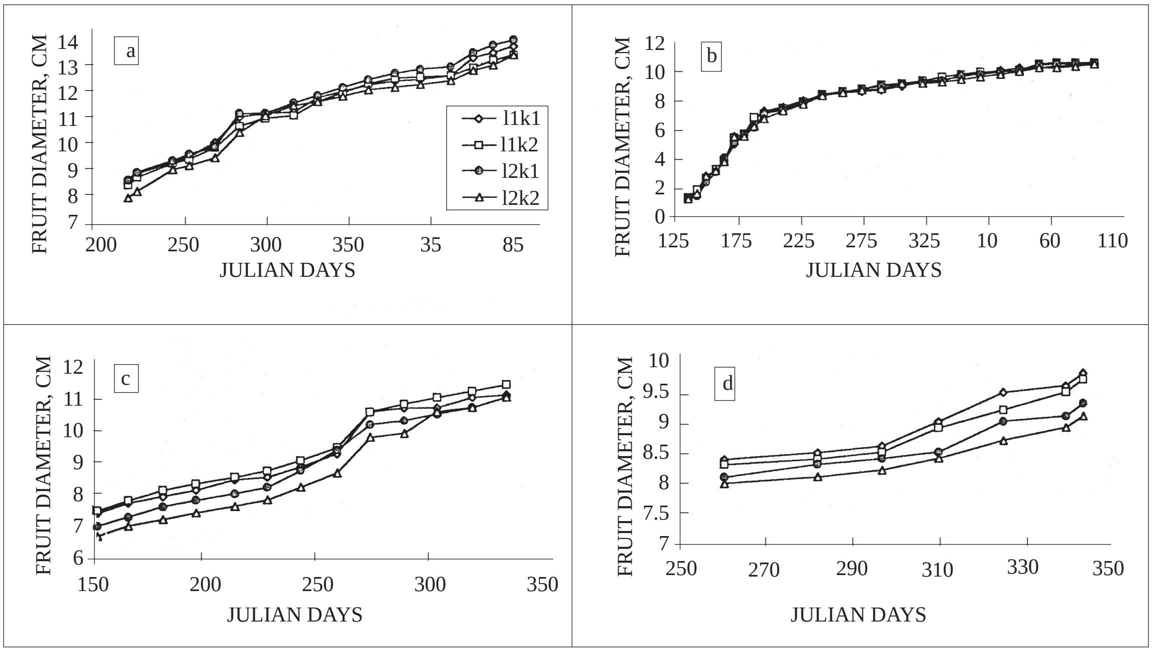

Figure 1. Cumulative fruit diameter growth versus time for different treatments (a. 1985 and 1986; b. 1986 and 1987; c. 1987; d. 1988).

Assaf et al. (23) have shown that frequent irrigation results in enlargement of the trunk and fruit. Marsh (8) and Legaz et al. (9) explained fruit size is influenced by irrigation. Levy et al. (20) found that shortening the irrigation interval increased the size of Marsh grapefruit, but shortening the interval further decreased fruit size. Stylianou (22) observed that there was a trend of decreasing fruit size with increasing irrigation intervals.

Fruit diameter growth rates according to year are plotted in Figure 1. Accelerated growth was observed following pollination in all the treatments. The growth rate decreased towards the middle of June, and afterwards growth was insignificant until the harvest period. Prior to the experimental years 1985 and 1986, the seasonal pattern of fruit growth was similar in all treatments. In this period, fruit diameter was determined to be approximately 40% to 90% of the final diameter. However, in these years, the fruit growth rate for the irrigation interval with k_1 was more or less faster than that with k_2. In 1987 and 1988, the fastest growth rate was observed in the frequent irrigation treatment I_1 with 13%-35%. The fruit growth rate in treatments I_1k_1 and I_1k_2 was more or less uniform throughout the experimental period. However, the growth rate in all the

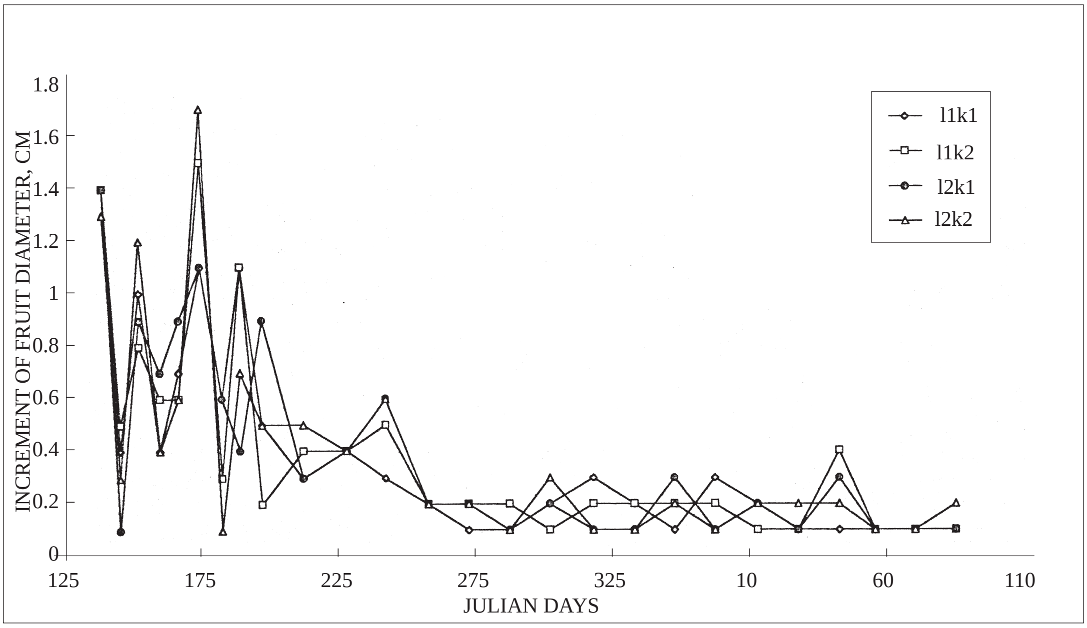

Figure 2. Weekly fruit diameter increments during 1986 and 1987.

treatments decreased gradually compared to the rest of the season. The weekly increments in fruit diameter growth were greatly affected by the frequency of irrigation. Figure 2 shows the weekly increments in fruit diameter in 1986 and 1987. The weekly increments in fruit diameter fluctuated less in treatments I_1k_1 and I_1k_2 than in the other treatments.

As can be seen from Table 1, the total fruit drop varied according to irrigation treatment. However, this also differred for periodicity or normal-yield years. In the normal-yield years, the drop ratio increased with an increasing pan coefficient and increasing irrigation intervals. In these years, the maximum drop ratio was obtained from the irrigation interval I_2 and coefficient k_2 with averages of 61% and 59%, respectively. Generally, it was observed that the drop ratio decreased with increasing pan coefficients for all irrigation intervals in the periodicity year. The fruit drop ratios were determined to be 37% for I_1k_2 and 35% for I_2k_2 treatment. In the final year, the mean fruit drop was 69%, higher than in the previous year. This may be due to the fact that the total number of fruits was at least twice as high as the figures recorded in the other years. The cumulative seasonal pattern of fruit drop is presented in Figure 3. As seen in Fig. 3, the variation in fruit drop exhibited a similar trend in all treatments. However, fruit drop in treatments I_1k_1 and I_1k_2 was less than in the other treatments. Clearly, initial fruit drop was very high, and the fruit drop rate then stabilized towards the middle of July, approximately 40 days after the beginning of observations. Fruit drop was negligible after this date until harvest. However, there was an increase in fruit drop towards harvest with the increase in fruit size, but it was not statistically significant. The fruit drop during this period was most probably due to climatic and cultural factors rather than irrigation. The incremantal fruit drop differred from treatment to treatment. In normal-yield years the maximum fruit drop varied from 120 to 260 fruit per tree per day for interval I_2, whereas, in the periodicity years, the maximum fruit drop decreased to 14-30 fruit per tree per day for the irrigation interval I_1. Figure 4 shows typical daily increments in 1986 and 1987. The maximum fruit drop was obtained from I_2k_2 with 170 fruit per day per tree during the first 10 days of observation. Then, it stabilized at a constant value of nearly 10 fruits per day per tree 20 days after the start of observations.

Growth differences were observed by measuring trunk circumference at the beginning and end of each season (Figure 5). The frequent irrigation treatment I_1k_1, which produced the highest yield, had the most uniform and fastest trunk development, followed by I_2k_1. The trunk development rate was higher in the initial years than the later years for all treatments. The maximum incremental development of the trunk in the initial year

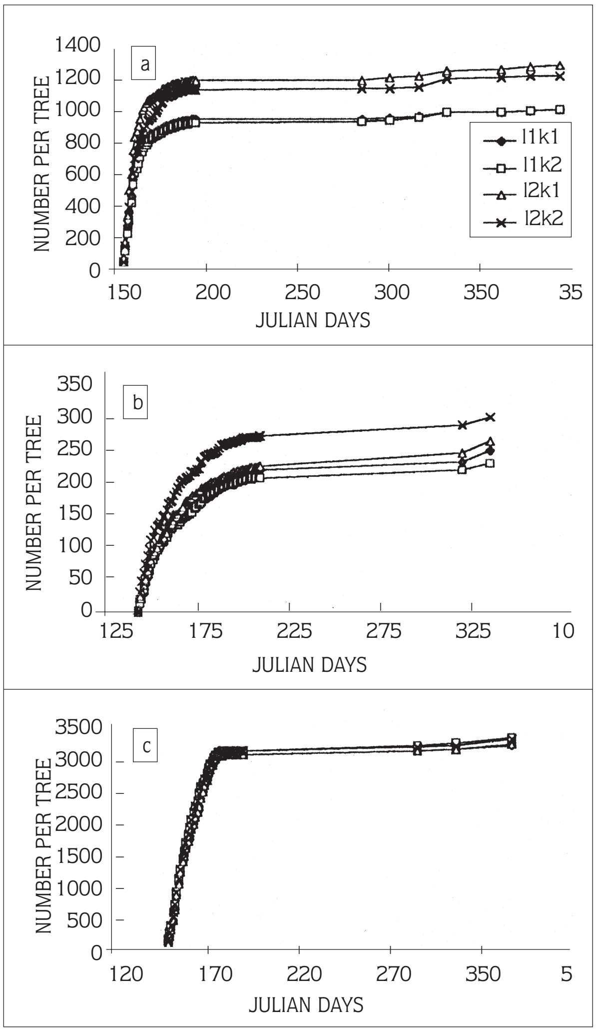

Figure 3. Cumulative fruit drop according to irrigation treatment (a. 1986 and 1987; b. 1987; c. 1988)

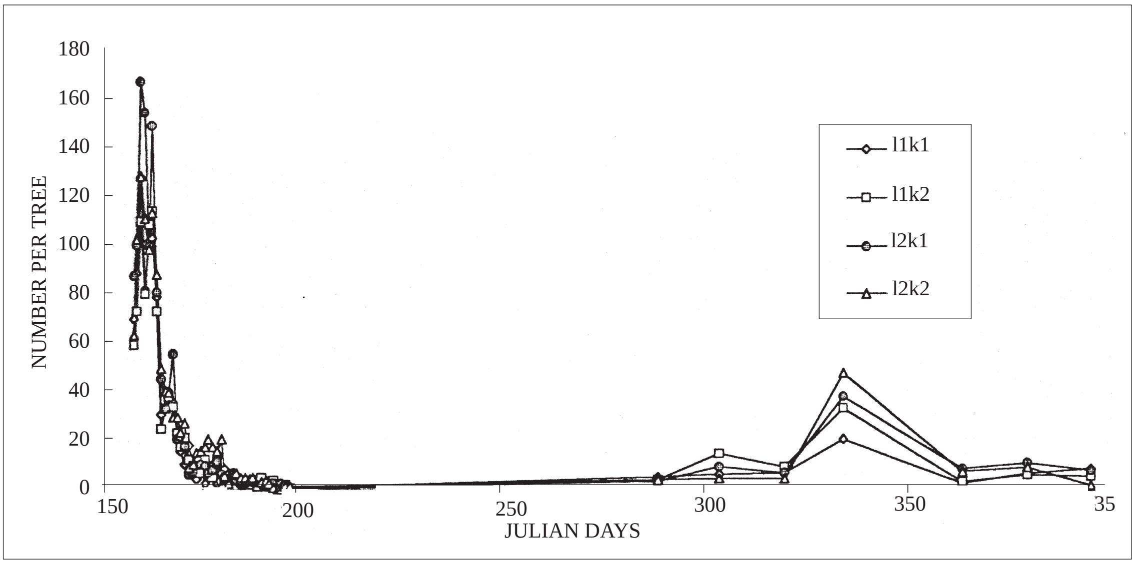

Figure 4. Fruit drop increments during 1986 and 1987.

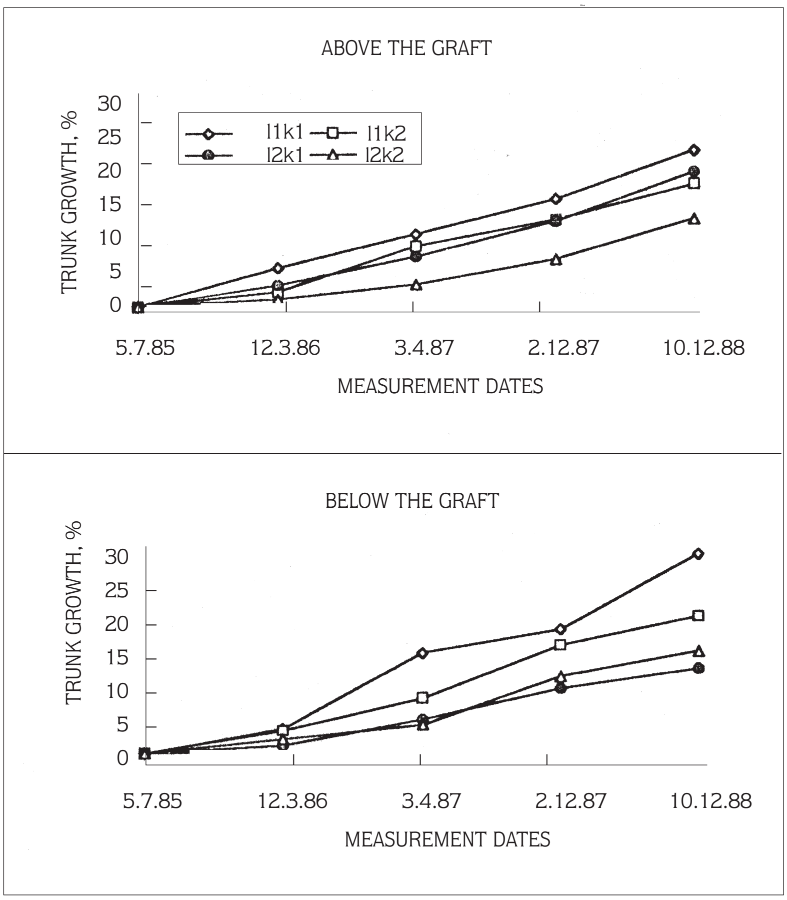

Figure 5. Relative growth of trunk diameter.

was in treatment l_1k_1 with 1.1 cm. In the final year of the study, trunk development in l_1k_1 was the minimum with 0.2 cm, whereas a maximum of 0.95 cm was recorded in l_2k_2 above the graft. The average trunk growth for l_2k_2 during the study years was 2.7 cm, and 3.5 cm in the rest of the treatments. Slow growth for l_2k_2 could be attributed to irrigation. The greatest relative growth of the trunk diameter during the entire experimental period occured in treatment l_1k_1 with 23% above the graft and 28% below the graft. The minimum relative growth rates, 10% and 12%, were observed in irrigation treatment l_2k_2, above and below the graft, respectively. Frequent irrigation increased trunk circumferences in Washington Navel orange, as observed by Abdel-Messih and Nokrashy (24). Various researchers have found that measurement of the growth of the trunk may be used to compare the response of trees to different irrigation treatments in the same orchard (2, 3, 5, 7). However, trunk sizes vary at different locations, and different rootstocks develop different trunk sizes due to poor correlation between trunk and canopy development (4).

The average weight, maximum diameter and length of individual fruit, number of seeds and segments per fruit, percentage of acid, extract, fibers, and total soluble solids (TSS) and peel thickness were not significantly different among the treatments (Table 2). However, fruit extract, seed number, peel thickness and TSS varied according to year. Although, fruit extract and seed number increased, peel thickness and TSS decreased in years of normal yield. The extract was 17% lower and peel thickness 18% higher in the periodicity years. Similarly, there was an inverse relationship between the percentage of fruit extract and TSS. As fruit juice increased to an average of 41.9 %, TSS decreased to an average of 11.1 % in years of normal yield. On the other hand, the number of seeds per fruit in normal-yield years was two to four times higher than in periodicity years. In general, the maximum values were obtained from irrigation interval l_1. Levy et al. (5, 20) explained that fruit parameters are affected only by irrigation stress during the growing season. They found that water stress resulting from long intervals reduced vegetative development and yield. Shortening the irrigation interval increased the amount of Marsh grapefruit juice and decreased peel thickness. In a study done by Cohen et al. (25), it was shown that the peel-to-pulp ratio in Marsh grapefruit increased with increasing stress. Similarly, Hilgeman (26) reported that thinner peel was obtained because of internal water stress. These results are in accordance with our findings, especially, those of normal-yield years.

Yield Estimation from Quality Characteristics

The relationship between yield, quality characterisctics and irrigation was determined using stepwise multiple regression analysis (Table 3).

As seen in Table 3, calculations were done in 4 steps. In the first step, the number of fruits included as part of

Table 2. Quality charecteristics of grapefruits.

Year	Treat.	Acit %	Fiber %	Extract %	seed per fruit	Segm. per fruit	Pell thick. cm	Fruit Length cm	Total suloble solid %
1885	I1k1	1.8	63.5	36.5	0.8	12.7	1.4	10.3	11.8
	I1k2	1.7	65.7	34.3	0.7	12.6	1.4	10.4	11.4
	I2k1	1.8	66.4	33.6	0.8	12.4	1.4	10.6	11.8
	I2k2	1.8	65.0	35.0	0.6	12.4	1.4	10.7	11.6
1986	I1k1	1.9	61.0	39.0	2.9	12.9	0.9	8.9	10.8
	I1k2	2.0	58.7	41.4	3.0	12.9	0.9	8.8	10.8
	I2k1	2.0	58.2	41.8	2.6	12.9	0.9	8.8	10.8
	I2k2	1.9	59.0	41.0	3.1	12.8	1.0	9.1	10.8
1987	I1k1	2.7	66.5	33.5	0.7	12.2	0.8	8.9	11.9
	I1k2	2.7	63.4	36.6	0.7	12.3	0.8	8.6	11.4
	I2k1	2.7	65.0	35.0	0.7	12.0	0.75	8.8	12.1
	I2k2	2.7	64.7	35.3	0.7	12.0	0.75	8.6	11.7
1988	I1k1	2.4	57.4	42.6	1.3	13.3	0.84	8.0	11.5
	I1k2	2.4	56.7	43.3	1.5	13.1	0.87	7.9	11.3
	I2k1	2.4	57.6	42.4	1.2	13.1	0.86	7.9	11.6
	I2k2	2.4	56.3	43.7	1.3	13.3	0.85	8.0	11.4
SD		n.s	n.s	n.s	n..s	n.s	n.s	n.s	n.s

Table 3. Relationship between yield and quality characteristics[1]

Step	Equations	R
1	Y= 17.316 +0.05 FN	0.915
2	Y= 141.518 + 0.058 FN - 10.359 NS	0.935
3	Y= 147.373 +0.053 FN - 11.108 NS+6.167 SN	0.952
4	Y= 11.933 + 0.052 FN - 9.275 NS + 5.615 SN + 0.021 IW	0.960

[1]Y = Yield, ton/ha
FD = Fruit Diameter, cm
FD/L = Fruit Diameter/Length
SN = Seed Number
NS = Number of Segments
FW = Fruit Weight, gr
IW = Irrigation Water, mm
PT = Peel Thickness, cm
EX = Extract, %
FN = Fruit Number

Table 4. Relationship between yield and fruit diameter

Step	Equations	R
1	Y= 259.939 - 20.641 (X_{20})	0.712
2	Y= 128.599 + 54.06 (X_{16}) - 52.304 (X_{20})	0.916
3	Y= 162.681 + 56.819 (X_{16}) - 41.10 (X_{20}) -17.65 (X_{19})	0.937
	For Treatment I_1k_1	
1	Y= 94.682 - 4.492 (X_{15})	0.105
2	Y= 239.25 - 17.57 (X_{21})	0.544
3	Y= 154.341 - 61.238 (X_{15}) + 65.996 (X_{21})	0.931

(X_{15}) : July 30
(X_{16}) = August 15
(X_{19}) : September 30
(X_{20}) = October 15
(X_{21}) : October 30

the yield was approximately 92%. When the number of segments was added to the equation, an R value of 0.935 was obtained. Thus, the grapefruit yield with the fruit number and number of segments was estimated to be 94%. In the other steps, the other factors were added, which resulted in better estimates. The fact that fruit yields were related more to the number of fruits than the size of the fruits was also reported by Hilgeman (3) and Assaf et al. (23).

As a result of these observations, the following equation can be suggested for use in predicting final grapefruit yield:

$$Y = 141.518 + 0.058FN - 10.359NS$$

where Y is the yield (t/ha), FN is the fruit number, and NS is the number of segments.

Measurements of fruit diameter during certain periods of the year can be used in the estimation of grapefruit yield. Fruit diameters were measured at 15-day intervals between July 30 and January 30 for this purpose (Table 4).

Careful observation of the equations in Table 4 shows that measurements taken between July 15 and October 15 can be used to estimate final yields. Measurements taken on October 15th (X_{20}) were added to the first step, followed by addition of measurements from August 15th (X_{16}) to step 2 and September 30th (X_{19}) to step 3.

The correlation coefficient R increased from 0.712 to 0.937, which is significant at a level of 0.01. It can be concluded that the equation shown in step 1 can be used only when there is one observation period (X_{20}); however observations on August 15th (X_{16}) and September 30th (X_{19}) should be made for a better estimate. Experienced growers can estimate yearly yield fluctuations with knowledge of fruit development and fruit number. This finding was also reported by Assaf et al. (1). The following equation is suggested for predicting the final yield of grapefruit:

$Y=162.681 + 56.819 (X_{16}) - 17.650 (X_{19}) - 41.100 (X_{20})$

Single and multiple regression analysis was used for treatment I_1k_1. R=0.105 found in X_{15} was statistically insignificant. However, R=0.931 found in the second step is a 0.01 level of significance. July 30 (X_{15}) and October 30 (X_{21}) should be used in estimating yields, and the following equation can be used:

$$Y = 154.341-61.238(X_{15}) + 65.996(X_{21})$$

Conclusions

The effects of two different irrigation intervals (I_1=15 days and I_2=25 days) and two different pan coefficients (k_1=0.6 and k_2=1.0) were evaluated from 1985 to 1988 in terms of fruit diameter and trunk growth rate, and the yield and quality of grapefruit in the eastern Mediterranean region of Turkey in medium-light textured soil.

The results revealed that the effects of the irrigation programs on the yield of grapefruit were not significantly different. However, frequent irrigation slightly increased yield. Periodicity resulted in decreased yield and reduced the number of fruits harvested by 45-52% and 77-85% with respect to the irrigation treatments studied. In normal-yield years, the average weight and diameter of fruits fell by 32% and 20%, respectively, compared to the values in the periodicity years. However, the seed number per fruit was two to four times higher than in the periodicity years.

The rate of increase, both in fruit diameter and trunk diameter was greater in treatment I_1k_1 than in the other treatments.

The relationships between final yield and quality characteristics of the fruit were analyzed in order to predict yield from observations made during the season. For example, fruit diameters measured on July 30 and October 30 were used to estimate the final grapefruit yield. Various prediction equations were derived through multiple regression analysis.

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