Effect of Four Irrigation Rates on Growth of Six Fig Tree Varieties

R. Tapia, C. Botti, O. Carrasco, L. Prat and N. Franck
Facultad de Ciencias Agronómicas
Universidad de Chile
Casilla 1004, Santiago – Chile

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Abstract

The fig tree is an attractive fruit crop for arid zones because of its tolerance to water deficit. However, there is very little information about its water requirements. A trial was conducted to determine the response of 4th leaf fig trees, in six varieties, to four irrigation rates in relation to estimated crop evapotranspiration (ETc), adapted for young trees and based on „Class A“ pan evaporation data. The irrigation treatments were T0 (not irrigated), T25 (25% ETc), T50 (50% ETc) and T100 (100% ETc). Rainfall in the region was 37 mm in the year of the study. The varieties were Brown Ischia (BI), Brown Turkey (BT), Kadota (K), Kennedy (KE), Larga de Burdeos (LB) and Royal Vineyard (RV), planted at 6 x 4 m. Significant differences in TCSA increase were observed in some treatments, except for var. BI and RV. Variety BT under T100 increased twice as much as under T50. In variety K , only T0 was different from T25. Regarding foliar area, significant differences were found only in varieties RV and LB, but in all others a good correlation between foliar area and TCSA increase, shoot length and leaf number was observed. In relation to shoot length only varieties BI and RV showed differences among treatments: T100 was significantly different to T0 and T25. In all treatments a good positive correlation between irrigation rate and shoot length was found. In xilem water potential, differences between T0 and T25, T50 and T100 were observed, but not between T50 and T100. In most varieties no differences between treatments in relation to phenological phase length were found. Most parameter showed no difference between T50 and T100. In conclusion, in the trial area, it‘s possible to irrigate 3-year old fig trees with 220 mm/year (2,200 m^3/ha-year), equivalent to 17% of „Class A“ pan evaporation.

INTRODUCTION

The fig tree is an attractive fruit crop for arid zones because of its tolerance to water deficit (Domínguez (1990)). However, there is very little information about its water requirements. Despite being considered a suitable crop for dry areas, its growth and development can be seriously affected by intense drought conditions (Melgarejo (1996)). Although the soluble solid concentration of fruit increases with a mild water deficit, irrigation is normally necessary at pre-harvest period in spring and summer. Irrigation in summer time is very important for growth of shoots, which are the points where the next season‘s first crop (brevas) and the second harvest of figs will occur. On the other hand, it must be recognized than the fig tree is a very sensitive plant to root rot, therefore excess of irrigation water must be avoided. (Domínguez (1990)).

Regarding water quality, the fig tree is less demanding compared with other fruit tree crops, tolerating an electric conductivity of irrigation water up to 5.5 dS/m (Flores (1990), quoted by Melgarejo (1996)).

D‘Andria et al. (1992) studied the productivity and vegetative growth of fig trees at different irrigation rates. Nonirrigated trees produced less fruit and less shoot length than irrigated ones. They also showed that there is good vegetative growth with irrigation equivalent to 50% of pan evaporation. In relation to the quantity and size of fruits, no significant differences between irrigation with 100% and 50% of ETc were found. Melgarejo (1996) indicates that one of the most important factor in fruit quality is the abrupt change in tree water status, which produces fruit cracking. In contrast, a wet soil causes fruit to be too large and watery, very sensitive to rot and dehydration.

Hernández et al. (1992), while searching for a response function in fig trees to nitrogen dose and irrigation, found that highest fruit yield was obtained with 1,787 mm of water (equivalent to 75% of „class A“ pan evaporation) and 379 g N/plant. On the other hand, Petrotti et al.(1982) conducted a trial to study the effect of five irrigation rates, as percentage of „class A“ pan evaporation, on vegetative growth and foliar mineral contents in fig trees. In the irrigation treatments, no differences in trunk cross-sectional area (TCSA) were found. Differences were observed in foliar nitrogen content, both at the beginning and at the end of season, as well as foliar phosphorus content at the end of season.

Goldhammer and Salinas (1999) conducted an intensive irrigation trial for improving the fig fruit production in the variety „Misión Negra“, and showed that in order to reach the highest fruit yield and profit, a supply of 914.4 mm of water must be applied by season in the trial area.

In the present study, the effect of four irrigation rates on different parameters of vegetative growth and development, in the semi-arid North-Central Zone of Chile, was evaluated.

MATERIALS AND METHODS

The trial was located in the IV Region of Chile, Experimental Station „Las Cardas“ (lat. 30° 13‘ – 30° 19‘ S ,and long. 71° 13‘ – 71° 19‘ W), Facultad de Ciencias Agronómicas de la Universidad de Chile. According to Koeppen‘s climatic classification the trial area belongs to „Bsk“ designation, that means „steppe with high atmospheric dryness and cold“, with 15.2°C of annual mean temperature. Rainfall in the region was 37 mm in the season of the study (1999/2000). The soil is sedimentary from marine origin, about one meter in depth, sandy loam in texture and of good drainage.

A total of 240 fig trees grown from cuttings were used and planted in 1996 at a distance of 6x4 m. The varieties were Brown Ischia (BI), Brown Turkey (BT), Kadota (K), Kennedy (KE), Larga de Burdeos (LB) and Royal Vineyard (RV).

The crop evapotranspiration (ETc) was estimated by a „class A-USWB“ pan, located on bare soil next to the trial area from where the pan evaporation (Epan) was measured daily. To control the irrigation system, the soil water potential was monitored with Watermark fiber blocks placed 40 cm deep and 50 cm apart from the tree trunk. They were measured every two weeks, the day after irrigation. A drip irrigation system was used, with two emitters per tree, each one meter distance from tree trunk. For the irrigation treatments (T25, T50, T100) emitters of different water volume were used: two, four and eight L/h respectively. The treatment without irrigation (T0 or control) had no emitters. The measurements at midday of xilem water potential in leaves were taken periodically during summer time, using a portable Scholander pressure bomb, Soilmoisture Equipment Corp. model 3005 (Scholander et al. (1965)). Two hours before the measurement, the leaves were covered with an internal plastic film and external aluminum foil, in order to equilibrate the xilem water potential between shoot and leaf.

The trial was conducted with four irrigation rates in relation to estimated ETc. The treatments were T0 (not irrigated), T25 (25% ETc), T50 (50% ETc) and T100 (100% ETc). The tree water requirements were calculated according to Doorembos and Pruitt (1976), adapted by Goldhammer (1998) for young trees, using the formula $\{ETc = ETo \cdot kc \cdot A\}$, where ETo is the reference crop evapotranspiration, kc is the crop coefficient (0.75 according to Hernández et al. (1996)) and A is a coefficient related to the soil surface crop covering and can be calculated by $\{A = 2 \cdot \text{shading area } (m^2)\}$. The predetermined irrigation frequency was 7 days.

In order to determine the increase of TCSA both at the beginning and at the end of the growing season, the trunk diameter was measured in all the trees at 20 cm height from the soil. Also, at the beginning of the growing season, four random new shoots per tree were selected in five trees per variety and treatment, in order to measure the shoot length, number of fruit and leaves. At the end of the season, the total number of shoots and their length per tree was registered. Based on the number and length of shoots, the total foliar area per tree was estimated according to Smith and Kliewer (1984).

In order to estimate the total yield of fig fruits per treatment, each tree was harvested from 16/March to 10/May , and the fruit quantity and weight was measured. However, varieties BI, BT and RV experienced fruit drop before maturity. Severe damage from birds reduced the total number of fruit, which meant that the estimation of potential yield per hectare was based on the average weight of the mature fruits multiplied by the quantity of fruit before maturity.

The phenological description was made according to Riquelme (1994), quoted by Melgarejo (1996). According to this method each phenological phase has a correlative letter: Winter bud (A), swollen sicones (B), opening of terminal bud scales (C), first leaves coming out (D), first leaves expanded (E), drop of terminal fruit (F), young sicones (brevas) emerging (G), brevas developing and fig fruit emerging (H), maturity of brevas (I), young fig fruit developing (J), fig fruit maturity (K) and leaf fall (L). In each variety and treatment the length in days of every phenological phase was registered. The experimental design was factorial and completely randomized (6 varieties x 4 irrigation rates x 10 repetitions). Statistical procedures included analysis of variance and correlations by linear and multiple regressions.

RESULTS AND DISCUSSION

The irrigation period was 39 weeks long, from 18.08.99 to 10.05.00. During this time the cumulative pan evaporation reached 1,314.5 mm and in each treatment the following total amount of water was applied: 439.7 mm in T100 (33.5% of Epan); 219.9 mm in T50 (16.7% of Epan) and 109.9 mm in T25 (8.4% of Epan).

With regard to soil water potential(ψ_m), it was possible to appreciate a relationship proportional to the amount of water applied in the different treatments. In T0 the values were –0.022 to –0.017 Mpa; in T50: –0.044 to –0.055 Mpa; T25: –0.069 to –0.095 Mpa , and T0 around –0.199 Mpa. With respect to xilem water potential (ψ_x), no considerable differences between T100 and T50 were registered. However in T25 and T0 it was possible to observe some differences, especially in the nonirrigated trees (T0), which indicates some extent of midday water stress.

Significant differences in TCSA increase were observed in some treatments (Table1), except for varieties BI and RV. A significant difference between T50 and T100 was found only in BT, which would indicate a greater sensibility of this variety to water stress. It is also interesting to emphasize that significant differences between T25 and T0 were only recorded in the variety Kadota. Over 85% of the increase in TCSA was related to other parameters, except in varieties BT and KE, when correlation analysis was carried out.

In order to determine the sensibility of the different varieties to irrigation treatments, a method for genotype comparison was used, according to Finlay and Wilkinson (1963), and Eberhart and Russell (1966). For this analysis, adjusted linear regressions of the different parameters in relation to irrigation treatments were made and the slopes (b1) calculated. The bigger the slope, the greater the sensibility to treatments. In this analysis, every correlation coefficients were greater than 75% and the average sensibility of the different parameters was very low (main average : b1= 0.0829). The order of the varieties from lower to greater sensibility is as follows: BI (0.0293), KE (0.0628), LB (0.0749), RV (0.0836), K (0.1188) and BT (0.1281).

Significant differences in total leaf area per tree were observed only in varieties RV and LB (Table 2). In the variety LB only T100 was different to other treatments, which would mean this variety is more susceptible to water stress; the same occurred with the TCSA increase. In the varieties BI, BT, K and KE, no significant differences were found probably due to a large dispersal of data. A good correlation (above 95%) between leaf area and shoot length, shoot number and leaf number was established. In varieties RV and LB a good correlation (93%) between foliar area and TCSA increase was found. With respect to leaf area response to irrigation, the sensibility order (b1 value) of the varieties is as follows: BT (0.22), K (0.48), RV (0.63), BI (0.71), KE (0.8) y LB (2.28), so that BT is the less sensitive and LB is the most sensitive variety to water deficit.

Significant differences between treatments in shoot length were observed only in the varieties BI and RV (Table 3). In the former, the difference between T100 and T50 with respect to T25 and T0 was considerable, in contrast to RV in which there was a gradual difference. The results from the varieties BT, KE and LB were probably due to a large dispersal of data. A good correlation (above 85%) between total shoot length per tree and TCSA increase was found, except for the variety BT (58%). An adjusted linear regression relating to total shoot length per tree and irrigation treatments was carried out. The coefficients of the multiple regressions obtained were above 90%, except for the variety BT (51%) and BI (79%). That would mean the shoot length has a relatively close relationship with water supply by irrigation. According to slope analysis of the linear regressions, it was possible to establish that LB is again the more sensitive variety to water deficit. With respect to total shoot length response of the varieties to irrigation, the sensibility order (b1 value) is as follows: BT (1.97), RV (4.62), BI (4.68), K (5.63), KE (5.82), LB (13.5). The variety BT is the less sensitive to irrigation treatments.

With regard to shoot number per tree, differences between treatments were not statistically significant in any of the six varieties. However, in all treatments the variety LB had the greater and BT the lesser number of shoots. Only in the variety RV were significant differences in the number of leaves observed (T100 with T25 and T0).

Table 4 reflects the potential yield (PY) and real yield per tree (YT) of the three varieties which produce parthenocarpic fig fruit. Concerning yield per tree, significant differences between some treatments were found, especially with T0. With respect to potential yield, it's important to point out that treatments T0 and T25 are probably overestimated to some extent, due to fruit drop at maturity in trees stressed by water deficit and damage from birds before harvest. According to Flores (1990), quoted by Melgarejo(1996), the yield of fig trees in 4th leaf, destined for fig fruit production, must be between 800 and 1,600 Kg/ha.

With respect to the length of the phenological phases, statistical analysis was not carried out. However, it was possible to observe for phase A a considerable difference between T0 and T100 in the varieties BT, K, KE and RV. In phase C differences between treatments were registered only in the varieties BT and K. In phases F, I and K differences between treatments were recorded only in the variety RV. Therefore, water restriction had a limited effect on the length of the phenological phases in some varieties, particularly on bud dormancy, maturity of brevas and fig fruit, although the effect was not the same in the different varieties.

On the basis of these results, we conclude that apart from the variety Brown Turkey, a 50% reduction of water supply in relation to estimated ETc, had no significant effect on the vegetative and reproductive parameters measured. Therefore, in the trial area it‘s possible to irrigate 3-year old fig trees with 220 mm/year (2,200 m^3/ha-year), equivalent to 50% of estimated crop evapotranspiration (ETc) or 17% of Class A pan evaporation (Epan). Furthermore, the capacity of this fruit tree to resist water stress was verified since no differences between treatment T25 and T0 were found in the parameter determined.

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Literature Cited

Burger, I.J. y de Wet, A.F. 1931. Culture of the fig tree. Farming in South Africa. 6: 70-149.

Condit, I.J. 1941. Fig characteristics useful in the identification of varieties. Hilgardia, 14 (1): 1-65.

D'Andria, R., Calandrelli, D., Grassi, G., Limongelli, F. y Maggio, A. 1992. Effetti dell'

irrigazione sulla produzione e sull' accrescimento del fico nel Cilento. Revista di frutticoltora (11): 75-81.
Domínguez, F.A. 1992. La Higuera, Frutal Mediterráneo para Climas Cálidos. Ediciones Mundi-Prensa, Madrid.
Goldhamer, D. 1998. Personal communication.
Hernández, F.B.T., Susuki, M.A., Frizzone, J.A., Tarsitano, M.A.A., Pereira, G.T. y Correa, L. de S. 1996. Funcao de resposta da figueira à aplicacao de doses de nitrogênio e laminas de água. Eng. Agricola, 16 (2): 22-30.
Maas, E.V. 1986. Salt tolerance of plants. Applied Agricultural Research 1 (1): 12-26.
Martínez, J. 1996. Caracterización ecofisiológica de seis cultivares de frijol bajo condición de estrés hídrico. Memoria de titulo.
Melgarejo, M.P. 1996. La Higuera (*Ficus carica L.*). (T.F.C.). EPSO (U.P.V.). Orihuela pp.82.
Pedrotti, E.L. 1983. Niveis de irrigacao, crescimento das plantas e concentracao de nutrientes nas folhas da figueira "Roxo de Valinhos". Agronomía Sulriogradense, Porto Alegre, 19(1):103-116.
Reginato, M.G. 1994. Hacia una tecnificación del raleo de frutales. Aconex 46: 25-29.
Rebour, H. 1970. Frutales Mediterráneos. Mundi-Prensa Madrid. 410 pp.
Riquelme, A. 1994. Contribución al estudio de los estados fenológicos de la higuera (*Ficus carica L.*). (T.F.C.). EPSO (U.P.V.). Orihuela pp. 89.
Schollander, P., Hammel, H., Bradstreet, E. and Hemmingsen, E. 1965. Sap in the rattan vine. Science 134: 1835-1838.
Schonfeld, M.A., Johnson, R.C., Carver, B.F. and Mornhinweg. 1988. Water relations in winter wheat as drought resistance indicators. Crop Science 28; 526-531.
Sellés, V.G. y Berger, A. 1994. Relación entre crecimiento diario de fruto y de tronco de duraznero y frecuencia de riego. Agricultura Técnica 53 (3): 252-258.
Tyree, N. and Hammel, H. 1972. The measurement of the turgor pressure and water relations of the plants to water by the pressure bomb technique. Journal of Experimental Botany 23; 267-282.

Tables

Table 1.Trunk Cross-Sectional Area increase (mm^2) (Significance $P \leq 0.05$)

Treatments	Varieties					
	BI	BT	RV	K	KE	LB
T0	6,22	5,14 a	3,94	2,46 a	4,77 a	6,75 a
T25	8,32	5,87 a	9,28	8,31 b	6,95 a	5,31 a
T50	10,15	9,77 a	14,07	12,61 bc	10,65 b	10,82 ab
T100	9,34	17,33 b	12,73	14,84 c	10,95 b	13,1 b

Table 2. Total leaf area per tree (cm^2) (Significance $P \leq 0.05$)

Treatments	Varieties					
	BI	BT	RV	K	KE	LB
T0	92.98	136.69	92.64 a	111.11	923	183.97 a
T25	89.94	84.2	104.00 ab	111.13	185.96	123.12 a
T50	160.64	165.63	123.87 b	145.12	136.1	197.79 a
T100	153.98	138.22	154.65 b	154.9	222.03	352.39 b

Table 3. Total shoot length per tree (mm) (Significance $P \leq 0.05$)

Treatments	Varieties					
	BI	BT	RV	K	KE	LB
T0	415,25 a	478,10	363,33 a	481,75	430,76	948,10
T25	442,75 a	275,30	521,30 ab	572,50	1033,56	520,50
T50	897,37 b	648,12	656,71 bc	744,40	821,67	1062,60
T100	826,70 b	583,75	797,42 c	1030,87	1058,30	1973,50

Table 4. Potential Yield per hectare and Yield per Tree. (Significance $P \leq 0.05$)

Treatments	Larga de Burdeos		Kadota		Kennedy	
	PY	YT	PY	YT	PY	YT
	Kg/ha	Kg/tree	Kg/ha	Kg/tree	Kg/ha	Kg/tree
T0	504.3	236.2 a	785.9	56.8 a	578.7	28.5 a
T25	571.4	274.8 ab	718.2	204.9 b	721.5	265.6 b
T50	677.5	501.4 b	772.2	472.9 b	1021.4	163.1 b
T100	731.5	597.0 b	743.5	295.1 b	661.9	192.4 b