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Water Rate Effects on Three Avocado Cultivars.

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Abstract. **An irrigation trial was conducted during 1984-1988, to evaluate the optimal water dose required for early and high production of avocado *(Persea americana,* cvs. Ettinger, Fuerte and Hass, grafted on seedlings of West Indian root-stocks). The trial was carried out in a silty-loam soil along the coastal plain of Israel. Irrigation treatments included a gradual increase of water dosage, adjusted to tree age, in a pre-determined ratio of 70%: 100%: 130%. Data was collected on water and nutrient inputs, soil and leaf analysis, soil matric potential, growth, yield, and fruit size.**

The 130% irrigation increased significantly the yield of 'Ettinger' and 'Fuerte' by 32% and 15%, respectively. The yield of 'Hass' was not affected. The higher rate of irrigation raised fruit size of 'Ettinger' but only in the first year of production when the crop load was light. Fruit size of the three cultivars was not affected by irrigation rate in the following years, when record yields were obtained.

Water uptake took place mainly from the 0 to 60 cm soil layer, although root activity could be detected at 90 cm as well, mainly at the lower rates of irrigation. With the exception of 'Hass' which showed reduced trunk growth at the higher irrigation rate, tree growth increased as irrigation rate was raised. The average electrical conductivity of the 0 to 90 cm soil layers at mid-summer was 1.8, 1.6 and 1.3 dS/m in the 70%, 100%, and 130% irrigation treatments, respectively. The electrical conductivity was proportional to the chloride concentration of the soil. The 'Hass' had higher %N, %P and %K in the leaves as compared to 'Ettinger' and 'Fuerte'. Leaf %K was raised proportionally to the cumulative K fertilization from year to year, with notable interaction with irrigation treatments. Higher leaching in the intensive irrigation resulted in lower soil and leaf K.

The present irrigation experiment pointed out the importance of intensive irrigation for rapid tree growth to achieve full canopy coverage for early production.

A major change in fruit culture during the last two decades was the introduction of reduced soil volume irrigation. It has been found that a regular and high production of fruit crops can be maintained when only 30% to 60% of the soil volume is irrigated. Reduction of the wetted soil volume requires maintenance of lower soil matric potentials and an optimal control of irrigation to avoid water percolation and poor aeration. Several irrigation experiments of avocado were carried out in the past using full soil volume irrigation (Bingham and Richards, 1958; Gustafson *et al.,* 1979; Kalmar and Lahav, 1977; Lahav and Kalmar, 1977; Richards *et a/.,* 1958), and more recently reduced soil volume irrigation with micro-sprinklers or drippers (Adato and Levinson, 1987; Gornat and Goldberg, 1972/73; Gustafson *et al.,* 1979). Almost all of these experiments were carried out on the Mexican rootstock.

Water quality for irrigation is gradually deteriorating. The avocado is most sensitive to salinity, particularly when grafted on Mexican rootstocks (Steinhardt *et al.,* 1984). West Indian rootstocks, which are more resistant to salinity, are being gradually introduced, although their productivity is not well known. The aim of our experiment was to evaluate the performance of the major avocado cultivars grafted on the West Indian rootstock in reduced soil volume irrigation.

Materials and Methods

The irrigation experiment was carried out during 1984-1988 in the avocado plantation of Kibutz Givat Brenner, along the coastal plain of Israel. The orchard was planted in 1980 as large blocks of single cultivars of Ettinger, Fuerte and Hass, grafted on West Indian seedling root-stocks, in a deep and uniform soil. Average soil mechanical and chemical properties for the 0 to 90 cm layer were as follows; 19.4% ± 1.0% sand, 36.9% ± 0.6% silt, and 43.7% ± 0.8% clay; 13.4% ± 0.1% total $CaCO_3$; pH of 7.78 ± 0.2: and cation exchange capacity of 36.5 ± 0.3 meq/100g. Planting densities were 280, 220 and 290 trees/ha of 'Ettinger', 'Fuerte' and 'Hass', respectively. The experimental layout was a randomized block of three treatments replicated five times. Each replicate consisted of 30 to 70 trees (a total of 950 trees).

Irrigation treatments with micro-sprinklers included a gradual increase of water dose adjusted to tree age in a pre-determined ratio of 70%: 100%: 130% (Table 1). The 100% treatment received the dose currently recommended in Israel by the Extension Service, Ministry of Agriculture (7000 m^3/ha for mature orchards). Class A pan evaporation during April to November in the coastal plain of Israel is ca. 1300 mm. Application of the various water rates was achieved by pairing the delivery rates of volume-regulated micro-sprinklers ('Dan Sprinklers', Kibutz Dan, Upper Galilee, 12245, Israel), to the planting densities of the cultivars. Micro-sprinklers used for 'Fuerte' delivered 70, 90 or 120 L/h water and for 'Ettinger' and 'Hass' 70, 90 or 160 L/h. A single micro-sprinkler per tree was used. A uniform wetting area of 20 m^2/tree (49% area wetted) was achieved by adjusting the micro-sprinkler orifice size.

Irrigation water contained 200 to 250 mg/L Cl. Soil fertility and salinity (0-30 cm, 30-60 cm and 60-90 cm) were measured at least once every year and in 1985 to 1986 three times (spring, summer and autumn). Leaf samples were collected in October from the middle portion of the spring flush growth. Standard analytical procedures were used for leaf analysis and determination of soil NH_4^+, $N0_3^-$, N, P, K and EC (Chapman and Pratt, 1961).

Tensiometers were installed at a distance of 80 to 100 cm from the micro-sprinklers, at 30, 60 and 90 cm depth and readings recorded regularly. Vigor was estimated by 5 to 7 independent individuals according to a rating of 1 (worst) to 4 (best). Trunk increment growth was calculated from circumference measurements taken close to the soil surface. The experimental orchard was pruned regularly to maintain tree height at 3.5 m. Pruning, carried out after harvest, consisted of limb removal from the tree center and heading back of vigorous major limbs to laterals. The spring flush growth was suppressed by soft bending of vigorous new growth. The growth of 'Ettinger' was also measured by recording an 8 h daily work output of pruning, carried out after harvest. The orchard was fertigated by incorporating NH_4, NO_3 and KCI into the irrigation water. Nitrogen input was equalized for all irrigation treatments by manual supplements to the 70% and 100% treatments. 'Ettinger' and 'Fuerte[1] received an average of 148 kg/ha N and the 'Hass' 174 kg/ha. Average annual application of K for all three cultivars was 326 to 364 kg/ha. Potassium was not equalized by manual supplements and the 130% treatment received ca. 12% more K than the other two treatments.

Yield of each tree was weighed annually and fruit size (1984-1986) distribution recorded as number of fruit packed in standard size packs, for a combined sample of 400 to 800 kg fruit per treatment.

Results and Discussion

Water rates. Water rate application increased gradually from year to year (Table 1). In the sixth year after planting (1985), the application in the 130% treatment (ca. 7000 m^3/ha) reached the dosage currently recommended by the Extension Service of the Ministry of Agriculture for irrigation of mature orchards along the coastal plain in Israel. Evaporation and irrigation rate increased every year from May until June-July and then decreased gradually (Fig. 1). Irrigation as a coefficient of open pan, however, increased continuously until November.

Growth. Tree vigor, as estimated visually, increased as irrigation rate increased (Table 2). Trunk increment of 'Ettinger' also increased as rate of irrigation was raised. The more vigorous growth of 'Ettinger[1] required additional input of time for pruning. The pruning of one hectare of 'Ettinger[1] required 26 h, 34 h and 53 h in the 70%, 100% and 130% irrigation treatments, respectively. Trunk growth of the other two cultivars also increased as irrigation rate increased, although exceptions were found in the 100% treatment of 'Fuerte' and the 130% treatment of 'Hass' (Table 1). Soil matric potential monitored with tensiometers indicated (data not shown) that the reduced trunk growth of 'Hass' at 130% irrigation may have resulted from excessive soil moisture since in the

130% irrigation treatment of 'Hass', all soil layers had a very high and non-fluctuating water potential (excess water) throughout the entire growing season. It has been shown that excessive irrigation of avocado in fine textured soils reduce trunk growth (Adato and Levinson, 1987). Tensiometer readings usually indicated that water withdrawal was mainly from the 0 to 60 cm layer, although the 90 cm layer could be depleted rapidly in the early spring when irrigation rate was low (i.e. 70% treatment of 'Fuerte' in 1984-1985, Table 1).

Yield and fruit size. The 130% irrigation treatment increased the total yield of 'Ettinger' and 'Fuerte' by 32% and 15%, respectively (Table 3). In 1986, when record yields were obtain ed, the increase was only 21% and 11%, but statistically significant in both cultivars. The yield of 'Hass' was not affected by rate of irrigation. Yield fluctuations from year to year were extreme, in all of Israel, indicating the existence of undefined productivity factors. Nevertheless, the imposed irrigation treatments also contributed to productivity. Since irrigation treatments conferred vigor and growth (Table 2), it can be assumed that the effect on yield was the result of rapid canopy development in 1984. This explanation is supported by the lack of significant yield response in 'Fuerte' in 1985, following its lower rates of irrigation in 1984 (Table 1). The yield in 1987 was biennially low, and low again in 1988, as a result of scorching hot winds at flowering.

Fruit size of 'Ettinger' was greater in 1984 in the 130% treatment (data not shown) but was not affected in later years in either cultivar (Fig. 2), when high and record yields were obtained. In contrast to our results, Lahav and Kalmar (1977) experimenting with a combination of frequency and rates of irrigation, showed a positive effect of irrigation on fruit size. The magnitude of the effect found, however, was relatively small (3-11 % in the various cultivars), and could have resulted from changes in frequency of irrigation rather than dose. In the present experiment a constant frequency was maintained while rate varied and under these conditions avocado fruit size was not affected by irrigation, even in years of extremely heavy yield.

Soil and leaf analysis. Electrical conductivity (EC) and soil Cl decreased as the rate of irrigation increased (Fig. 3), although chloride input increased proportionally to the rate of irrigation. Fertilizers can contribute significantly to soil salinity (Bingham and Richards, 1958; Richards *et a/.,* 1958) and leaching by higher rates of irrigation probably minimized this effect. The highest rate of irrigation was 86% (130%/70%) greater than the lowest rate. The overall EC of the 0-90 cm soil layer decreased from 1.8 dS/m in the 70% treatment to 1.6 and 1.3 dS/m in the 100% and 130% irrigation treatments, respectively. The EC was lowest at the end of the winter rainy season and increased up to midsummer (Fig. 3). In all the soil layers of the 70% treatment and in the upper soil layer of the higher irrigation rates, Cl and EC decreased by late autumn, as a result of occasional rains (October 1986, Table 1) and the continuous increase of irrigation coefficients (Fig. 1). Estimating the total Cl input (250 mg/L in irrigation water + fertilizer) up to the time of the mid-summer soil analysis in 1985 to 1986, and comparing it to the increase of its concentration in the 0-90 cm soil layer during the same interval, indicated that the increase of soil Cl accounted for 108%, 56% and 34% of Cl input in the 70%, 100% and the 130% irrigation treatment, respectively. These estimates (in addition to the tensiometer readings) indicate that there was no significant water percolation and leaching in the lowest rate of irrigation. Steinhardt *et al.* (1984) claims that a 30% leaching factor nullifies the input of 300 mg/L chloride. An 86% increase in water input was not sufficient to completely eliminate Cl and EC buildup in the soil during mid-summer (Fig. 3).

Higher %N, %P and %K were found in leaves of 'Hass' than in the other two cultivars (data not shown). Potassium was applied via fertigation annually, in addition to N, since sub-optimal K levels were found in leaf analysis before the experiment started. Leaf K content was raised proportionally to the cumulative K fertigation, with a notable interaction with the irrigation treatments. The intensive leaching in the highest irrigation rate reduced soil (data not presented) and leaf K (Fig. 4), as compared to the lower rates of irrigation. It should be pointed out that the response to K fertigation in the silty-loam soil (36.5 % CEC) is exceptionally rapid. It can be attributed to the reduced volume (surface) irrigation of the shallow rooting avocado and the practice of continuous fertigation which has been shown to increase K concentration in the soil solution while fertigation continues (Klein and Spieler, 1987).

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Table 1. Yearly rate of water application in the irrigation trial (m^3/ha).

	Ettinger			Fuerte			Hass		
Year	70%	100%	130%	70%	100%	130%	70%	100%	130%
1984	3510	5020	6530	2980	4250	5520	3720	5320	6920
1985	4020	5750	7470	3090	4420	5750	3840	5490	7140
1986[z]	4500	6430	8360	4440	6340	8240	4550	6500	8450
1987[v]	4960	7030	9140	4570	6530	8490	4440	6340	8240
1988[x]	5070	7250	9430	4890	6980	9080	5090	7280	9460

[z] 94 mm rain on October 1-2.
[y] 60 mm rain on October 16-30.
[x] 80 mm rain on November 14-18.

Table 2. Visual estimate of vigor and trunk increment growth.

	Visual estimate[z]			Trunk increment growth (cm^2)		
	Ettinger	Fuerte	Hass	Ettinger[v]	Fuerte[x]	Hass[x]
70%	2.8	3.0	3.0	242	312	184
100%	3.3	3.3	3.0	283	208	255
130%	4.0	4.0	4.0	339	387	221

[z] Rated from worst (1) to best (4) during 1984 and 1986.
[y] For 1984-1986.
[x] For 1984-1987.

Table 3. Yield of avocado in the irrigation trial (t/ha).

	Ettinger			Fuerte			Hass		
Year	70%	100%	130%	70%	100%	130%	70%	100%	130%
1984	4.05	3.88	4.53	5.57	5.33	6.66	8.08	9.18	7.70
1985	4.22 b	5.93 b	8.69 a	4.75	5.66	6.46	14.38	15.98	14.80
1986[z]	14.55 b	14.91 b	18.10 a	19.85 b	21.82 b	24.20 a	11.43	10.69	10.74
1987[v]	3.53	3.76	3.76	0.64	0.51	0.38	2.25	3.26	3.40
1988[x]	8.89	7.15	11.97	1.11 b	0.95 b	1.62 a	1.15	1.10	0.71
Total	35.3 b	35.6 b	47.0 a	32.0	34.4	39.5	36.7	40.6	37.6
%	99	100	132	93	100	115	91	100	93
% (1986)	98	100	121	91	100	111	107	100	100

Mean separation (between irrigation treatments) by Duncan's multiple range test, $p < 0.05$.

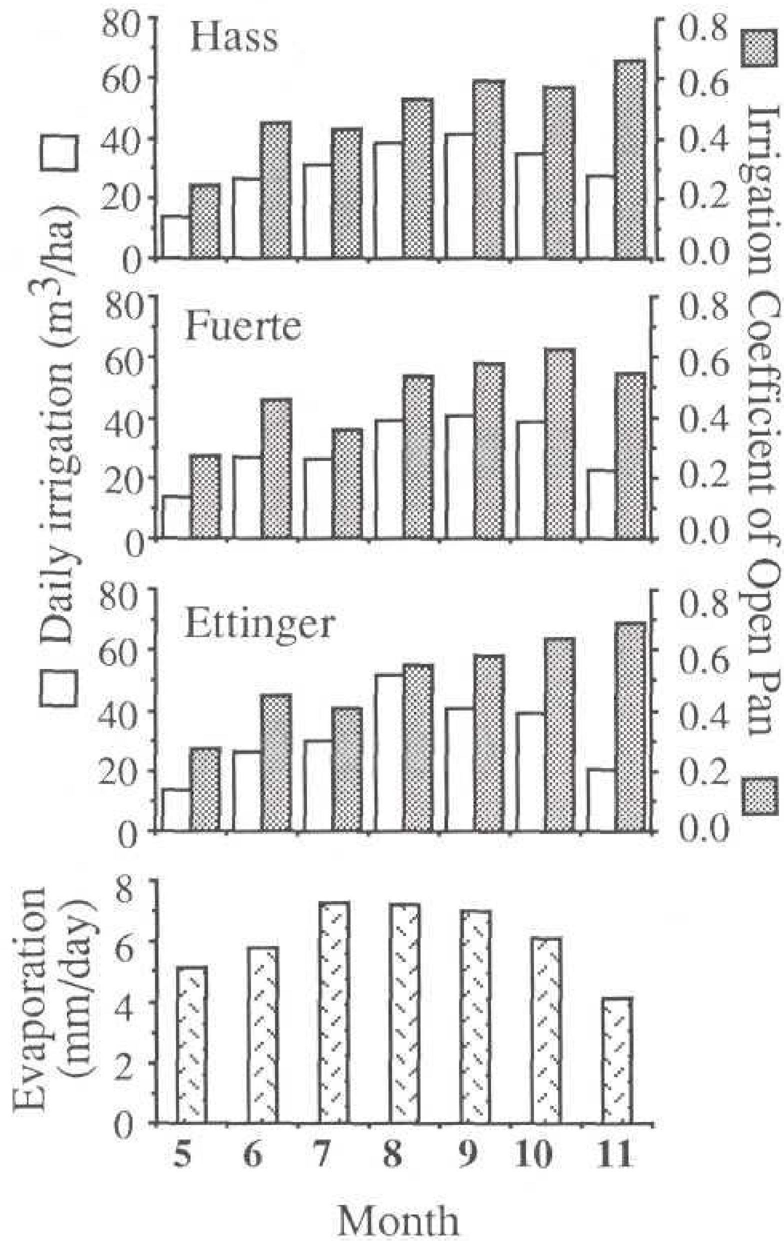

Fig. 1. Average evaporation, irrigation and irrigation expressed as coefficient of class A open pan during 1984-1985.

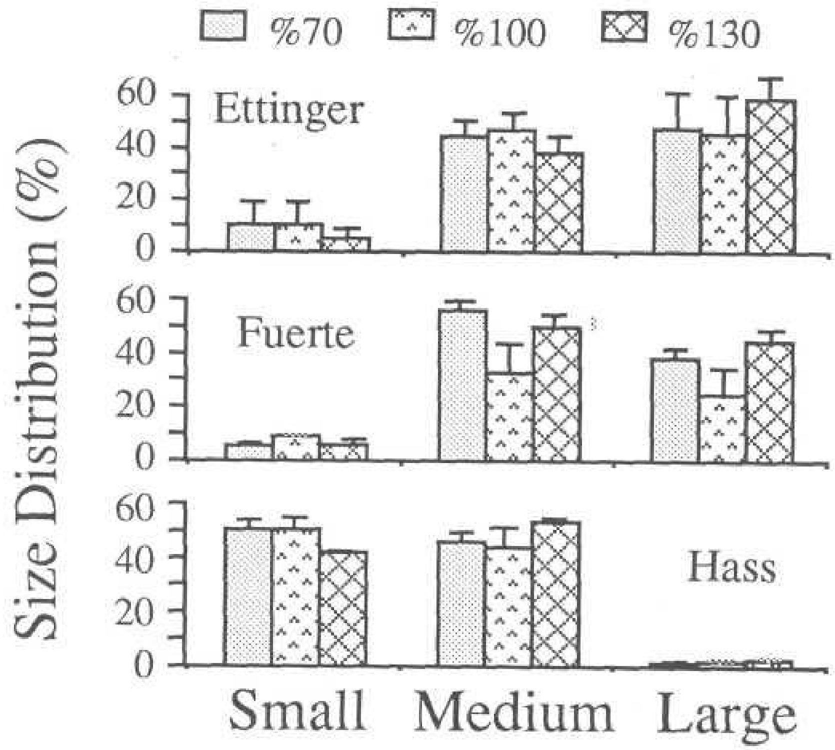

Fig. 2. Fruit size distribution of 'Ettinger', 'Fuerte' and 'Hass' in 1985-1986. Small, medium and large fruit refer to 20-24, 14-18 and 8-12 fruits per pack, respectively.

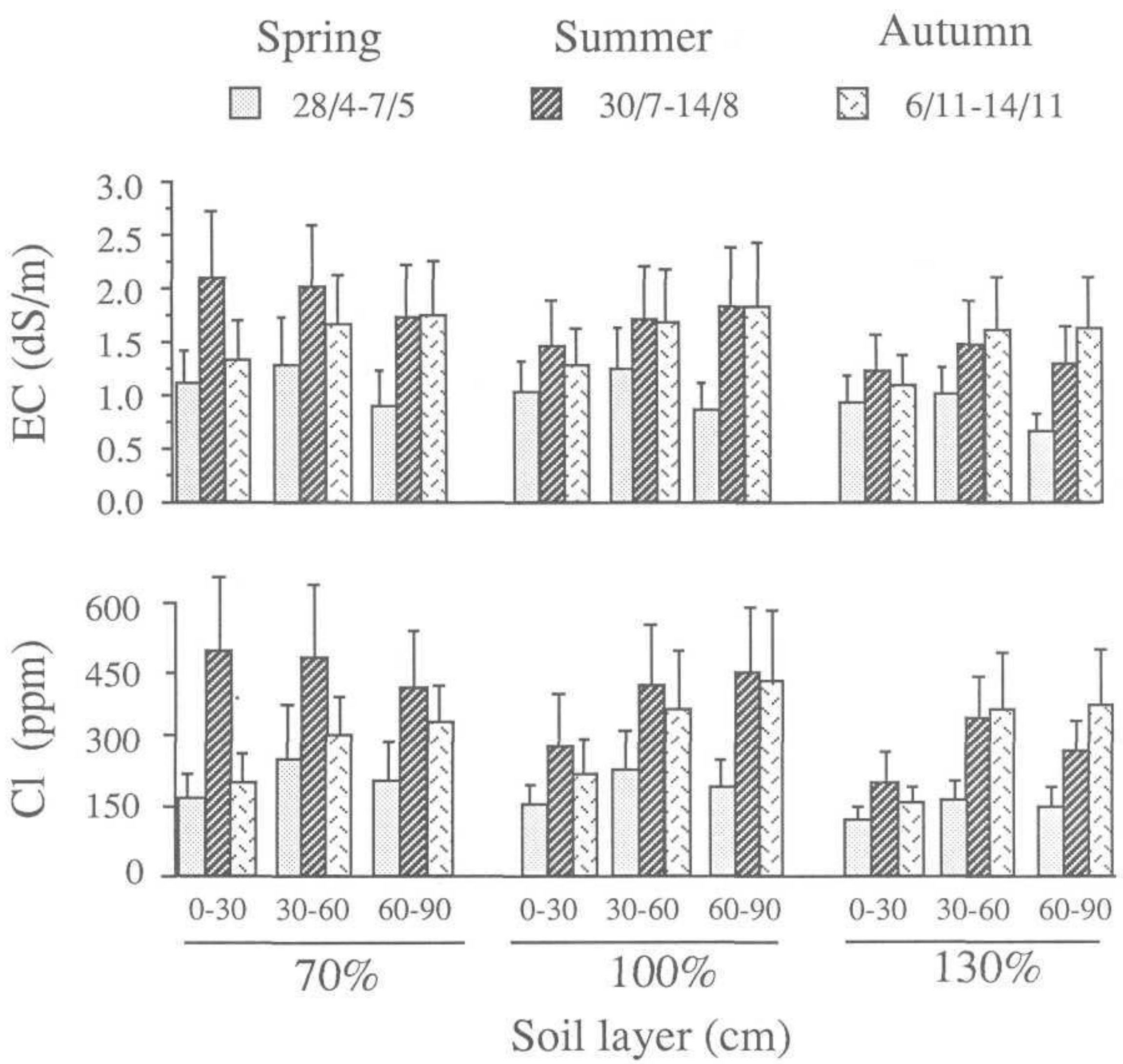

Fig. 3. Chloride and electrical conductivity of three soil layers at three sampling times. Average for 1985-1986.

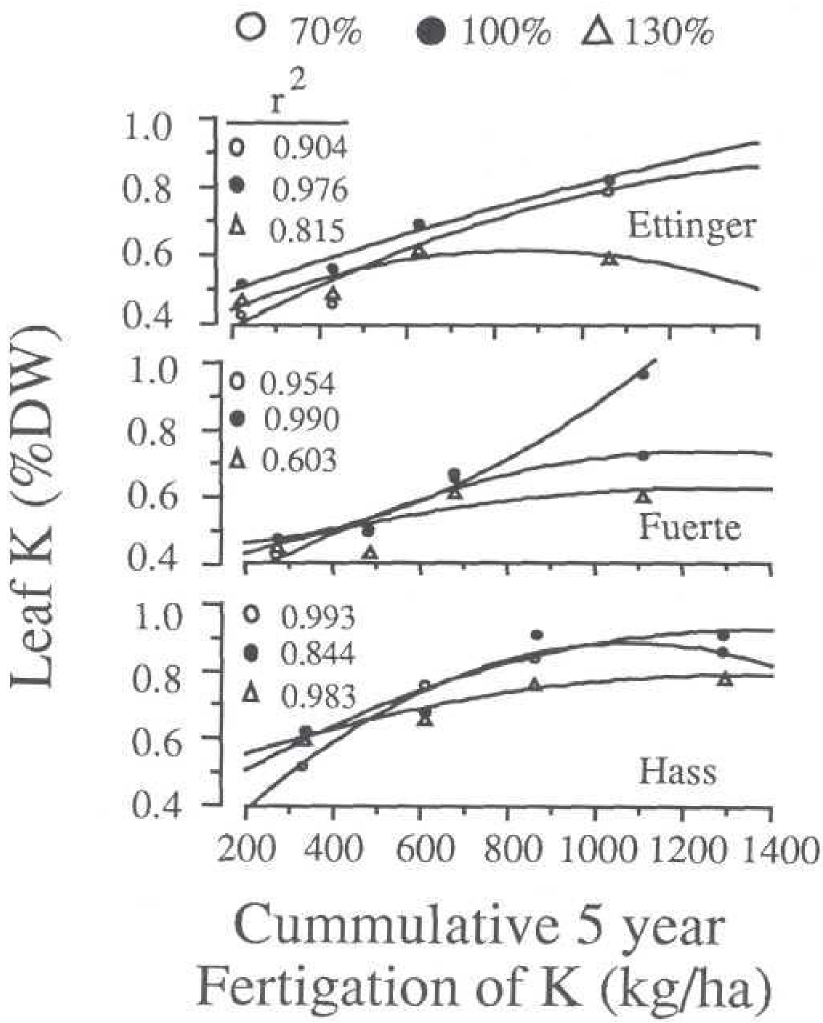

Fig. 4. The effect of irrigation rate on leaf K content during cumulative 5 year fertigation of K.