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EFFECT OF FOUR WATER REGIMES ON PERFORMANCE OF GLASSHOUSE-GROWN NURSERY APPLE TREES

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SUMMARY

Increasing the frequency of water application to potted nursery apple trees from 3-weekly to fortnightly, weekly and daily produced a significant positive effect on six growth indices, but had no effect on final shoot number.

Minimum and maximum leaf xylem water potentials observed varied from −2·3 atm to −45·0 atm, indicating the severity of stresses imposed on the plants. These observed stresses are discussed in relation to field leaf water potentials of apple trees in Granite Belt orchards.

Three commonly used indices of growth in the field, namely girth increment, total shoot growth and final shoot number, are examined in relation to total dry-weight increment.

Granny Smith and Delicious apple varieties used in this study behaved differently in response to treatments imposed and these differences are discussed.

Leaf, shoot and girth growth are shown graphically for the duration of the trial, indicating how watering influenced the progressive developments of these plant parts.

I. INTRODUCTION

Goode (1967) emphasized that early growth of deciduous fruit trees governs the future cropping potential of such trees.

Previous studies by the author (Chapman 1968) showed that plant water stress recorded in apple orchards of the Granite Belt in south-eastern Queensland can be severe and that growth and cropping may be restricted by this stress even when rainfall and evaporation are at or near average values.

Therefore, this study was initiated to examine the relative effects of four water regimes on the growth indices of the two major apple varieties grown in the Granite Belt, namely Granny Smith and Delicious. Also, some values of the minimum and maximum plant water stresses experienced by the two varieties, when subjected to the four watering regimes, were recorded.

In view of the recent upsurge of interest in trickle irrigation in Australia, watering treatments were designed to supply water to plants at different frequencies of application.

II. MATERIALS AND METHODS

Grafted nursery trees of two varieties, Granny Smith and Delicious on Merton 778 rootstocks, were selected for uniformity of size from the nursery. Each tree before planting was pruned back to a 40 cm "whip", and was trimmed and then weighed to obtain initial fresh weight. The root and top trimmings were used to calculate moisture percentages of the plant, and initial dry weight was deduced.

Trees of both varieties were planted into a soil : peat moss mixture (2 : 1 by volume) in 12·6 *l* containers, and placed in a glasshouse.

Four replicates were utilized and four watering regimes were imposed on each of the two varieties using a microtube trickle irrigation system. The design of the trial was a completely randomized factorial array, and the four water regimes were:—

1. Plants watered daily to field capacity.
2. Plants watered weekly to field capacity.
3. Plants watered each 2 weeks to field capacity.
4. Plants watered each 3 weeks to field capacity.

Each fortnight all plants received 500 cm^3 of a double-strength, soluble, complete fertilizer solution ("Aquasol").

During the course of the trial, which lasted 30 weeks, all trees were sprayed three times with 0·05% dicofol for red spider mite (*Tetranychus urticae* Koch).

Fortnightly measurements of girth, leaf number and total shoot growth were made throughout the 30-week growing period of the trial. The girth was measured with a steel tape at a fixed position on the main trunk of the tree, and total shoot growth was measured to the nearest 0·5 cm with a metre rule.

Final leaf number, leaf area, leaf weight, shoot number, shoot growth and total plant dry weight were recorded, and dry-weight increment and girth increment were deduced for all plants.

All dry weights refer to oven-dry weights and all leaf areas were determined with a leaf area photometer. The photometer was calibrated against planimeter measurements for apple leaves of each variety and for each watering treatment. Shoots were defined as extended growth of 2·5 cm or greater in length from buds on the main stem or laterals.

On each occasion when early morning leaf water stress was assessed, this was done using a leaf xylem water potential measurement, determined with a pressure bomb, after Goode (1968). These determinations were made during the third hour after sunrise (Chapman 1970), before and after rewatering of plants.

III. RESULTS

Growth indices.—Tables 1 and 2 show the main effects of the various water regimes on the final shoot number of apple trees. There was no interaction between variety and watering treatment.

TABLE 1

EFFECT OF FOUR WATER REGIMES ON FINAL SHOOT NUMBER

Water Regime				L.S.D.	
Daily	Weekly	Fortnightly	3-weekly	5%	1%
3·50	4·25	4·00	4·00	N.S.	N.S.

TABLE 2

EFFECTS OF VARIETY ON FINAL SHOOT NUMBER

Variety		L.S.D.	
Delicious	Granny Smith	5%	1%
3·56	4·31*	0·70	N.S.

The effect of water regime on final leaf dry weight showed an interaction between variety and treatment. There were significant differences, often at the 1% level, between the varieties and between the treatments imposed (Table 3). Table 4, which summarizes treatment and variety effects on leaf area, shows results comparable with those for leaf dry weight.

TABLE 3

VARIETY AND WATER REGIME EFFECTS ON FINAL LEAF DRY WEIGHT (g)

Variety	Water Regime				L.S.D.	
	Daily	Weekly	Fortnightly	3-KWeekly	5%	1%
Delicious	88·80	39·90	19·69	9·94	9·16	12·48
Granny Smith ..	77·87	57·84	27·92	21·96		

Interaction: Variety x Water regime significant at 1% level.

TABLE 4

VARIETY AND WATER REGIME EFFECTS ON FINAL LEAF AREA (cm°)

Variety	Water Regime				L.S.D.	
	Daily	Weekly	Fortnightly	3-Weekly	5%	1%
Delicious	5 354·6	2 147·3	950·9	363·7	420·4	572·4
Granny Smith ..	3 613·4	2 168·9	1 396·2	869·7		

Interaction: Variety x Water regime significant at 1% level.

Total dry-weight increments, as related to treatment and variety, appear in Table 5.

TABLE 5

VARIETY AND WATER REGIME EFFECTS ON TOTAL DRY-WEIGHT INCREMENT (g)

Variety	Water Regime				L.S.D.	
	Daily	Weekly	Fortnightly	3-Weekly	5%	1%
Delicious	261·25	93·67	15·12	— 6·78	56·61	77·07
Granny Smith ..	141·42	87·30	6·93	— 49·75		

Interaction: Variety x Water regime significant at 5% level.

Figures 1–6 include data on the effect of water regime on shoot growth, girth increase and leaf number of the two varieties. Total shoot growth was similar for the two varieties and main effects are shown on each figure.

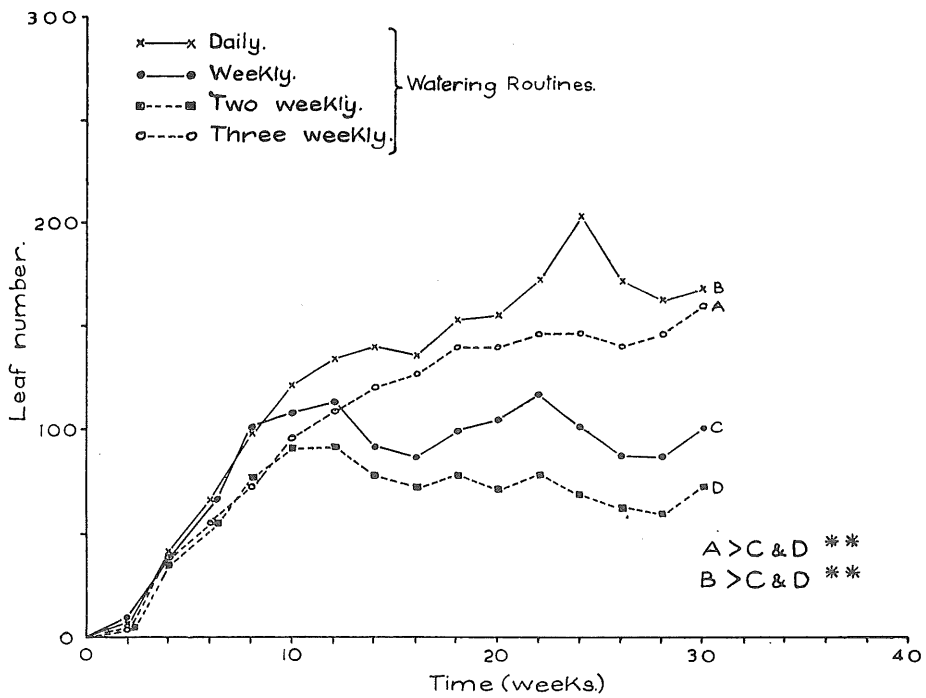

Fig. 1.—Leaf numbers of Granny Smith apple trees as influenced by water regime.

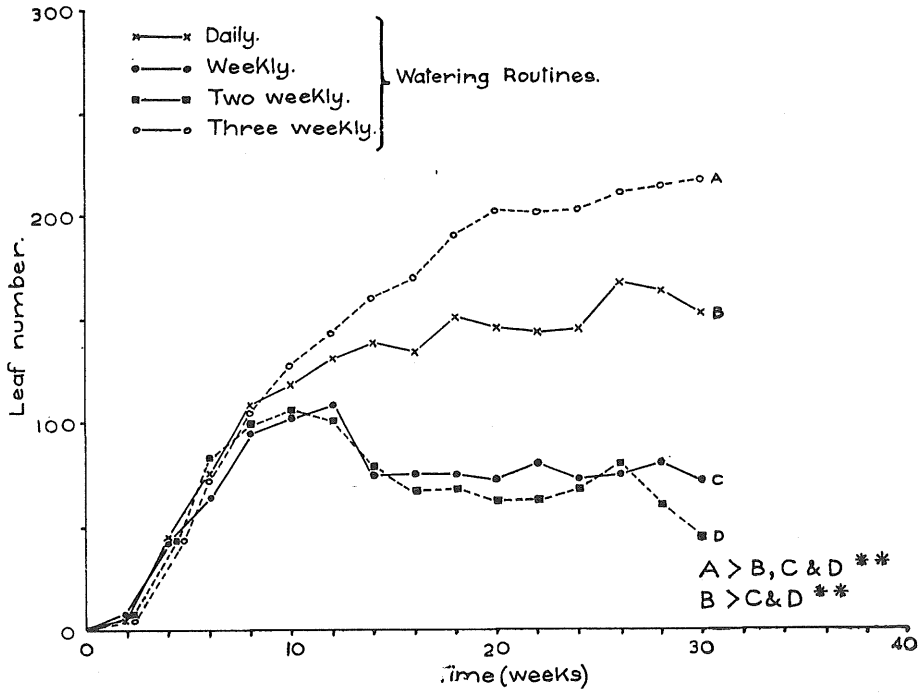

Fig. 2.—Leaf numbers of Delicious apple trees as influenced by water regime.

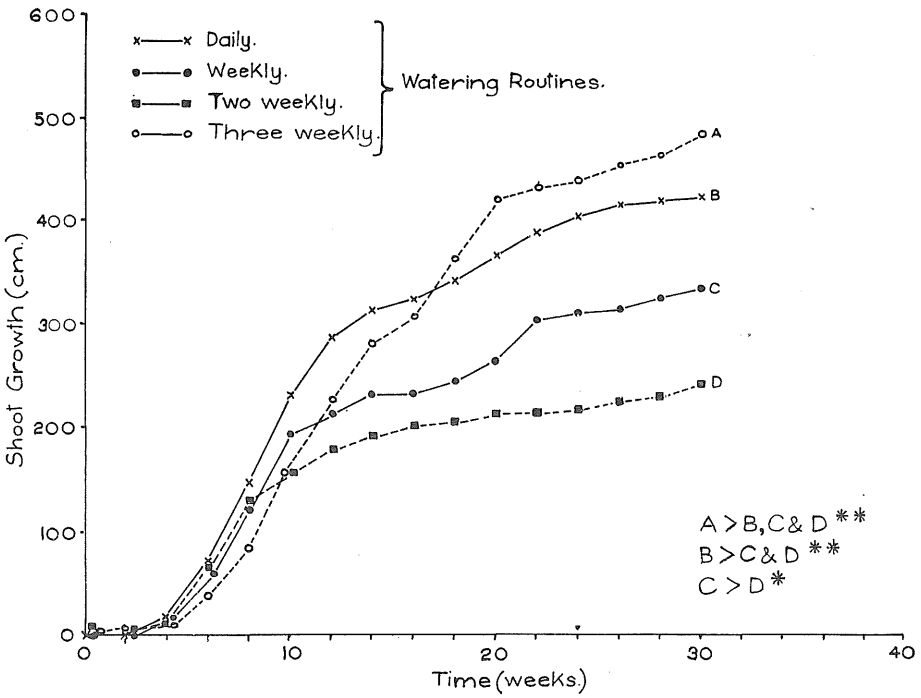

Fig. 3.—Shoot growth of Granny Smith apple trees. Effects of water regimes shown.

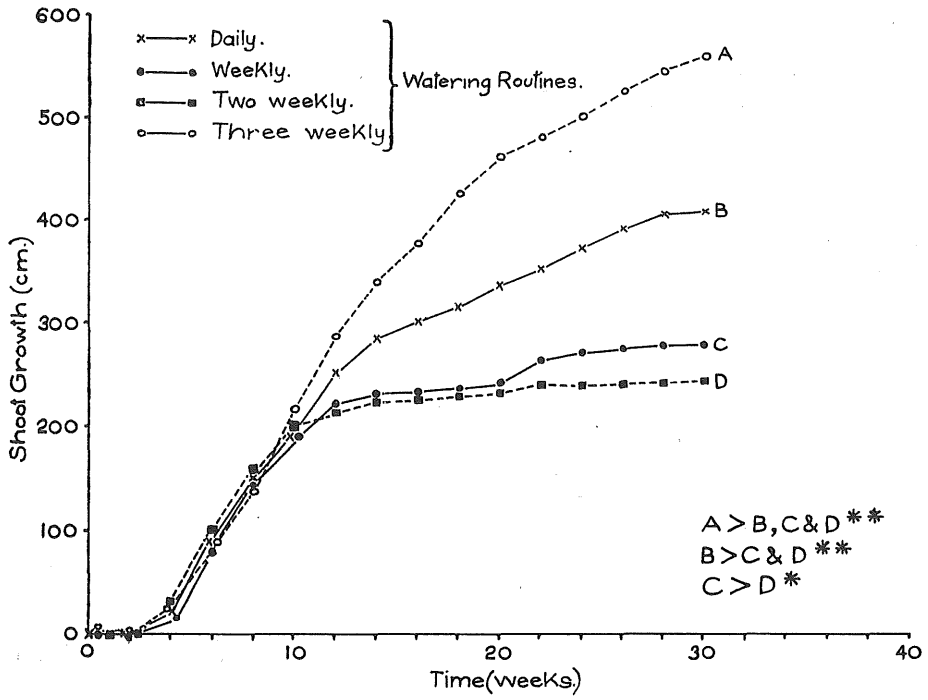

Fig. 4.—Shoot growth of Delicious apple trees. Effects of water regimes shown.

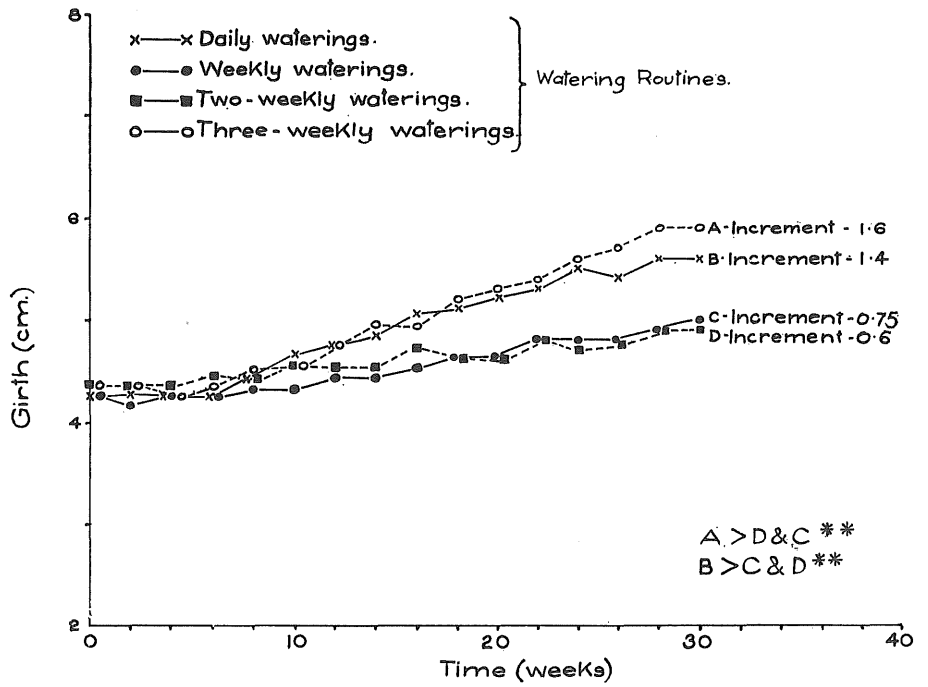

Fig. 5.—Influence of water regime on girth increase of Granny Smith apple trees.

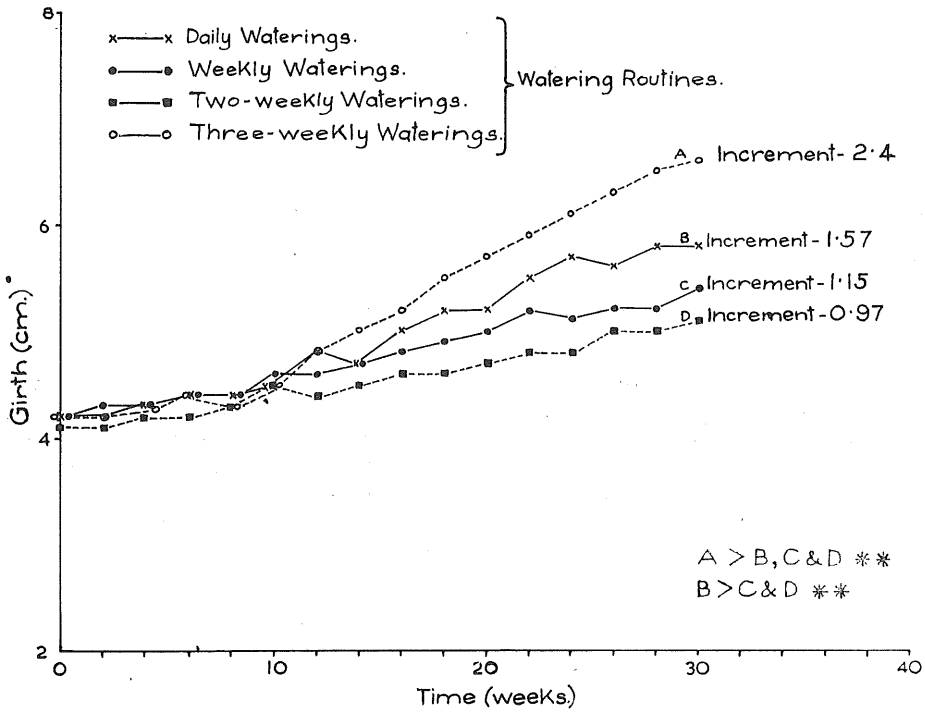

Fig. 6.—Influence of water regime on girth increase of Delicious apple trees.

For girth increment there was interaction between variety and treatment, and details corresponding with Figures 5 and 6 are shown in Table 6. Similarly, data on final leaf number are contained in Table 7, which corresponds with Figures 1 and 2. This duplication of data has been made for convenience of discussion.

TABLE 6

VARIETY AND WATER REGIME EFFECTS ON GIRTH INCREMENT (cm)

Variety	Water Regime				L.S.D.	
	Daily	Weekly	Fortnightly	3-Weekly	5%	1%
Delicious	2·40	1·57	1·15	0·97	0·29	0·40
Granny Smith ..	1·60	1·40	0·75	0·60		

Interaction: Variety x Water regime significant at 5% level.

TABLE 7

VARIETY AND WATER REGIME EFFECTS ON FINAL LEAF NUMBER

Variety	Water Regime				L.S.D.	
	Daily	Weekly	Fortnightly	3-Weekly	5%	1%
Delicious	217·50	153·75	72·0	45·50	41·39	56·35
Granny Smith ..	161·75	169·75	101·25	83·00		

Interaction: Variety x Water regime significant at 5% level.

Leaf xylem water potential.—Leaf xylem water potentials are shown in Table 8. Maximum and minimum potentials observed for each variety and treatment are presented. These observations were taken at random on plants subjected to the various treatments. True replication was difficult to achieve, due to the time involved in taking leaf xylem potential with the pressure bomb. Error due to daily stress fluctuations would have been introduced had all replicates been sampled one after the other, and this was considered undesirable.

TABLE 8

MINIMUM AND MAXIMUM LEAF XYLEM WATER POTENTIALS (atm) OF TWO APPLE VARIETIES GROWN UNDER FOUR WATER REGIMES

Variety	Water Regime							
	Daily		Weekly		Fortnightly		3-weekly	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Delicious	− 2·5	− 4·2	− 2·8	− 40·1	− 2·4	− 42·3	− 2·0	− 45·0
Granny Smith ..	− 2·3	− 4·0	− 2·5	− 35·0	− 2·0	− 38·4	− 2·1	− 41·2

IV. DISCUSSION

In this study seven growth indices were used to assess the effect of the four water regimes on plant performance of the nursery apple trees. Maggs (1961) and Edwards (1963) have shown the value of using a number of growth indices to provide additional information about treatments imposed.

All growth indices, with the exception of final shoot number, showed a significant positive response to an increase in the frequency of watering.

Interaction between variety and treatment occurred with final leaf dry weight, final leaf area, final leaf number, girth increment and total dry-weight increment (Tables 3, 4, 5, 6 and 7 respectively). However, no interaction between variety and treatment was evident for total shoot growth and final shoot number (Figures 3 and 4 and Tables 1 and 2).

The lack of response of number of shoots to watering treatment was attributed to two factors. First, all plants of each variety were "headed back" to "whips" of a similar height with a similar number of buds. Second, the

nursery trees used in this work were all grown under identical conditions and with selection for size should have had comparable stored reserves, and Mochizuki and Hanada (1957) have shown that initial growth is dependent on these stored reserves.

However, it should be noted that while shoot numbers did not vary with treatment, there was a varietal difference, with Granny Smith producing significantly more shoots than Delicious.

A comparison of final shoot number, total shoot growth and girth increment with a total plant dry-weight increment is made here to indicate the reliability of the first three indices, which are often used in the field, for indicating true plan performance.

Final shoot number as mentioned above was not related to treatment imposed, and also was not related to total plant dry-weight increment (Tables 1, 2 and 7). Total shoot growth (Figures 3 and 4) showed significant differences between all treatments with both varieties. However, these differences were not directly comparable with those of total plant dry-weight increment (Table 7), where the differences between fortnightly and 3-weekly watered plants were not significant for either variety. It should also be noted that while total shoot growth was similar for both varieties, total dry-weight increment differed for the daily-watered plants.

A comparison of girth increment and total dry-weight increment (Tables 6 and 7) shows similar results for all watering treatments, but varietal differences were evident for girth increment with daily, fortnightly and 3-weekly waterings.

Therefore, in this trial, girth increment was well related to total dry-weight increment, total shoot growth was somewhat less reliable as a guide, while final shoot number provided no useful guide for assessing treatment effects.

Final leaf dry weight, final leaf area and final leaf number (Tables 3, 4 and 5), which provide a measure of the photosynthetic capacity of the plants, were markedly influenced by the frequency of watering.

Daily watering produced over four times the leaf area development in Granny Smith, and over 14 times the development in Delicious, that was produced by 3-weekly watering. These differences are huge, and indicative of the effects which water shortage can exert on apple trees.

Daily-watered Delicious trees carried more leaves and had greater final leaf areas and leaf dry weights than Granny Smith trees. However, this varietal difference was not apparent with less frequent waterings, and in fact for the 3-weekly treatment Granny Smith performed significantly better than Delicious.

Figures 1 and 2 demonstrate the rate of development of leaves of both varieties when subjected to the four water regimes. Leaf numbers were similar for all treatments during the first few weeks. However, as time progressed production of leaves in the less frequently watered plants of both varieties decreased markedly and in some cases foliage was lost, due to the early senescence and drop of droughted leaves. The more frequently watered plants continued to produce leaves and showed only a gradual decline in the rate of leaf production.

Total shoot growth (Figures 3 and 4) for both varieties was similar and the effect of watering treatment on each variety is shown on the respective figures.

In Figures 5 and 6 and Table 6, the rate of development of girth and final girth increment are shown. With both varieties, there was evidence of girth shrinkage between measurements in all but the daily-watered plants. Delicious had significantly greater total girth increment than Granny Smith for all treatments.

For leaf development, shoot growth and girth increase (Figures 1 to 6), the rate of development of these various plant parts began to diverge with treatment after about the 8th to the 10th week. This was attributed to a depletion of reserves and an increasing dependence of the plant on the new foliage developed. Also as the summer progressed, evaporative demand and foliage display increased and greater stresses were presumably placed on the plants, particularly those receiving water less frequently. This added stress would have then contributed to the divergence in development observed with treatment.

Total plant dry-weight increment (Table 7) shows that some of the less frequently watered plants only changed their form, respired themselves away during the growing season, and in fact decreased in weight. In these cases, plant water stress was excessive and negative growth rates resulted. This is a surprising effect which could also occur in the field, where very hard pruning and severe water stress conditions may combine to produce a similar result.

Differences in total dry-weight increment were evident between treatments and varieties, with Granny Smith performing less creditably under all regimes except the weekly watering treatment. This latter result would seem to indicate that Delicious is capable of better performance under both minimum and maximum stress conditions. However, in practice, with regard to both growth and cropping performance it should be remembered that Granny Smith has a longer growing season, stomata which are more responsive to the onset of water stress, and a higher stomatal resistance (unpublished data of author). The interplay of all these factors will dictate the final result.

Minimum and maximum leaf xylem water potentials, measured at random throughout the course of the trial prior to and after rewatering (Table 8), showed a range of $-2{\cdot}3$ atm to $-45{\cdot}0$ atm. These potentials were generally higher for Granny Smith than Delicious and were related to the water regime imposed. The values for maximum potentials exceeded maximum leaf water potentials measured in field studies (viz. -20 atm (Chapman 1971)), and are indicative of the severity of the water stress conditions even allowing for the fact that xylem potentials for apple leaves may differ from water potentials (West and Gaff 1971). Also it can be seen that weekly-watered plants had xylem potentials which approached those of the fortnightly and 3-weekly watered plants and therefore in many instances the latter plants experienced severe stresses over long periods before rewatering took place.

In view of the magnitude of the water stresses imposed by treatment in this trial, it is reasonable to assume that many of the effects on growth indices were exaggerated when compared with field-grown plants. Because of this, field trials are now under way to establish the effects of watering frequency on growth and cropping of the Delicious and Granny Smith varieties.

Other factors such as stomatal behaviour, desiccation resistance and plant tissue relative water content-water potential relationships are under examination. Present data indicate that while the apple tree is capable of withstanding considerable protoplasmic desiccation, small water stress values will have a large effect on tree productivity. Confirmatory photosynthetic studies are also under way in an attempt to explore these issues.

V. ACKNOWLEDGEMENTS

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