developed here to study the effect of NG and IW on the appearance of the processed product, and to determine if the presence of IW might affect the persistence of chlorophyll in the pods.

Studies are needed to determine the genetic relationships and possible pod quality interactions between IW and the persistent green seedcoat characteristic (3). Extensive additional study would be required to determine the relationships between the factors controlling IW and the known mature seedcoat color factors of beans.

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The Effects of Regulated Water Deficits on Pear Tree Growth, Flowering, Fruit Growth, and Yield

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Additional index words. *Pyrus communis*, irrigation

Abstract. **Three levels of water deficit generated by 3 levels of irrigation applied at times of rapid vegetative growth and/or slow fruit growth were compared to determine their suitability for restricting vegetative growth on 5-year-old 'Bartlett' pear (*Prunus communis* L.) trees trained to a Tatura Trellis. For the period of Regulated Deficit Irrigation (RDI), the amount of water applied replaced 92%, 47%, and 23% of the evaporation calculated over the planting square (Eps). In the subsequent period of rapid fruit growth until harvest, all trees were irrigated with 150% Eps to ensure that the wetting pattern from the trickle system wetted the entire root zone. Shoot and frame growth declined in proportion to the water deficit. Fruit tended to grow more slowly on the 23% than 46% treatment during RDI, but growth on the 46% and 92% Eps treatments was similar. In the subsequent period of full irrigation, fruit growth initially was significantly faster on the RDI treatments, and the same trend was maintained for most of the remainder of fruit growth. The net result was that yield was marginally increased RDI treatments. In the subsequent season, flowering was increased on trees recieving RDI in the previous season.**

The Goulburn Valley of Northern Victoria is the center of pear production in Australia. 'Bartlett', the major cultivar, grows vigorously in the area, and heavy winter pruning and frequently summer pruning is required to maintain consistent production, high fruit quality, and to facilitate orchard management. Close plantings are especially difficult to manage.

Regulated Deficit Irrigation (RDI) during slow fruit growth and rapid shoot and frame growth greatly reduced peach vegetative growth without loss of fruit size or yield (2, 4). The rapid stages of fruit and vegetative growth of pears is similarly out of phase. Our observations indicate that most pear tree growth occurs before rapid fruit growth begins, and the amount of vegetative growth may be restricted by a similar irrigation strategy to that developed for peach. This paper reports an experiment in which we evaluated 3 levels of RDI to determine the suitability of these approaches for controlling vegetative growth in pear.

Materials and Methods

Experimental site and design. The experiment was located on a 0.05 ha block of 5 year-old 'Bartlett' pear trees trained to a Tatura Trellis, and growing on a Lemnos loam (6). The block layout consisted of 3 rows of trees spaced 4 m apart with the row tree spacing arranged in 3 blocks of 0.5, 0.75, and 1.0 m. The irrigation treatments were replicated by randomizing within these blocks. The central row was used as the plot row. Plot size varied slightly, being 4 m long at the 0.5 m (8 trees) and 1.0 m (4 trees) spacing, and 3.75 m long (5 trees) at the 0.75 m spacing. On each side, the adjacent trees of guard row received the same irrigation treatment as the experimental plot.

Irrigation. The trees were trickle irrigated through drippers spaced along the tree line at 0.5 m. The 3 irrigation treatments were obtained by varying the rate of water application in the ratio 4:2:1 until 7 Dec. (about 60 days from full bloom) after which all treatments were irrigated at the same rate. Irrigation was applied according to evaporation from a U.S. Class A pan evaporimeter. A water meter measured the quantity of water applied, which was expressed for the high level of irrigation as liters/m of row or percentage of replacement of evaporation from the planting area (Eps), for 3 periods of time in which the replacement factor varied significantly (Table 1). The 3 treatments are henceforth described by the replacement factor between 1 Oct. and 7 Dec., (i.e., 92%, 46%, and 23% Eps).

Measurements. All trees were summer pruned on 14 Dec. and the prunings were weighed. Trunk cross-sectional area (TCA) was estimated from measurements of trunk diameter on 1 Oct., 7 Dec., and 26 Jan. Shoot extension was measured on 2 tagged limbs per plot on 16 Nov. and 7 Dec., and the mean shoot length was calculated. Tagged fruit on 2 trees per plot were measured weekly across the horizontal axis from 2 Nov., and an estimate of the fruit volume was obtained (1). Gross yield, canning yield (fruit diameter >60 mm), fruit number, and mean fruit weight were determined at harvest on 26 Jan. In the following spring, blossom clusters were counted on 2 limbs per plot and the cluster density per m^2 of limb cross sectional area calculated. Data was analysed by analysis of variance and regression.

Received for Publication 15 Nov. 1983. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Table 1. Irrigation applied to Bartlett pears in relation to evaporation and row length.[z]

Date	Liters/m of row	Evaporation replacement from planting area, Eps (%)	US Class A pan evaporation (mm)
23 to 30 Sept.	12	10.8	28
1 Oct. to 7 Dec.	1600	92.0	433
7 Dec. to 26 Jan.	3553	149.5	594

[z]For treatment receiving the highest level of irrigation during the period of Regulated Deficit Irrigation.

Results

Tree growth. The weight of summer prunings, mean shoot length prior to summer pruning, and TCA increase all indicate that additional water increased vegetative growth (Fig. 1, 2). Most of the increase in shoot growth occurred prior to 16 Nov. (Fig. 2), and shoot extension after this date was confined to those treatments receiving more than 23% Eps. At the time of summer pruning, shoot extension had ceased on the 46% Eps, and only the strongest shoots were still growing in the 96% Eps treatment (visual observations).

Fruit growth and yield. RDI did not decrease final fruit size or yield. In fact, gross yields of 36.8, 36.3, and 32.8 kg/m of row and canning yields of 33, 31.5, and 29.1 kg/m of row, respectively, for the 46%, 23%, and 92% replacement are increased for the RDI treatments. Except on 2 occasions, fruit measurements both during and after RDI showed similar growth between treatments. (Fig. 3).

On 7 Dec., when RDI was discontinued, fruit size was significantly larger on the 46% than on the 23% treatment while in the following week the fruit grew more rapidly on the 46% than on the 92% Eps treatment. There was a trend for the latter effect to be maintained over the following 3 weeks when 50%, 47%, and 43% of the total estimated fruit volume was accumulated in the 23%, 46%, and 92% Eps treatments, respectively. Consequently, the size difference between fruit from the 46% and 23% Eps treatments on 7 Dec. (5.3 cm^3) declined to 2.7 cm^3 at harvest. The importance of these differences in growth and trends in fruit size is increased when one considers that the 46%, 23%, and 92% Eps treatments carried crops of 3.45, 3.26, and 2.64 fruit/cm^2 TCA, respectively. These differences were also not significant but were consistent with previous results with peaches (2, 4). They establish that fruit growth and yield of pears is not reduced by RDI.

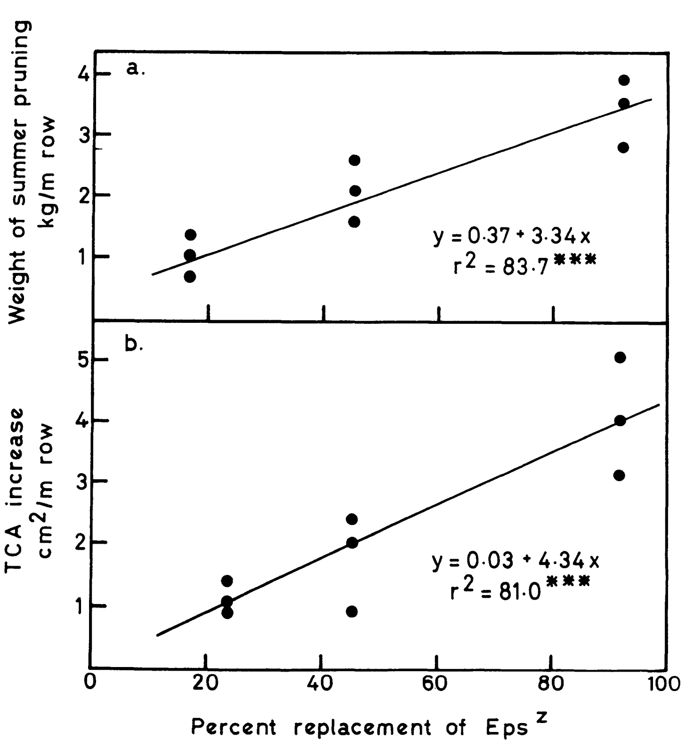

Fig. 1. Influence of irrigation on (**a**) trunk cross-sectional area and (**b**) fresh weight of summer prunings of 'Bartlett' pears (Z. Evaporation calculated over the planting square).

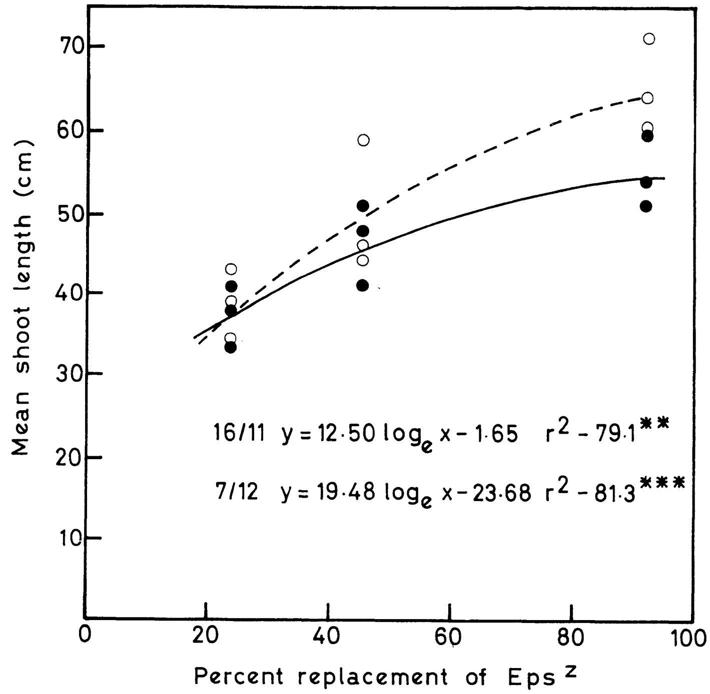

Fig. 2. Influence of irrigation treatment on mean shoot length of 'Bartlett' pears on 16 Nov. (●) and 7 Dec. (○) (Z Evaporation calculated over the planting square).

Flowering. Blossom density was increased in the following spring by RDI with flower clusters/cm^2 of limb cross sectional area of 2.39, 2.01 and 1.36 ($P > 0.05$, LSD = 0.83) respectively on the 0.23, 0.46, and 0.92 Eps treatments.

Discussion

As occurred with peaches (2, 4) RDI reduced vegetative growth in proportion to the water deficit. In contrast to the peach, however, fruit growth of the pear was not significantly depressed during RDI. At the high water deficit, there was a trend towards reduced fruit growth, but at 46% Eps there was no discernible effect of water deficit on fruit growth. This observation has a number of important practical implications. First, it confirms our earlier conclusion that competition with vegetative growth has at least as strong an effect on fruit growth as moderate levels of water deficit (2). Secondly, it indicates that the mechanism regulating the effects of RDI on competition between fruit and vegetative growth involves a differential response by the competing organs to the tree water potential. The latter conclusion suggests that the response of specific organs and tissues to tree water potential should be thoroughly studied. Organs, tissues

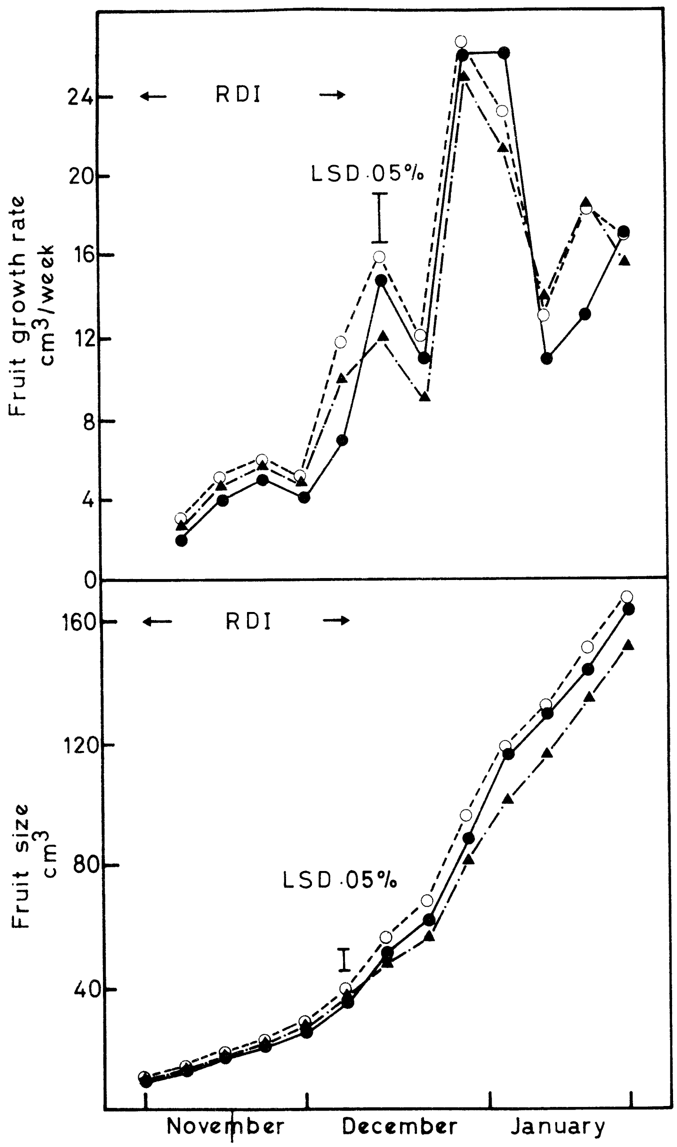

Fig. 3. Influence of irrigation treatment on rate of growth of fruit (**a**) and fruit size (**b**) of 'Bartlett' pears, ● 0.23 Eps, ○ 0.46 Eps, and ▲ 0.96 Eps.

and physiological processes (e.g., flower initiation) may respond more of less sensitively, or perhaps have thresholds (as the above data suggest) that could be manipulated precisely by regulating the water deficit.

From a practical point of view, the effects of RDI on fruit and vegetative growth are especially encouraging. The spring of 1982 was exceptionally dry and by mid-November, a large difference existed between the net evaporation (260 mm) and the amount of evaporation replaced by the low level of irrigation (65 mm). Under these conditions of high water deficit, 5-year-old pear trees yielded 79 MT/ha of canning grade fruit compared to 72.5 MT/ha harvested from fully irrigated trees.

The time when RDI was discontinued was important. Fruit measurements suggest (Fig. 3) that irrigation at the high level should have commenced on 30 Nov. rather that 7 Dec. Between the above dates fruit began growing rapidly, and there was a tendency for less growth on the 23% compared to the 46% Eps treatment. This tendency is important from a practical point of view, because shoot growth declined under the former treatment, but fruit size and yield favored the latter. It may have been possible to gain the increased level of growth control without any loss in yield (compared to the 46% Eps treatment) if RDI had been discontinued a little earlier. In this context, it should be noted that shoot growth had ceased on the 23% treatment by mid-November (Fig. 2), and it is likely that additional water could have been applied at this stage without re-initiating shoot growth. These data may indicate that a short period of RDI in the spring could control vegetative growth in early maturing fruit species and cultivars, in which competition from fruit growth commences earlier. Clearly, for fruit that mature sufficiently early to permit vegetative growth to re-initiate after harvest, RDI could be reimposed readily.

The effect of RDI on blossoming also has major practical implications. The pear trees in this experiment had entered a biennial bearing habit, and blossom density was increased in the off-season. Close investigation of RDI is warranted on species and cultivars with pronounced biennial characteristics.

In our experiments on both peach and pear, all trees were trickle irrigated. The majority of conventional spaced trees are either flooded or sprinkler irrigated. In theory, trickle and microjet systems which wet smaller root volumes (5) and can apply the deficit irrigation daily should give the best results with RDI. First, restricted root volumes (with consequently higher root densities) will dry the soil rapidly. Secondly, when irrigation interval rather than volume of water applied is used to produce a water deficit, the tree will be subject to low water potential for extended periods, which may lead to fruitlet abscission and other deleterious effects. Nevertheless, considering the high cost of pruning trees irrigated with conventional irrigation systems, it is clear that the value of using RDI to control vegetative growth must be determined.

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