Irrigation scheduling for regulated deficit irrigation (RDI) in stonefruit

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Irrigation is generally associated with minimising moisture stress. Under such conditions trees grow quickly and are very vigorous. Until a tree has reached its desired size it should not be stressed for water. Once the tree has grown to its desired size, however, vigorous growth not only increases the need for pruning but can reduce yield. Irrigation needs to be managed in such a way as to control the growth of shoots. Such management is known as regulated deficit irrigation (RDI) and in experimental plots has maintained yields of peaches and nectarines, and reduced irrigation by about 30 - 40 %.

The RDI technique

With RDI, trees are kept short of water when fruit growth is slow or after harvest but are given ample water during the time of rapid growth of fruit. This reduces the growth of shoots. If RDI is properly managed, there is no reduction in the size of fruit or yield and fruit quality (sweetness, maturity, firmness, colour) is maintained. The reason why the above technique works relates to the growth pattern of shoots and fruit. On most deciduous fruit trees, the shoots grow rapidly early in the season and their growth slows down as the fruit begins to grow rapidly. In contrast, early in the season the fruit grows slowly. Water stress at this time will reduce the growth of shoots without markedly affecting the growth of fruit.

With RDI, the irrigation season can be divided into four periods. The duration of these periods is determined by both weather and the relationship between vegetative growth and the growth of fruit.

Period 1

During this period immediately following flowering, care needs to be exercised to avoid water stress particularly in stonefruit. For example, in peaches there is an initial rapid fruit growth for approximately 4 weeks following flowering when the soil should not be allowed to dry out beyond 40 kPa in sandy soil and 60 kPa in clay loam soils.

In most seasons in the Goulburn Valley, crops are not irrigated until reference crop evapotranspiration (ET_o) exceeds rainfall by 125 mm. Generally, this is in late October but could be as late as mid-November in a wet spring. However, in recent years there has been insufficient winter and early spring rain to wet up the root zone. Root zone soil moisture must be measured to avoid water stress. Similarly, in environments dissimilar from the Goulburn Valley (for example, trees growing in lighter soil types) measurements of soil moisture will avoid the root zone drying out excessively.

Period 2

Period 2 commences approximately four to five weeks after flowering and continues until six weeks before harvest for early-maturing fruits (that is, before mid-January), and eight weeks before harvest for later maturing fruits. Trees are irrigated with greatly reduced volumes of water compared to that which would normally be applied. Irrigation to replace 30 % of orchard water use capability is recommended. Soil moisture in the middle of the wetted fibrous root zone should not exceed 100 kPa in sand or 400 kPa in clay loams.

Period 3

In this period six to eight weeks before harvest, the fruit is growing rapidly, and the tree now needs ample water to reach maximum fruit size. Water stress must not occur during this final period of fruit growth. Irrigation to replace 100 % of orchard water use capability is recommended. Soil moisture in the middle of the wetted fibrous root zone should not exceed 40 kPa in sand or 60 kPa in clay loams.

Period 4

After harvest a similar strategy as during period 2 can be implemented. In early maturing varieties and species (for example, cherries and apricots) there is considerable shoot growth after harvest which should be kept in check to maintain fruitfulness and even cropping within the canopy. Irrigation to replace 30 % of orchard water use capability is recommended. Soil moisture in the middle of the wetted fibrous root zone should not exceed 100 kPa in sand or 400 kPa in clay loams.

Scheduling RDI from ET_o

In all three periods, reference crop evapotranspiration (ET_o) readings, which are readily available in most districts, can be used to schedule irrigation. However, it is strongly recommended that soil moisture monitoring be integrated into an irrigation schedule to avoid over- or under-irrigating trees.

In Table 1, examples of how to use ET_o to schedule RDI in a peach/nectarine orchard are shown for drip, microjet and sprinkler irrigation. The table is divided vertically into three sections; each section refers to a different form of irrigation - drip, microjet and sprinkler.

To show the influence that the spacing between trees has on the calculations for scheduling of irrigation, different spacings between trees are used for each of the three systems of irrigation. As previously mentioned, the irrigation season is divided into three periods, and the calculations needed during each of these periods are set out below the appropriate period. These calculations are divided into various sub-headings shown on the left side of Table 1. The following explains these sub-headings and should be read in conjunction with a perusal of the table.

Weekly ET_o

Values for daily and weekly ET_o (mm) can be obtained from the Bureau of Meteorology. Data shown in the table are typical for the Goulburn Valley. To use the table, you merely have to replace the figures given in the example by those that you have collected in the previous week.

Effective area of shade

Orchard effective area of shade (EAS, %) is a simple and practical estimate of tree size and hence the actively transpiring leaf area in an orchard. EAS is determined from measurements of the percent shade cast by the trees at three key times a day (3½ h before solar noon, at solar noon and 3½ h after solar noon). Taking three measurements per day accounts for differences in foliage extent (i.e. training system and tree size), planting arrangement (i.e. row orientation and tree spacing) and leaf area density (i.e. pruning management). EAS is calculated from the average of the three measurements. The percent shade can be estimated visually or measured using a light bar known as a ceptometer.

Understorey coefficient

The understorey coefficient (K_e) is a factor to convert ET_o to understory water use; the combination of soil evaporation and cover crop water use. For modern high-density orchards, micro-irrigation is designed to deliver water requirements to individual trees and minimize the contribution of irrigation to understorey water use. Hence under drip irrigation K_e can be set to 0.1 and under microjet set to 0.2. Whereas under sprinkler irrigation there is substantial understorey water use and K_e can be set to 1-EAS. For example, if EAS = 20 % then K_e = 1-20 % = 0.8.

Stress coefficient

The stress coefficient (K_s) is a factor used for setting the amount of stress deliberately imposed on the orchard. A value of 1.0 is no stress. For example, during period 2 under RDI it is recommended to replace 30 % of orchard water use capability, hence K_s = 0.3.

Weekly orchard irrigation

Weekly irrigation for a peach orchard (I) is calculated from weekly ET_o, effective area of shade (EAS), the understorey coefficient (K_e) and the stress coefficient (K_s) using the following formula:

$$I = K_s \times ET_o \times [(1.1 \times EAS) + K_e]$$

Area of planting square

The area of planting square (m^2) is calculated from the distance between rows multiplied by the in-row distance between trees. Different spacings between trees are given for each form of irrigation in the example in Table 1.

Weekly tree irrigation

Weekly irrigation requirement per tree is calculated from the the weekly orchard irrigation multiplied by the area of planting square.

Recommended interval between irrigations

The interval between irrigations (day) is also important with RDI, and recommended intervals are given in Table 1. For drip irrigation, the rationale behind these recommendations relates to the size of the wetted root zone. In period 2, frequent irrigation (that is, daily) wets a small volume of soil regularly. In contrast, using a two-day interval in period 1 (and daily interval in period 3) enables a much greater volume of water to wet a larger root zone. This manipulation in wetting the root zone could be responsible for the observed improved growth of fruit in period 3 and higher yields on RDI-managed trees. If, with drip irrigation, the system must be run for more than 24 hours every second day to provide the required quantity of water, serious thought should be given to upgrading the system to a higher rate of discharge.

The longer interval between irrigations in period 2, than in period 1 and 3, for both microjet and sprinkler irrigation is necessary to allow enough water to wet the soil to a reasonable depth.

In period 2, with microjet and sprinkler irrigation, an interval of seven and 21 days respectively is recommended. If the combined effects of evaporation, spacing of trees and rate of application result in less than two- and eight-hour irrigation times respectively for microjet and sprinkler irrigations, the interval will need to be extended until such figures are reached. For these long intervals, irrigation is based on the accumulated evaporation since the previous irrigation.

Water required at each irrigation

The quantity of water required at each irrigation is multiplied by the interval between irrigations in days and divided by 7 (that is, by the number of days in the week). For example, if the weekly irrigation requirement is 52 litre but the interval is only two days, then approximately 15 litre of water is applied every 2nd day (52 x 2 ÷ 7 = approximately 15).

Application rate

Application rate (litre/hour/tree) is the amount of irrigation applied to each tree per hour. This is calculated from the emitter discharge rate multiplied by the number of emitters per tree. If not known, this should be measured.

Run time

Run time (hour) is calculated by dividing the number of litres per tree required at each irrigation by the application rate.

RDI with flood and furrow irrigations

With surface irrigations, such as flood or furrow, it is difficult to control the amount of water applied per irrigation. Nevertheless, the principles discussed above apply; the initial irrigation can be delayed and the interval between irrigations can be increased in period 2. After 12 years of experimenting with RDI it became obvious that in the past, much water was wasted on early irrigation. Our results at Tatura indicate that mature trees would have cropped better with less water.

Table 1. Example calculations of irrigation interval and run time for RDI under drip, microjet and sprinkler irrigation.

	Drip 4.5 m × 1.5 m planting			Microjet 4.5 m × 1.5 m planting			Sprinkler 5 m × 3 m planting		
	Period 1	**Period 2**	**Period 3**	**Period 1**	**Period 2**	**Period 3**	**Period 1**	**Period 2**	**Period 3**
Weekly ET_o (*mm*)	20	35	45	20	35	45	20	35	45
Effective area of shade *(%)*	30	60	60	30	60	60	20	50	50
Understorey coefficient (K_e)	0.1	0.1	0.1	0.2	0.2	0.2	0.8	0.5	0.5
Stress coefficient (K_s)	1	0.3	1	1	0.3	1	1	0.3	1
Weekly orchard irrigation (*mm*)	8.6	8.0	34.2	10.6	9.0	38.7	20.4	11.0	47.3
Area of planting square (*m^2*)	6.75	6.75	6.75	6.75	6.75	6.75	15	15	15
Weekly tree irrigation (*litre/tree*)	58	54	231	72	61	261	306	165	710
Recommended interval between irrigation *(day)*	**2**	**2**	**1**	**10**	**10**	**3**	**5**	**21**	**5**
Water required at each irrigaton (*litre/tree*)	17	15	33	103	87	112	219	495	507
Application rate *(litre/h/tree)*	8	8	8	40	40	40	120	120	120
Run time *(hour)*	**≈2**	**2**	**≈4**	**2½**	**≈2**	**≈3**	**≈2**	**≈4**	**4⅓**

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