Chapter D9. Irrigation scheduling

PURPOSE OF THIS CHAPTER

To explain how to plan and schedule your irrigation program

CHAPTER CONTENTS

- factors affecting irrigation intervals
- influence of soil water
- using the water balance method for scheduling

ASSOCIATED CHAPTERS

- A3 'Features of soil'
- D1 'Soil examination and structural rating'
- D2 'Soil texture tests'
- D7 'Cultivation and soil structure'

THE IMPORTANCE OF DETERMINING YOUR WATER NEEDS

All plants need water to grow and produce good yields. When plants are water stressed they close their stomata (the small holes in the leaf surface) and cannot photosynthesise effectively. Best growth can be achieved only if plants have a suitable balance of water and air in their root zones. Some stages in the growth of a crop are particularly sensitive to moisture stress.

Water shortages sufficient to hinder crop growth can occur without producing obvious wilting of foliage, while waterlogging can cause large yield reductions too. The grower must therefore rely on some other method of determining the water needs of the crop to avoid production or quality losses. This requires an understanding of the movement and storage of water in the root zone of the crop and the rate of water use by the crop.

FACTORS AFFECTING THE IRRIGATION INTERVAL

The interval between irrigations and the amount of water to apply at each irrigation depend on how much water is held in the root zone and how fast it is used by the crop. This is determined by

- soil texture
- soil structure/water penetration
- depth of effective root zone of the soil
- the crop grown
- the stage of development of the crop.

All soils are composed of solid particles of various sizes, organic matter, and pore spaces that hold air and water. The size of these pores, and the amount of water they hold, depends on the texture and structure of the soil.

Soil texture

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See Chapter D2 for more information on soil texture testing.

Soil texture refers to the feel of the soil. There are three types of particles that make up the soil; these are classified as sand, silt or clay depending on their size. The proportion of these particles in the soil determines the feel or texture of the soil and the size of the micropores between the particles, as well as the amount of water that can be stored in them (Table D9–1).

Soils are classified into texture classes such as clay loams, heavy clays, loams and sandy loams, as determined by the proportion of sand, silt and clay in the soil.

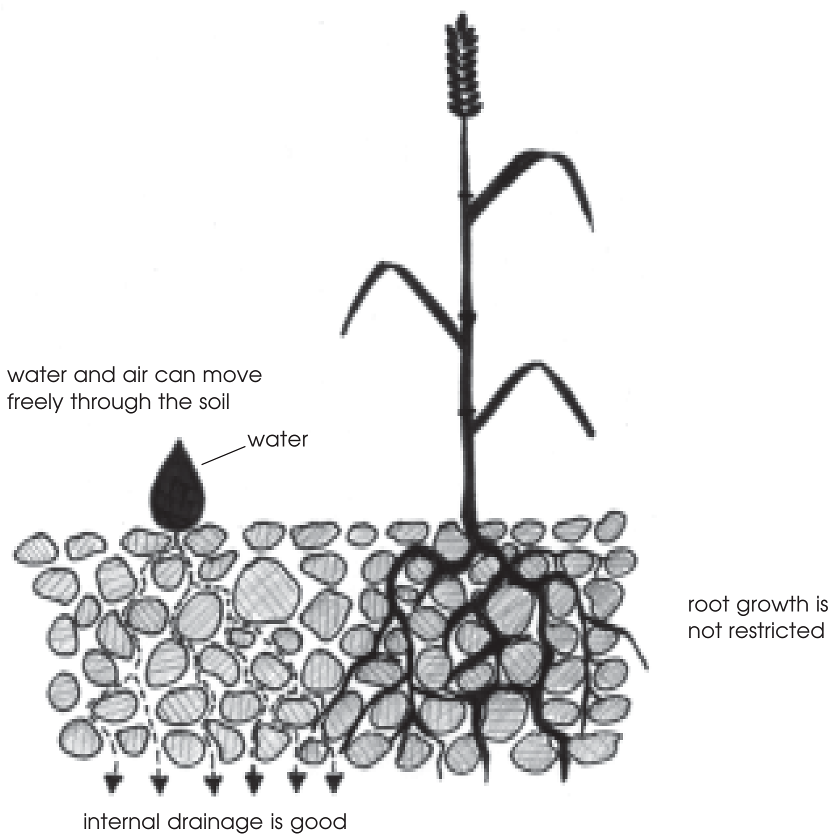
Table D9–1. Available moisture according to texture (mm of plant-available water per metre). Note that this is not a complete list of soil texture classes.

Soil texture	Range	Average
Sand	up to 65	49
Loam	155 to 172	164
Clay loam	155 to 172	164
Clay	137 to 147	137

SOIL STRUCTURE

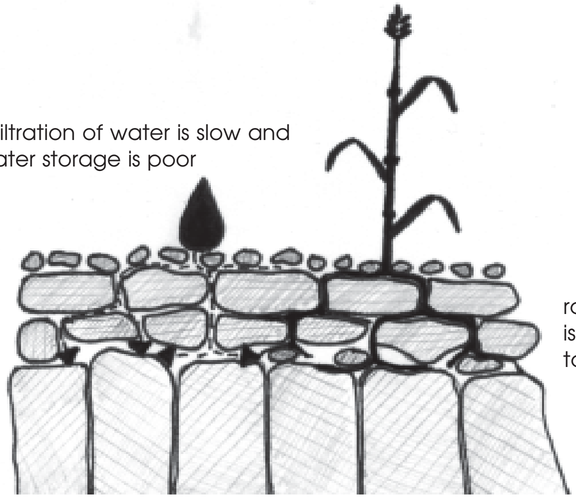
Soil structure refers to the natural aggregation of soil particles that are stable when wetted. The size and shape of these aggregates affect the way they stack together and the size of the pore spaces between them. A well structured soil (Figure D9–1) contains many pores that

Figure D9–1. A well structured soil



will hold water and air and aid infiltration of water into the soil. A poorly structured soil (Figure D9–2) has fewer large pores; it will have a reduced water-holding capacity and poor water infiltration, and will probably restrict root growth.

Figure D9–2. A poorly structured soil



It is clear from Figure D9–1 that a well structured soil will give plant roots an environment favourable to healthy growth and the extraction of water and nutrients.

The structures of many soils have been damaged by years of cultivation and compaction by traffic; others have been damaged by sodicity. This has led to the development of soil crusting and hardpans, which reduce water penetration and retention and restrict root growth. This results in a reduction in plant growth.

Some natural features of a soil may affect its structure independently of the soil management. For example, a sodic soil is likely to be poorly structured and will restrict air and water movement through the soil.

SOIL WATER CONSIDERATIONS

Before you consider your soil moisture status you need to understand a few terms. These include field capacity, wilting point, saturation, available soil water and refill point.

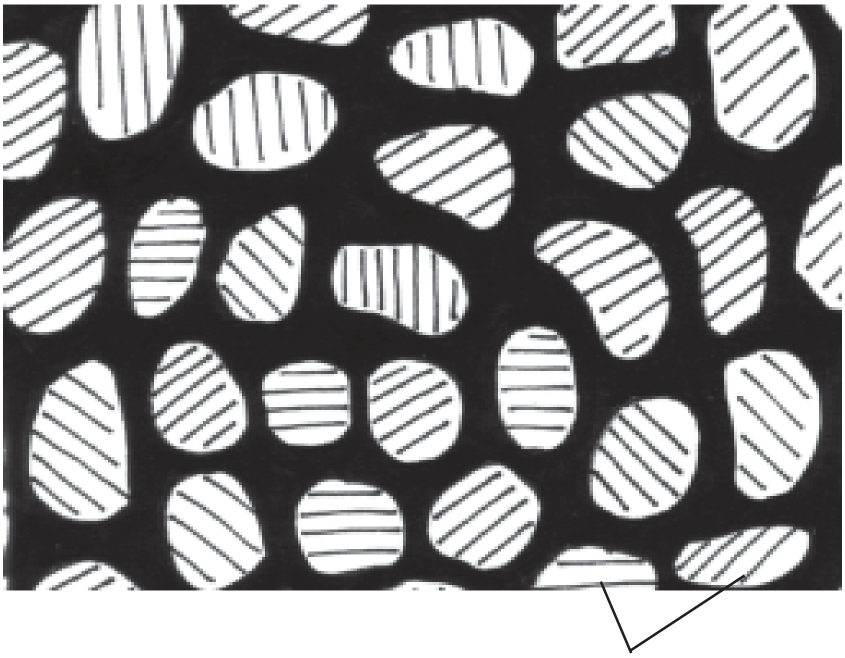
Saturation

Immediately after a soil has been irrigated it is at saturation (Figure D9–3). Almost all of the soil pore spaces are filled with water and very little air remains. If the drainage is adequate, water will drain away from the larger pore spaces and allow some air to enter the soil. This takes about 48 hours, depending on the soil type. If the internal drainage of the soil is restricted the soil becomes waterlogged. With no air in the soil, the roots begin to die from lack of oxygen.

Field capacity

Once the soil has drained by gravity for about 48 hours, water is held in the pore spaces by surface tension around the soil particle, and little further drainage will take place. This condition is called field capacity, and at this time the soil is holding as much water as it can

Figure D9–3. Saturation (soil contains no air)

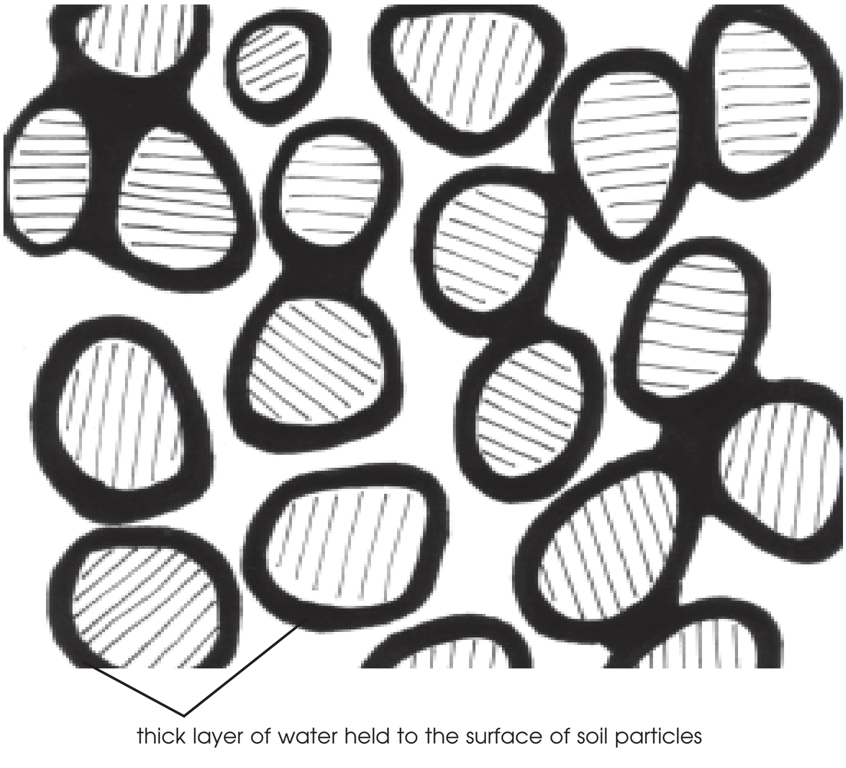


(Figure D9–4). In soil that is well structured there is also enough air in the soil to supply plant roots with the oxygen needed for them to live and grow.

Wilting point

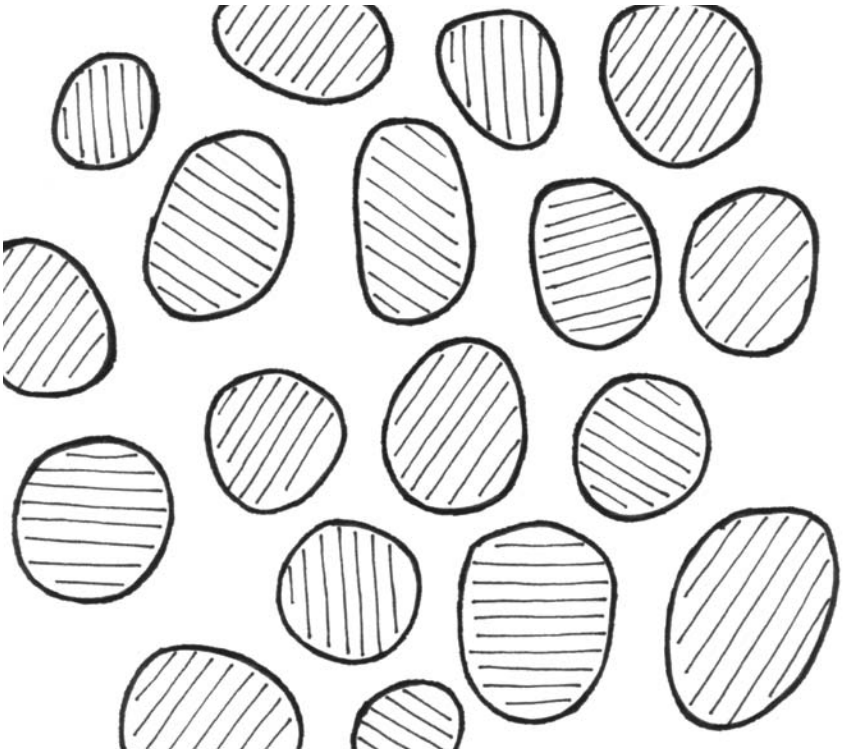
As plants use water from the soil the roots are working against the surface tension that holds the water in the soil. That is, the roots are sucking water from the pore spaces within the soil. Naturally, plants use

Figure D9–4. Soil at field capacity (good balance of water and air)



the most easily extracted water first, and as the soil dries out they must work harder to get water. Water is extracted from the soil until a point is reached when the plant's root system can no longer obtain water from the soil. This is called the wilting point for that soil (Figure D9–5). The soil is not totally dry, but the remaining water is held so tightly that the roots cannot extract it. As a soil approaches wilting point the plant growth slows. Plants do not grow in a soil at wilting point and will die if moisture is not replenished. Irrigated agricultural crops should never be allowed to approach the wilting point.

Figure D9–5. Soil at wilting point (no water available to plants)



Available soil moisture

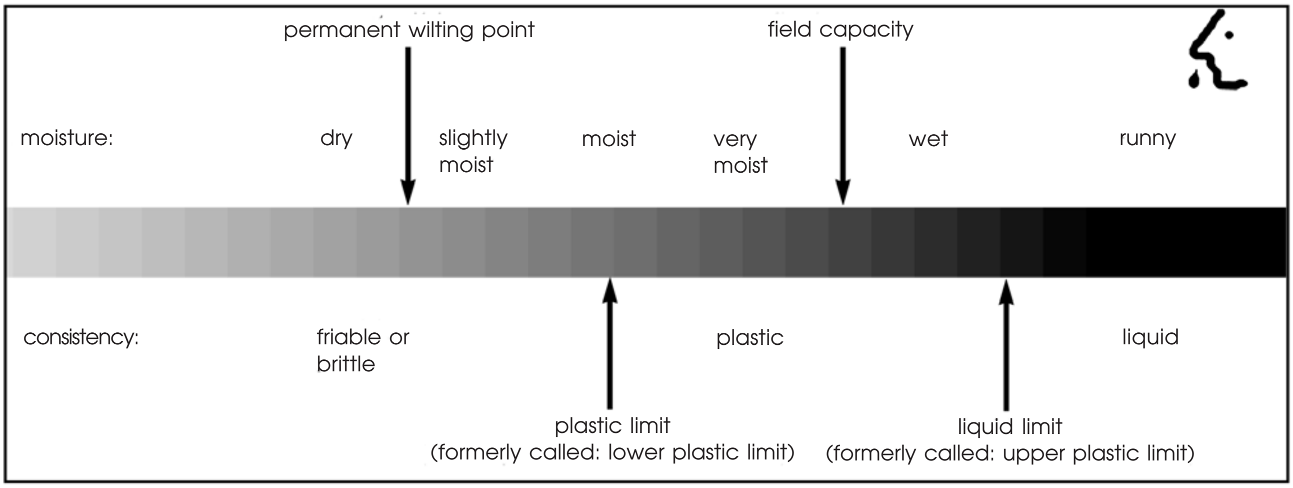
The amount of water held in the soil between the field capacity and the permanent wilting point is known as the available soil moisture. The amount of water in a soil can be expressed as a percentage, or in millimetres per metre of soil. For example, a soil with 15% water has 150 mm of water per metre of soil.

The available water-holding capacities vary within each texture class due to variations in soil structure and soil organic matter. A soil with better structure and more organic matter will have more pores of the right size to hold plant-available water than poorly structured soils. Organic matter retains water and binds soil particles to improve soil structure.

Refill point

Ideally, aim to keep the water content of the soil close to the field capacity for as much of the season as possible, without saturating the soil for periods of greater than 15 hours. A useful strategy to avoid crop stress is to define how much water your soil holds between field capacity and wilting point and then aim to replenish the water stored in the soil by irrigating when half of this has been used (Figure D9–6). Crops are therefore irrigated before yield-reducing stress occurs.

Figure D9–6. Soil moisture for irrigation scheduling



Root depth

Another factor that affects the amount of water available to crops is the effective root depth (the depth of the majority of the plants' feeder roots). For example, most subclover pastures have an effective root depth of about 30 cm, whereas perennial pastures such as lucerne may exploit a greater depth of soil. This means that on a soil that holds 100 mm of water per metre, subclover can exploit only 30 mm of water (that is, 100 mm/m x 0.3 m), but lucerne may (in some soils) exploit the full metre of soil and therefore have more water available to it. The effective root depth will vary depending on the soil and the crop grown.

SCHEDULING USING THE WATER BALANCE METHOD

Irrigation can be scheduled using a variety of different methods based on observations or measurements of plants, soil, the weather or a combination of these. All methods aim to determine when to irrigate to avoid water stress (Figure D9–7) and how much water to apply to refill the soil.

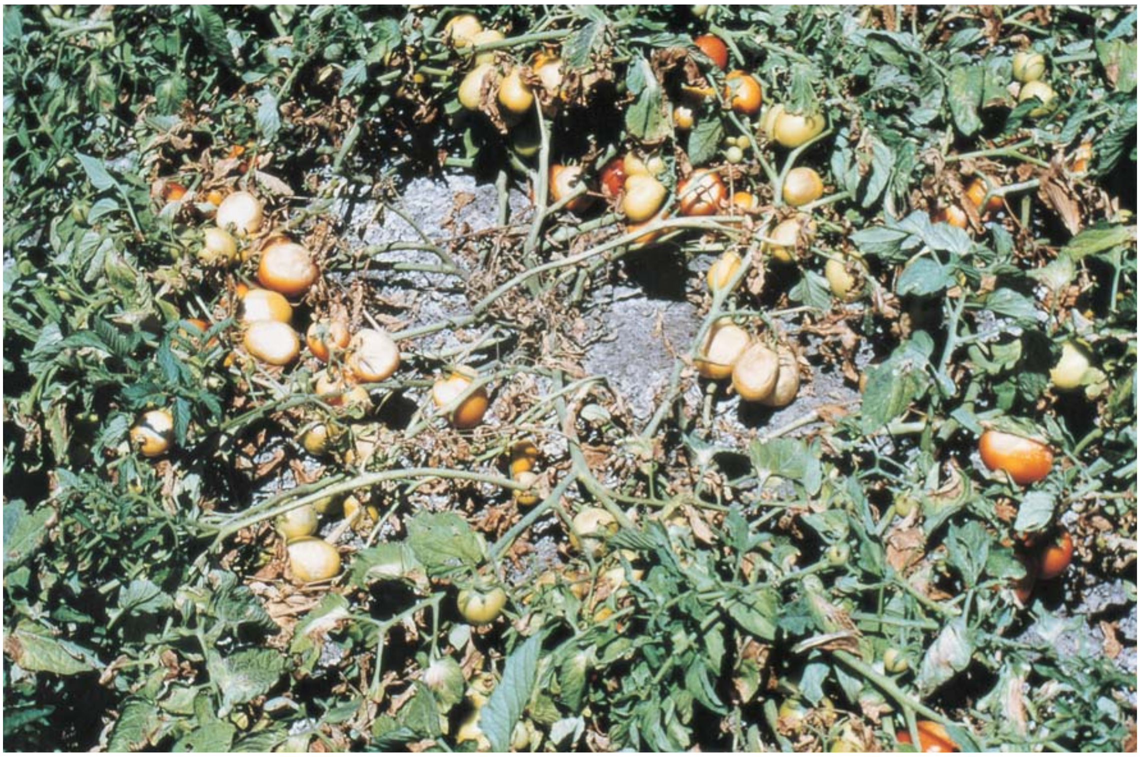
As already mentioned, various factors control how much plant-available water a soil will hold at each irrigation. Crop water use can be calculated using daily evaporation totals and crop factors. When crop water use is subtracted from water storage, an irrigation interval can be arrived at.

Calculating the soil water storage capacity

The first step in scheduling is to calculate the soil water storage capacity. Table D9–2 lists the soil moisture storage between the field capacity and the refill point (called the 'allowable depletion') for different soil groups.

The allowable depletion figures quoted in Table D9–2 are only a rough guide to the water storage capacities of different soils. Variations in soil structure, sodicity and management will cause variations in water storage. An improvement in soil structure may result in an increase in the water storage capacity of the soil.

Figure D9–7.



A processing tomato crop on clay soil that has collapsed due to waterlogging from excessive irrigation. Note the sunburn on the fruit, resulting in significant yield loss. (Bernie McMullen)

Calculating the plant water use

To fine-tune your allowable depletion figures for your soil, dig a hole and assess the soil moisture immediately before irrigating to see if your allowable depletion figure is correct. If the soil is still too wet for irrigation, increase the figure you use by 10 mm. If the soil is too dry just before irrigation, reduce your figure by 10 mm. Continue this process until you arrive at a suitable figure.

The water storage in a soil must be balanced against plant water use. Plant water use is affected by two main influences: the leaf area of the crop or pasture and the daily evaporation.

Plant water use is proportional to evaporation. The higher the evaporation, the higher the plant's water use. Evaporation is affected by humidity and temperature, so plant water use in summer is much higher than in winter.

Table D9–2. Approximate water storage according to soil group

Soil/group/conditions	Allowable depletion (mm of water) (field capacity refill-point)
Hardsetting red brown earth	45
Friable non crusting red brown earth	60
Transitional red brown earth	45 o 70
Well structured transitional red brown earth	75
Non-self-mulching clay	60 to 80
Self-mulching clay	85 to 90

Plants draw water from the soil via the roots and release this water as vapour into the air via the leaves. If the plant (or crop) has a large amount of fresh, green leaves, then water use will be higher. High water use is a desirable characteristic, since yields are well correlated with water use. Soon after emergence a crop has only a small amount of leaf material, so water use is relatively low, while water use will be highest when the crop reaches maximum leaf area. The **crop factor** is a number used to calculate the water use. It accounts for the crop leaf area. Crop factors vary between times of the year and stage of crop growth. Check with your local horticultural adviser for crop factor information.

The daily crop water use

To calculate the crop water use, multiply the crop factor by the daily or weekly evaporation totals.

Daily crop water use (mm) = crop factor x daily evaporation (mm)

Example:

In December sweet corn has a crop factor of 1.0. On a particular day the evaporation is 14 mm.

Therefore, crop water use (mm) = 1.0 x 14 mm
= 14 mm (on that particular day)

Evaporation data

Evaporation data can be obtained by:

- calling your local post office, which keeps weather data
- Waterwatch no longer available. Evaporation data can be obtained through the website www.clw.csiro.au/services/weather
or check with your local horticultural advisor.

The service provides evaporation figures for the last 10 days and forward estimates for the next six weeks. The data are measured in Griffith, but are reasonably accurate for the Murray Valley and MIA.

Calculating the irrigation interval

- Subtract the daily crop water use from the allowable depletion figure appropriate for your particular soil (field capacity – refill point (mm)) (Table D9–2). This figure is the amount of plant-available water remaining in the soil at the end of the particular day (the soil water storage).
- Account for any effective rainfall in the period between irrigations.

Effective rainfall = total rainfall – 5 mm in spring, summer and autumn
= total rainfall in winter.

Add the effective rainfall to the water storage figure. Remember that the water storage cannot exceed the initial amount determined for that soil as the allowable depletion amount. Any additional rainfall will evaporate, run off, or drain through the soil profile.

- When the allowable depletion is zero, start the next irrigation.

Example:

A tomato crop growing on a hardsetting red brown earth with an allowable depletion of 50 mm is irrigated on 1 October. When will the next irrigation be due if the evaporation figures for the month are as shown in Table D9–3?

To calculate when to irrigate you must record the daily evaporation figures and calculate the crop water use for each day. This is best done in table form, as shown in Table D9–4.

This system of irrigation scheduling is relatively simple to use. When it is used correctly, scheduling is likely to increase yields by avoiding periods of waterlogging and drought stress. Additionally, scheduling may help to reduce rises in the watertable and minimise structural decline (Figure D9–8).

Table D9–3. Example: evaporation and rainfall figures

Date	Evaporation	Rainfall
2/10	3.0	
3/10	2.3	
4/10	5.0	
5/10	8.0	
6/10	6.0	
7/10	5.5	
8/10	7.5	
9/10	8.5	
10/10		10
11/10	5.5	
12/10	9.0	
13/10	5.0	

Table D9–4. Example: calculating irrigation frequency

Date	Evaporation (mm)	Crop factor	Crop water use (mm) (= evaporation × crop factor)	Effective rainfall (mm)	Soil water storage (mm)
1/10				*irrigation*	50
2/10	3.0	0.9	2.7		47.3
3/10	2.3	0.9	2.1		45.2
4/10	5.0	0.9	4.5		40.7
5/10	8.0	0.9	7.2		33.5
6/10	6.0	0.9	5.4		28.1
7/10	5.5	0.9	5.0		23.1
8/10	7.5	0.9	6.8		16.3
9/10	8.5	0.9	7.7		8.6
10/10		0.9		5.0[1]	13.6
11/10	5.5	0.9	5.0		8.6
12/10	9.0	0.9	8.1		0.5
13/10	5.0	0.9		*irrigate today*	

[1] Actual rainfall is 10 mm. However, effective rainfall = total rainfall – 5 mm in summer, autumn and spring.

Figure D9–8.

A cracking clay soil showing the large cracks that occur when these soils dry out. (Bernie McMullen)