Water management

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Water management

1. Introduction

Irrigation replaces water used by crops during their growth cycle and that lost through evaporation and soil drainage. As such, it is a key component of vegetable crop production and one that is easily controlled. However, some good irrigation practices are neither widely understood nor implemented. This chapter provides information on how to assess and maintain your irrigation system for optimum performance. It's not necessarily about using less water but, rather, about using it more efficiently to achieve high yields of quality produce. The aim, then, is to encourage positive changes as part of a process of continual improvement.

Efficient irrigation minimises water wastage and leaching of nutrients and chemicals. Vital considerations here are the design of the irrigation system itself and the way in which the watering program is scheduled. Adjustments related to crop water requirements, climatic conditions, sprinkler uniformity, soil type, water quality and irrigation method will all be necessary in order to optimise performance.

1.1 Performance measures

Irrigation performance, as discussed by McConnell *et al* (2003), can be measured by way of the following.

- Water use, measured in megalitres (ML) per hectare (ha) (ML/ha).
- Gross return per ML ($/ML).
- Assessment of water losses.

1.2 Training courses

Western Australian vegetable growers interested in improving their knowledge of, and skills in relation to, irrigation should telephone vegetablesWA on 9226 0244 or email office@vegetableswa.com.au for details of training courses in their region.

2. Professional advice

Have your irrigation system designed by a qualified irrigation designer – the system itself, as well as soil-moisture monitoring sites, should be appropriate for the soil type on your property.

Designing an irrigation system is best left to the experts. For such a system to work efficiently, the pipe sizes, mains, sub-mains, valves, laterals and filtration and fertigation systems must all synchronise as part of an overall scheme rather than being simply added on.

The Code of Conduct of the Certified Irrigation Designer (CID) Program run by the Irrigation Association of Australia includes a commitment to:

- promotion of water, soil and energy conservation;
- conformity to responsible procedures, standards, codes and laws, and
- staying abreast of both product development and research.

More information on irrigation system design in general, and CIDs in particular, is available from irrigation suppliers, as well as the Irrigation Association of Australia's website at www.irrigation.org.au.

3. Site characteristics

Provide your qualified irrigation designer with information on the characteristics of your site – it will help him configure a system that meets both your production requirements and the demands of the land.

The following information, which should be part of every farm plan, will assist in determining the irrigation system appropriate for a given situation.

- **Maps** showing the size of the property and its boundaries.
- A **topographic survey map of the property** – where a significant investment in permanent irrigation systems is required, the area should be mapped with 1-metre contours.
- **Details of surrounding land usage**, especially with regard to sensitive areas such as residential areas, conservation wetlands and public drinking water supply areas where spray drift and leaching may be issues.
- **Climatic data** for the area, including rainfall and evaporation graphs or tables, plus details of average temperatures and wind intensity and frequency.
- The **soil characteristics** of the property – soil maps and descriptions of soil profiles, including texture, wetting properties and infiltration rate.
- The **depth to summer and winter water tables** – for areas in which the depth is less than 2 metres mapped.
- The location of any **water sources** and the **quantity and quality of the water** available.
- The **types of crops to be grown**, their **spacing**, and the estimated **rate and frequency of irrigation**.
- The location of any **energy sources** and the **amount of energy available**.

4. Soil characteristics

Most vegetables produced on the Swan Coastal Plain are grown in sandy soils, of which the three main types are:

- Spearwood sand;
- Karrakatta sand, and
- Bassendean/Joel sand.

Soil type and texture affect the amount of water readily available for crops, as well as the rate of water infiltration. These in turn influence the type of irrigation system to be used and its design, as well as the scheduling of irrigation. A well-designed irrigation system increases watering efficiency by minimising evaporation. It also avoids soil erosion, which can occur if the application rate exceeds the infiltration rate of the soil. Thus, the **application rate of the system** should be **slightly less than the infiltration rate of the soil**.

The infiltration rates of different types of soil are shown in Table 1 below. To determine the texture of the soil on your property, refer to Appendix 2: *Determining soil texture*. Soil types – and therefore soil textures – can vary across the one property, so a number of different areas within the property boundary should be tested.

Table 1. Basic infiltration rates and water-holding capacity for various soil types

[adapted from tables by Brouwer et al *(1988) & Ramsey (2007)]*

Soil type	Basic infiltration rate (mm/hour)	Readily available water (mm/metre)
Sand	> 30	30–40
Sandy loam	20–30	45–70
Loam	10–20	50–90
Clay loam	5–10	30–80
Clay	1–5	25–70

For optimum water usage, it is important to be aware of the water-holding capacity of the soil in the root zone of a crop. This is the amount of water in the soil between ‘field capacity’ (the point at which the soil cannot hold any more water) and the ‘refill point’ (the point at which soil moisture is so low that it slows crop growth and stresses the plants). Thus, the water-holding capacity of the soil indicates how much water is readily available for the crop. If the amount of water applied to a crop exceeds ‘field capacity’, then the extra will be lost as drainage water. Soil-moisture monitoring equipment – which allows correlation between the soil-moisture reading and the point at which the soil ceases to drain rapidly after irrigation – makes for easy estimation of the water-holding capacity of an area of land.

5. Topography

The topography of a site will also influence the design of an irrigation system, as it can affect pumping efficiency and the uniformity of water application. That said, sprinkler, drip-irrigation and micro-sprinkler systems can all be adapted to suit any farmable slope, remembering that appropriate pipe diameters and pressure compensation devices are crucial to ensuring acceptable uniformity coefficients over all irrigation sectors.

A qualified irrigation designer will take topography into account when designing an irrigation system.

6. Water quality

Impurities in a water supply will influence the following.

- The **type of irrigation system** selected – some types of system are more prone to blockages from impurities.
- The **filtration system** chosen – this will be determined by the likelihood of the irrigation system becoming blocked by impurities in the irrigation water.
- The **frequency and extent of salt leaching** – if the irrigation water contains an excessive amount of dissolved salts, drip irrigation is preferable (because the irrigation water is applied directly to the soil with this type of system, there is less surface evaporation and so less water is used).
- The need for special **pre-treatment** for impurities such as colloidal clay, silt, iron, algae and calcium.

For more information on water quality and irrigation management, refer to Brouwer *et al* (1988) and McConnell *et al* (2003).

7. Type of irrigation system used

On the Swan Coastal Plain, most irrigation water for crops is applied by way of **sprinklers**, which can also be used to control frost, cool the crops and minimise damage from sand-blasting.

Drip or trickle irrigation systems release water onto the soil at very low rates (from 2 to 20 litres per hour) via small-diameter plastic pipes fitted with outlets called emitters or drippers. Unlike sprinkler irrigation, which involves wetting the whole soil profile, drip or trickle systems apply water to the plants in such a way that **only the soil in which the roots grow is wetted**. This reduces deep percolation, surface run-off and evaporation, so water usage is minimised.

Moreover, with drip or trickle irrigation systems, water is generally applied more frequently than with sprinkler systems, and this helps maintain a soil moisture level at which plants flourish.

8. Uniformity

An even application of water to your crop is vital for efficient water and fertiliser usage: the better the uniformity, the greater the area receiving the average amount of water and the smaller the area being over- or under-watered.

With an overhead sprinkler irrigation system, it is not possible for all areas of a crop to receive the same amount of water. However, water must be applied as evenly as possible so that all areas of the crop receive a similar quantity of moisture and nutrients. While a new, well-designed irrigation system should offer good uniformity, the components will wear with time and may require modification. Therefore, regular checks of the uniformity of water distribution are an excellent maintenance strategy.

Both sprinkler pressure and sprinkler nozzle size affect irrigation uniformity, as do the type of sprinkler used, sprinkler and lateral spacing, and wind strength and direction.

The irrigation uniformity of a sprinkler system can be calculated mathematically using what are known as the ‘coefficient of uniformity’ (CU) and ‘distribution uniformity’ (DU). In order to do this, catch containers (see photograph above) are placed in a grid pattern between the sprinklers and laterals to measure application rates.

Once measurements are obtained, they are used to calculate the CU and the DU. Internationally, the design standards for irrigation uniformity are a CU greater than 85% and a DU greater than 75%.

For more information on how to calculate distribution uniformity, refer to Appendix 17: *Coefficient of uniformity and distribution uniformity*.

9. Sprinkler pressure

To help your crop grow evenly, ensure that the pressure within your sprinkler irrigation system is uniform and appropriate for the sprinklers (use a pressure gauge with a pitot tube to check pressures).

All sprinklers have recommended operating pressures, designed to optimise the volume of water a sprinkler will distribute (flow rate), as well as the distance the stream of water is thrown (the diameter).

Sprinkler jets operating outside their recommended pressure range are not operating efficiently.

- Sprinklers that run at a lower-than-recommended pressure form larger droplets and this decreases the diameter of throw. As a result, dry patches will form around the sprinkler, producing what is known as a ‘doughnut effect’.
- Sprinklers that run at higher-than-recommended pressure create mist; this means the stream of moisture is more susceptible to wind and evaporation before it reaches the ground. Also, the stream can be disrupted, meaning that the water will not be thrown as far.
- Matching sprinklers to their recommended pressure (the manufacturers provide a guide for each jet size), and checking that the pressure in the lines is even, are simple ways of enhancing irrigation uniformity. As a rough guide:
    - 2.4 to 4.8 mm jets require 240 to 345 kilopascals (kPa);
    - 4.8 to 6. 3 mm jets require 310 to 415 kPa, and
    - 6.3 to 9.5 mm jets require 345 to 480 kPa.

The influence of pressure on irrigation uniformity can be illustrated by the following example. If a 4-mm jet runs at 200 kPa (less than recommended pressure), it puts out roughly 15.5 litres of water per minute, whereas the same 4-mm jet running at 300 kPa will put out 18.5 litres per minute. While a difference of 3 litres a minute may not seem much, it means that in actual fact one section of the crop is receiving 20% less water than expected.

A pressure gauge with a pitot tube (available from irrigation suppliers) should be used to check for pressure differences in an irrigation system in at least three different places. Good places to do this are at the valve, at the end of the lateral, and halfway in between. (Note: for uniform water application, there must be a pressure difference in the laterals of less than +/- 5% of the average pressure.)

10. Irrigation scheduling

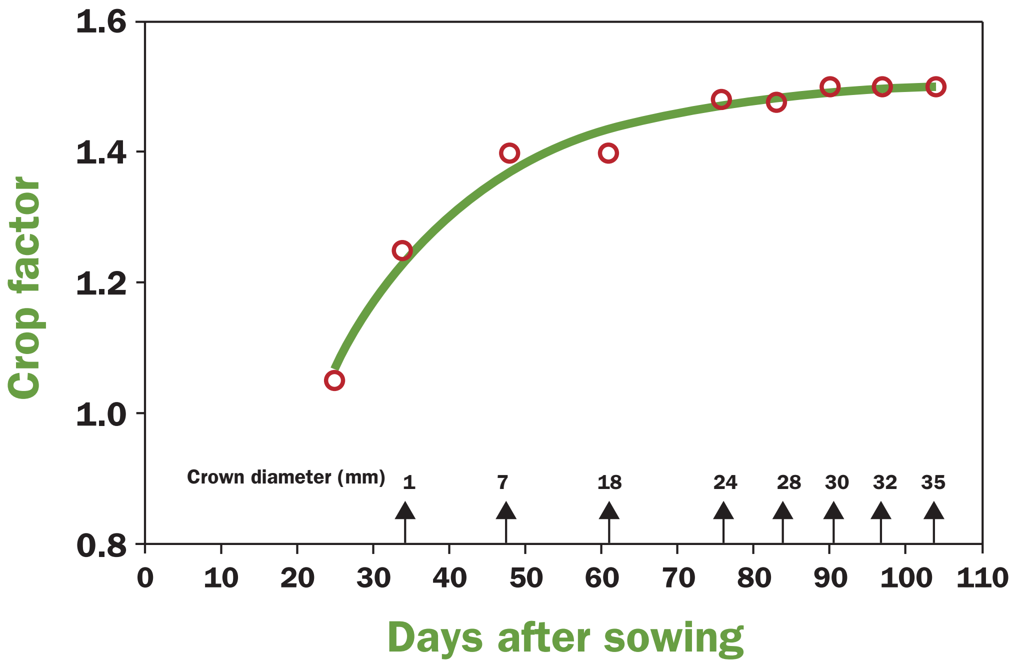
Use a combination of tools, including evaporation replacement and soil-moisture monitoring, to schedule your irrigation.

With the growing emphasis on efficient water use, growers are becoming more aware of the fine line between wasting water and using just enough to achieve optimum production.

Once the operating efficiency of an irrigation system has been established, the amount of water a crop requires can be determined with reference to the growth stage of that crop and daily evaporation rates. The latter can be measured directly or calculated from weather station data on temperature, wind speed, solar radiation and relative humidity.

The proportion of daily evaporation that must be replaced by irrigation is referred to as the 'crop factor', which will vary according to the type, vigour and growth stage of the crop in question. By way of example, crop factors for carrots growing on the sandy soils of the Swan Coastal Plain are shown in Figure 1 below. Crop factors are higher for sandy than for heavier soils because of inefficiencies related to the low water-holding capacity of sands.

Figure 1. Crop factor curve for irrigation of carrots on sand.



To calculate the water required by a particular crop at a particular growth stage, the previous day's evaporation is multiplied by the crop factor for the growth stage of that crop. Evaporation data is available from long-term recordings, which can be adjusted for warmer-than-average or cooler-than-average conditions (see Table 2).

Evaporation rates for the previous day are recorded by automatic weather stations on the Swan Coastal Plain at Lancelin East, Wanneroo, South Perth, Myalup and Medina.

There are 12 other live weather stations in Western Australia, among them those at Manjimup, Carnarvon and Kununurra.

Evaporation figures from the automatic weather stations are available by logging on to www.vegetableswa.com.au – simply follow the 'Grower information' link to 'Weather station information'.

As an example of irrigation scheduling, assume that a sprinkler system operating uniformly applies 7 mm of water per hour to a block of carrots the root diameter of which has reached approximately 18 mm. (Note: sprinkler output must be confirmed during sprinkler testing.) From Figure 1 we can see that the crop factor is 1.4, while weather station data shows that evaporation the previous day was 6.8 mm. The water requirement for our carrot crop can be calculated thus:

irrigation required (**mm**) = **crop factor** x **evaporation** (**mm**)
= 1.4 x 6.8 mm
= 9.5 mm.

As the irrigation system outputs 7 mm of water per hour, the total system run-time for the day can be calculated as follows:

run-time (**minutes**) = **irrigation required** (**mm**) ÷ **output** (**mm/hour**) x **60**
= (9.5 ÷ 7) x 60 minutes
= 81.4 minutes.

Table 2. Average daily evaporation with adjustments for cooler and warmer windy days *[courtesy of DAFWA Medina Research Station]*.

Month	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sept (mm)	Oct (mm)	Nov (mm)	Dec (mm)
Daily evaporation average	8.8	8.8	6.8	4	2.6	2	1.9	2.3	3.3	4.8	6.6	8.4
Cooler, less windy days	6	4	3	2	1	1	1	1	2	3	4	5
Hotter, more windy days	11	10	9	6	5	3	3	4	6	7	10	11

Determining mm applied during irrigation

In simple terms, 10 kL applied to 1 ha, or 1 L applied to 1 m^2, is equal to 1 mm applied.

The number of mm applied can be determined by the following three methods.

- **Using a rain gauge** – with overhead irrigation, mm applied can be measured using a rain gauge. It is simply placed on the surface of the soil during irrigation, with a reading taken at the end of that irrigation period.

- **Using a water meter** – if a water meter is installed, the reading can be recorded (usually in kL) at the beginning and end of an irrigation period. The first reading is then subtracted from the second reading to determine kL used. That figure is then divided by the size of the area irrigated in hectares (as per the irrigation plan) and divided by 10.

  Thus:

  mm applied = **water used** (**kL**) ÷ **area irrigated** (**ha**) ÷ **10**.

- **Measuring the area irrigated and discharge** – the area being irrigated by each outlet is measured in square metres (m^2) by measuring the distance between the irrigation rows (in metres) and multiplying by the distance between the outlets down the row (in metres). To arrive at a figure for mm applied, the discharge from each outlet, measured in litres (L), is divided by the area being irrigated. Thus:

mm applied = **discharge** (**L**) ÷ **area irrigated** (m^2).

(Note: 1 kL = 1,000 L, so 10 kL = 10,000 L; 1 hectare = 10,000 m^2.)

On sandy soils it is best not to apply more than about 6 mm (50 minutes for the example given) in any one irrigation session, so the watering should be split into two shifts – one early, between 4.00 am and 8.00 am in summer, using off-peak power, and the other around the middle of the day, assuming that water quality is good.

In the summer months, when average evaporation is high (that is, more than 7 mm per day), irrigation is sometimes applied two or three times daily. During the winter months, however, when average evaporation is low (around 2 mm per day), a ‘deficit’ of the irrigation requirement can be allowed to accumulate before water is applied. (In winter, on yellow sands, a deficit of up to 8 mm is possible for an established crop.)

11. Monitoring soil moisture on sandy soils

Use evaporation-based scheduling, combined with soil-moisture monitoring, to ensure that your crop receives the right amount of water.

There are many ways to check moisture levels in soil. While kicking the dirt or digging may have been popular in the past, these methods relied very much on the operator's experience and were not very reliable indicators of soil moisture content. Today, there is a range of soil moisture sensors to choose from. However, while most of them work well in soils of a heavier texture, only a few are sensitive enough to provide useful information in sands such as those found on the Swan Coastal Plain.

Soil moisture data reveals what is happening below the soil surface, in the root zone of the crop. Soil moisture sensors that are sensitive enough for use in sand can detect very small changes in soil moisture and provide continuous readings. This is because moisture changes in sand tend to occur rapidly.

The types of soil-moisture sensors currently used in sands include:

- sand tensiometers (such as the Irrometer LT);
- capacitance probes (such as Enviroscan®, C-Probe® and AquaSense®), and
- time-domain reflectometry (TDR) probes (such as Campbell CS625® and Aquaflex®).

Sand tensiometers fitted with 0- to 40-centibar gauges provide the most direct output when monitoring moisture levels in sand. They are inexpensive, simple to install and read, allow direct measurement of soil water tension and are not affected by salinity.

While capacitance probes are more expensive and more complicated to install and operate, they do produce graphs useful for monitoring soil moisture content and checking irrigation scheduling. Moreover, their operations can be automated and the data transmitted for display on a computer screen, which reduces labour requirements.

TDR probes (each 30 centimetres long) calibrated to sand are placed in the soil at different depths. Connected to a data logger, they record moisture content as a percentage. In this way, what is happening in the root zone is illustrated by graphs. TDR probes are very robust, requiring minimal maintenance, and the process can be automated to allow data to be displayed on a computer screen.

12. General maintenance

Before sowing your crop, check the maintenance schedule of your irrigation system (provided by the system's designer) thoroughly.

Irrigation systems should be inspected prior to the start of the crop to ensure that they distribute water evenly (thereby reducing water losses) and operate efficiently (thereby reducing energy use).

In addition to regular checks of uniformity and pressures, as described previously, the following maintenance procedures will improve overall system performance.

- Checking for **leaks** – pipe fittings and the rubber seals within should be examined under normal operating pressure.
- Performing **pump maintenance** as per the manufacturer's recommendations – pressures and relief valves should also be checked (as a sudden reduction in pressure usually indicates a new leak, a gradual reduction may indicate wear of the impeller or sprinkler nozzles, and an increase in pressure suggests a blockage).
- Provided flushing valves are installed, the **mains and sub-mains should be flushed out** – laterals should be flushed both during and at the end of the season (depending on water quality).
- Performing **regular filter maintenance** to control blockages – the potential for system blockages is influenced largely by the quality of the irrigation water, a chemical analysis of which will help determine not only the design of the system but also the type of filter and maintenance schedule required. Filters should be regularly disassembled, cleaned and checked for damage, in line with the manufacturer's recommendations. Moreover, pressure gauges should be installed on either side of filters to enable monitoring of filter performance. Filters should be cleaned (flushed or brushed) before the pressure difference between the gauges is greater than 20 kPa.

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