BASIC PRINCIPLES OF PROTECTED CROPPING

For Improved Productivity and Sustainability

Primary Principles

Local Land Services North Coast

NSW GOVERNMENT

Coffs Harbour Regional Landcare

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Principles of protected cropping
for improved productivity and sustainability

Prepared for

Coffs Harbour Regional Landcare and North Coast Local Land Services

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Introduction

Protected Cropping is a high-input / high-output intensive cropping system that is complex and technical. The crop's growing conditions are managed for optimum results and controlled elements include:

Light	**Humidity**
Temperature	**Water**
Nutrients	

There are basic practices in protected cropping that lead to a productive and sustainable farm. Success depends on understanding and following these principles. As you develop skills and experience, you can refine all these practices and customise them to your farm and management style for improved efficiency and even greater returns.

This guide provides 13 best management objectives upon which all growers can develop a protected cropping enterprise. The layout of your farm and siting of the greenhouse, managing the greenhouse to avoid pest, disease and environmental problems are highlighted together with the key characteristics of a good greenhouse.

Important skills including installing and using an irrigation and run-off monitoring station, checking your hydroponic irrigation system and understanding what type of hydroponic set up and substrate will work for you are explained. With these skills you will use fertilisers and water efficiently.

Management targets for running a greenhouse and hydroponic system are provided to guide day to day decisions and example charts have been included to help you get started straight away.

1: Location of the greenhouse

Principle: A well-located greenhouse is easier to manage, cheaper to run and minimises the potential impact on the surrounding environment.

To develop a successful and sustainable protected cropping farm, appropriate site selection is essential. A property needs to be able to accommodate the greenhouse and hydroponic systems and include an effective clean zone. It should provide suitable management of surface water and facilitate the collection of rainwater and management of liquid wastes from structures where appropriate.

1.1 SITE ACCESS, FACILITIES AND LOGISTICS

A **level** site reduces building costs, minimises soil erosion and improves manageability of the site while an **elevated** site provides superior natural ventilation. Minimise soil erosion and costs of soil management by keeping existing vegetation and landforms wherever it is practical.

In addition to the greenhouse itself, you need to consider how to plan and manage a large number of ancillary facilities including sheds, tanks, access ways and drains which are essential in operating a productive and sustainable enterprise.

Surrounding vegetation: To avoid shading of the greenhouse, a cleared distance of up to 2.5 times the height of buildings and vegetation is needed. On the north east, this distance needs to be increased to 4 times the height. This space also allows for airflow around the greenhouse and facilitates ventilation.

Maintaining vegetation around the farm is very important. Except in the buffer area (see page 5), you should aim to keep existing vegetation. Native vegetation provides habitat for beneficial insects and birds which help to control crop pests. Short (regularly mown) grass needs to be maintained in all cleared areas around the greenhouse and associated structures. Avoid areas of exposed (bare) soil.

Direct exposure to strong winds not only increases risk of damage but also greatly increases the loss of heat during cool conditions – so keep native vegetation for windbreaks around the farm.

Water: Consider the supply, storage, use and release of water as critical factors. Water catchment, storage and treatment facilities are essential and you need to have sufficient volume of clean water to meet the peak daily demand of your crop. Waste water management including drainage, and water retention needs to be included in the site plans.

Fuels and chemicals: (including pesticides and cleaning products) need to be stored properly. Storage facilities[1] must include bunding to prevent spills from entering the soil or water ways. Facilities should be lockable.

Have you considered …

Greenhouses
Packing shed
Cleaning area
Storage shed
Pump shed
Waste management
Fertiliser shed[1]
Chemical shed[1]
Fuel storage[1]
Rainwater collection
Water disinfection
Clean water storage
Nutrient run-off collection
Wastewater retention
Surface water drainage
Roadways
Screens and windbreaks
Buffer areas
Landscaping
Noise mitigation
Expansion?

[1] When storing Dangerous Goods (packaging that displays a diamond shaped label), there are specific legal requirements you must follow including keeping the storage area locked, ventilated and ensuring that if a chemical is spilt, it cannot go into the soil or waterways.

1.2 SURFACE WATER, RUN-OFF AND EROSION

Management objectives

- Avoid exposed soil
- Stop surface water from entering the greenhouse
- Use drains to control, direct and manage stormwater
- Collect and use rain and storm water, if permissible
- Prevent nutrient rich water entering the environment
- Maintain natural vegetation around the production area

Exposed soil: Mud and dust can carry crop pathogens (diseases) into the greenhouse. Exposed soil is easily eroded and will pollute waterways and it is more costly to fix the problem than to prevent it. Dust is a disease risk to your crop and water supply. Continuously wet and muddy areas near the greenhouse provide habitat for crop pests.

All soil surfaces need to be kept covered with appropriate vegetation[2], weed mat, mulch or gravel.

Surface water: It is important to make sure that surface water cannot flow into the greenhouse. Raise the base of the greenhouse slightly above ground level and provide a gentle slope away from the greenhouse on all sides. Open sided greenhouses should have splash skirts[3] along the open sides.

Drains need to be installed to collect surface run-off and direct this water away from the greenhouse and away from the buffer area (see figure 1). Structures and hard surfaces increase the amount of run-off from a site during a rain event. This water must be controlled to prevent erosion and contamination of water courses.

Wide, gently sloping open drains that are grassed and kept tidy and free from weeds are a cost effective option which will minimise soil erosion and can readily be maintained as part of a clean zone around the production area. Vegetation in drainage lines will also help filter sediments and nutrients from run-off.

Install a detention pond and/or constructed wetland to collect and slow the water, particularly during storm events. This reduces the risk of erosion and possible damages. Alternatively, consider collecting, disinfecting and using this rainwater for irrigation, if permissible. Rainwater is a low-cost source of good quality water. Roof run-off can be readily directed to storage tanks which will keep it clean, however it should still be disinfected prior to use in the greenhouse.

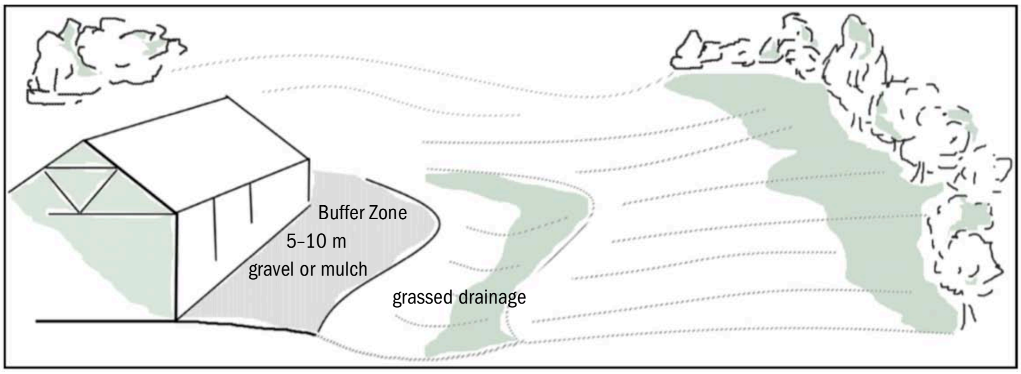


Figure 1: The greenhouse site should consider the shading effect from vegetation and windbreaks, include a plant free buffer zone and grassed drainage lines to manage surface water and prevent soil erosion. Avoid exposed soil.

[2] In the area around the greenhouse, you need to avoid plants which can harbour crop pests and diseases. Avoid broadleaf weeds and flowering plants. Short (regularly cut) grass is a good option.

[3] A splash skirt is a low wall (up to 0.6m high) along the sides of a greenhouse with open sides. It prevents rain splash and run-on water entering the greenhouse. It can also reduce the risk of pest entry into the crop.

Greenhouse run-off: In addition to drainage around the greenhouse to prevent entry of surface run-off, you need an effective drainage system for the greenhouse too. Nutrient run-off is an important management strategy in hydroponics. The run-off water is also a valuable resource. It contains a high concentration of expensive fertiliser as well as the water itself. When cropping, nutrient solution run-off from a plant needs to be drained away from the plant, but it must also be contained and prevented from reaching natural water courses. More information on hydroponics and run-off is in section 6.

When cleaning the greenhouse between crops, the drainage system will remove the cleaning water which may contain detergent and chlorine (or another disinfectant). This wastewater must be treated before discharge. A detention pond exposes the water to sunlight and air, which degrades chemicals such as chlorine. Always use a biodegradable detergent. To remove nutrients and sediments as well, the water needs to be held for a minimum of 7 – 10 days[4]. Constructed wetlands, reed beds and holding dams can be used. More information on management of waste and run-off is in section 13.

2: Establish a buffer and clean zone to reduce pests and diseases

Principle: A space around your production area is used to create a barrier to pests and diseases.

The productivity of your protected cropping system is significantly increased and waste is substantially reduced when you can use preventative practices to stop or delay pests and diseases from getting into the crop.

The first and most important step in reducing the impact of pests and diseases is to be aware of the potential sources of pests and diseases and to stop access to the greenhouse.

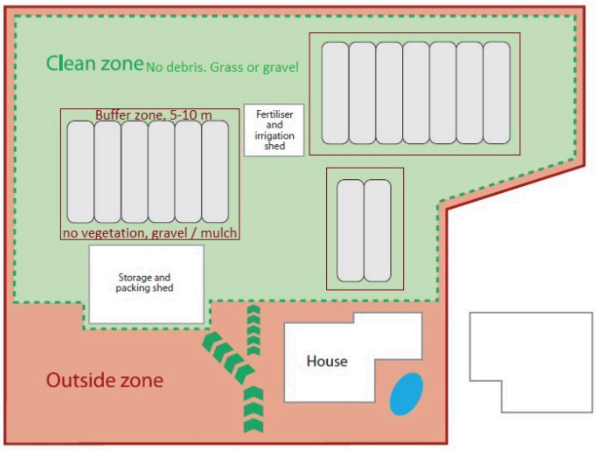
Separate your farm into a clean zone and an outside zone.

Sources of pests and diseases	
Weeds	People
Other crops	Tools, boxes, buckets
Crop debris (residues)	Vehicles
Seedlings	Substrates and containers
Irrigation water and crop run-off	Surface run-off
Soil (and dust)	Rubbish

2.1 BUFFER AREA

Providing a clear space around your cropping areas and structures is the simplest and usually the cheapest method of reducing pests and diseases. It can also reduce the need for pesticides.

The area immediately surrounding the greenhouse is called the buffer area. A space 5 – 10 metre wide on all sides of the greenhouse is best. If you are fixing up an existing site and there is limited space, make the buffer area as wide as possible.



This area needs to be kept empty – no equipment, no rubbish, no substrates, no containers and no crop debris or weeds and no exposed soil.

[4] A retention system such as a wetland needs to have a water volume at least equal to the daily volume of waste water multiplied by the number of days of required retention. For example, to hold 1000 litres for 7 days requires a minimum volume of 7000 litres. Note, the movement of the water must also be slowed and the incoming water must not be able to flow directly towards the exit point.

▶ **TIP** For best results, the buffer area should be completely plant free and covered with mulch, weed mat or gravel. Do not rely on herbicides to keep this area clean. Do not leave soil exposed in this area.

2.2 CLEAN ZONE

The clean zone is the space around your greenhouses and production area. In the clean zone there should be no weeds, no crop debris, no rubbish, no muddy areas and no exposed soil. This area is used to create a barrier to pests and diseases. Everything must be cleaned before it is taken into the clean zone.

It is essential that the clean zone of a farm be kept weed free. Grass is a good option but it needs to be kept short (mown regularly) and there must be no broadleaf or flowering weeds in the grassed area. Mulch, weed matting and gravel are also good choices. Over the longer term, weed mat covered with gravel is one of the best and most cost effective ground covers for the areas around a greenhouse.

▶ **TIP** If you are using a grassed area, make sure it can be mown during wet weather and that you will have time regularly to maintain the grass and keep it short.

2.3 OUTSIDE ZONE

The outside zone is the rest of the property. This area should be kept clean and tidy to minimise the presence of pests and diseases. Maintain natural vegetation, actively control weeds and avoid exposed soil.

Assume that there are pests and diseases in the outside zone. This includes off-farm as well.

3: Design and manage the greenhouse to optimise growing conditions

Principle: When the growing conditions and management practices are optimal for the crop, plants are healthier and yields are higher. Production is more efficient and there is less waste.

The protective structure is a way to make growing conditions suitable for the crop you are producing.

Growing conditions directly affect the costs of production, the yield and the impact of pests and diseases. In good growing conditions, the crop will grow more efficiently and have fewer problems. This means that less input such as pesticides are required and both water and fertiliser are used more efficiently, which in turn reduces costs.

The suitability of the growing conditions accounts for almost all of the yield you will achieve from your crop. The key components are light, temperature, relative humidity, vapour pressure deficit, carbon dioxide, nutrition, water and the root zone environment. All these factors interact and influence the plant balance – the relationship between vegetative growth (producing leaves and roots) and generative growth (producing flowers and fruit) – and importantly, plant health.

▶ **TIP** A more expensive greenhouse is not always a better greenhouse. Height, ventilation and light transmission are key characteristics to look for.

3.1 PRINCIPLES OF THE GREENHOUSE

Light - Maximise the amount of light that can reach the crop

Light is the key growth driver of your crop. The amount of light varies throughout the year. A greenhouse needs to ensure sufficient light is available inside the structure during periods of low light. A typical greenhouse covering material will transmit 60 – 80% of the solar radiation, while only about half of the total solar radiation is used by the plants for growth and development. Design and materials of a greenhouse need to aim to maximise light levels.

- Cladding material needs to have a high light transmission and be kept clean and in good condition.
- Diffused or scattered light is better than direct light.
- Minimise structural materials and equipment above the crop.
- Moveable shading screens can be used to manage daily conditions.

▶ **TIP** It is better to use screens and other strategies to reduce light when it is too much or to cool the greenhouse when it is too hot, than to add light during overcast or low light conditions.

Ventilation - Maximise the air exchange (venting) capacity.

Air exchange is absolutely essential in an effective greenhouse. Ventilation is used to manage several critical factors including removing excess heat and moisture as well as to maintain adequate levels of carbon dioxide.

The ventilation of a greenhouse must be sufficient to:

- exchange enough air to prevent excess heat building up in the greenhouse,
- maintain adequate carbon dioxide (CO_2) levels,
- remove moisture to prevent excessive humidity in the greenhouse.

Ventilation can be achieved actively with fans and/or passively with vents. In a warm climate, the ventilation needs to be able to exchange a complete volume of air every minute. To achieve this with passive ventilation, the area of vents needs to be equivalent to at least 30% of the floor area. The area of a vent is calculated depending on the type and shape of the vents. Figure 2 illustrates two different vent types. Add up the areas of all the vents in the greenhouse and divide this by the floor area to calculate the proportion of venting.

Roof vents should be used where possible. Roof vents are more effective than wall vents at removing hot air and circulating air in the greenhouse. Structures with roof vents on both sides of the roof perform better in a wider range of conditions.

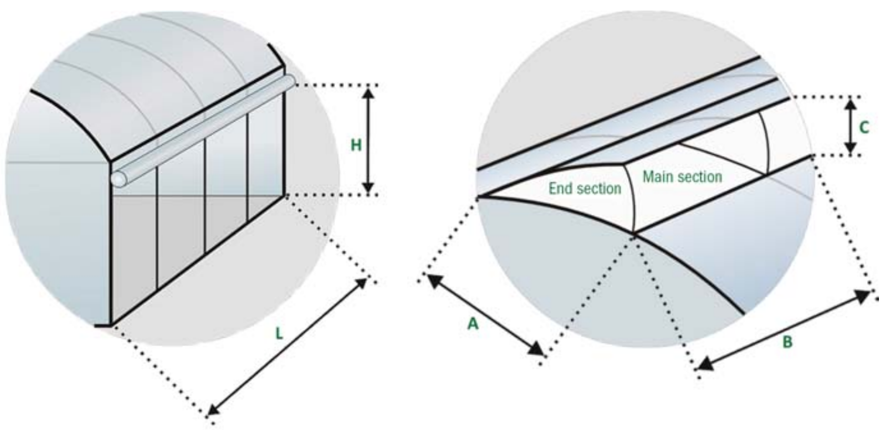


Figure 2: [Left] The area of a side wall vent is calculated by multiplying the length (L) by the height (H).

[Right] The area of this type of roof vent is calculated by adding together the area of the two end sections (A x C) and the area of the main section (B x C).

▶ **TIP** If there is more venting capacity than you need, it does not have to be used. But if you do not have it, you can't use it when you need it.

Uniform conditions in the greenhouse

Uniformity in a greenhouse is a key aim in protected cropping. Uniform conditions support a uniform crop which is easier to manage, has fewer problems and is more productive. Air circulation is a primary means of maintaining crop uniformity. Uniform irrigation (see section 7) is another. Effective ventilation produces good air circulation within a crop, however, when venting is reduced to maintain temperature and humidity within the structure, circulation fans are necessary.

Air circulation is essential to move and mix air within the structure to:

- avoid hot and cold areas within the crop,
- prevent areas of excessive humidity,
- reduce conditions that favour diseases,
- maintain active growing conditions,
- ensure an evenly growing and efficient crop.

Figure 3: This structure is just tall enough for the crop and doesn't allow for excess heat to rise above the canopy.

Height - Optimise the height of the structure

The conditions achieved within a protected cropping structure are an interaction between the design and features of the structure, the outside conditions and how the greenhouse is managed. The height of a structure directly impacts on the internal environment.

Increasing height influences:

- the air volume and how quickly conditions change within the structure,
- the capacity for air to mix and circulate,
- whether excess heat can rise above the crop canopy,
- how effective vents are in removing hot air.

The lowest part of the roof of a structure needs to be a minimum of 1.5 m above the top of a fully-grown crop, and roof vents should be at least 3.5 m above ground level. For example, for a crop such as tomato or cucumber, aim for a greenhouse with a gutter (wall) height of at least 3.5 m. As height increases more than this, the capacity to achieve consistently good growing conditions within the structure improves. Exposure to wind also increases with height and this needs to be considered, as it will add to engineering and construction costs.

▶ **TIP** Space above the crop is not wasted space – it is important in managing a good growing environment.

Figure 4: Ample height above the crop allows for a good growing environment.

4: Always start a new crop with a clean greenhouse

Principle: Cleanliness is the single most important preventative pest and disease management practice to reduce costs and losses in protected cropping.

As soon as a crop is **finished**, you need to conduct a greenhouse **CLEAN OUT**[5]. Remove the old crop, the substrate and all plant material – leaves, dropped fruit, weeds.

1. Remove old crop and dispose of material away from the greenhouse.
2. Remove all equipment and dispose of items that will not be reused including substrate, bags, twine.
3. Sweep down walls, floors and all internal structures.
4. Make sure **ALL** plant material is removed

Just **before** a new crop is transplanted (or sown), the greenhouse needs another **CLEAN UP**[5]. Everything in the greenhouse needs to be washed and disinfected.

1. Wash walls, floors and all internal structures, including drains with a high-pressure hose and detergent.
2. Rinse walls, floor and all internal structures with clean water.
3. Clean and disinfect hydroponic (irrigation) system (see page 19).
4. Open up the greenhouse and allow surfaces to dry.
5. Wash walls, floors and all internal structures with an appropriate disinfectant (for example, a 0.5 – 1 % chlorine solution).
6. Rinse walls, floor and all internal structures with clean water.
7. Close up the greenhouse with just a small vent opening and leave to dry.
8. Wash and refill footbaths.
9. Clean all equipment, tools, plant containers, bins and other items to be returned to the greenhouse.
10. Disinfect all equipment and items to be returned to the greenhouse.
11. Set greenhouse for the next crop, making sure that no items, tools, equipment get contaminated.

▶ **TIP** A pressure washer does a better job than a normal hose. Some models enable cleaning products to be injected into the water.

[5] Adapted from J Badgery-Parker (2009) Keep it Clean – Reducing the costs and losses in the management of pests and diseases in the greenhouse, NSW Dept. of Primary Industries.

5: Have a reliable and adequate supply of pathogen (disease) free water

Principle: A reliable supply of clean water is essential in protected cropping.

In all hydroponic systems, a clean and pathogen free source of water is required and there needs to be enough water to meet the demands of the crop. Any water that may have had contact with soil or plant material needs to be disinfected before being used in the greenhouse.

5.1 WATER STORAGE

A typical greenhouse in Australia, on average will require 5 litres/m^2 per day, or approximately 1800 litres per square metre over a whole year. In some production areas this figure is higher. For example, in the Coffs Harbour region a greenhouse crop will need close to 2200 litres per square metre over a whole year (represented by the green columns in figure 6). More water is needed during summer than during winter.

This amount includes water for irrigation as well as basic cleaning of the greenhouse.

The required amount of water relates to the type and the age of the crop, the way in which it is being grown and by the growing conditions – light, temperature, relative humidity and air flow (wind).

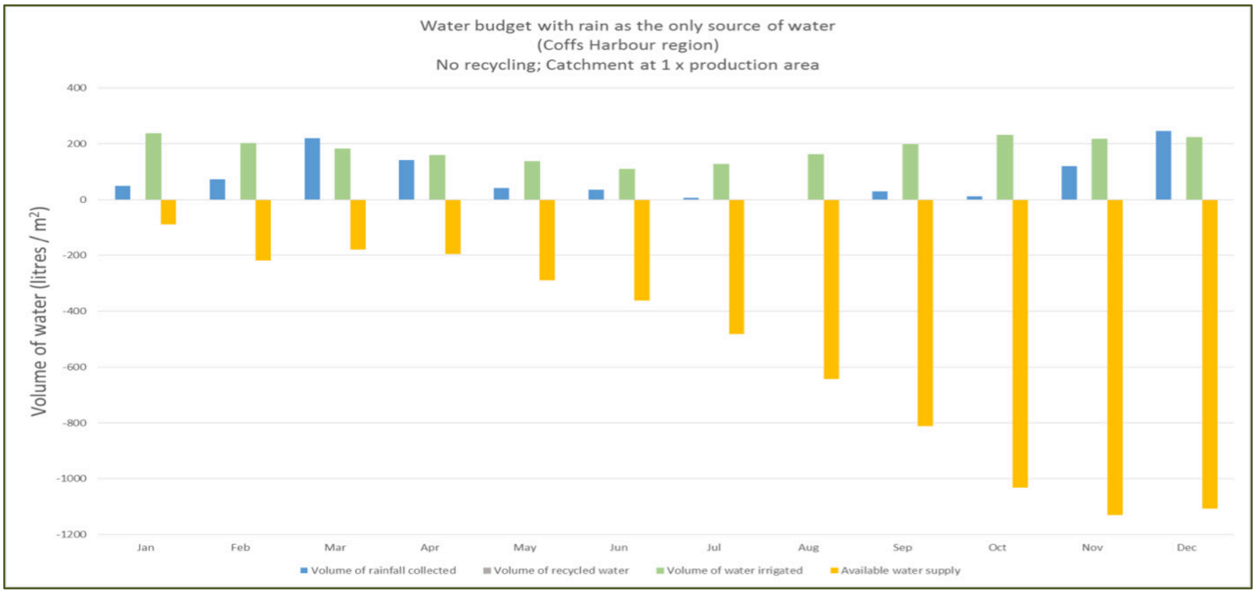
Peak demand is the greatest amount of water you will need for a crop during a year. Peak demand is usually the amount of water a mature crop needs in the middle of summer. Not only must your irrigation system be designed to deliver the peak demand, you also need to ensure you have sufficient water available. The approximate peak demand for a mature vine crop such as tomato or cucumber in Australia is around 8L/m^2/day.

A water budget (weekly or even daily) can be prepared to show the volume of all your water supplies and the volume available each day. If your water supply includes rainwater, you need to include the expected rainfall. You also need to include the expected crop water use corresponding to the same period. If you subtract the daily (or weekly) water use from the daily (or weekly) water supply, you will get an estimate of the water that you would need to have stored (represented by the orange columns, in figure 6. A negative value will indicate that you will run out of water and you need to either increase your water storage or reduce your cropping area.

▶ **TIP** Producing a weekly or daily water budget spanning a couple of years will give you a better indication of how much water storage you might need. If you are dependent on rainwater, you should also assume a dry (below average rainfall) year.

Figure 6 shows the direct ratio of the average rainfall in the Coffs Harbour region (represented by the blue columns) to the expected crop water use (green columns).

The bottom water budget illustrates that with recycling of the nutrient run-off (grey columns), a 0.5 ML storage would be required for each 1000 m^2 of greenhouse and a rain catchment area twice that of the greenhouse is needed.



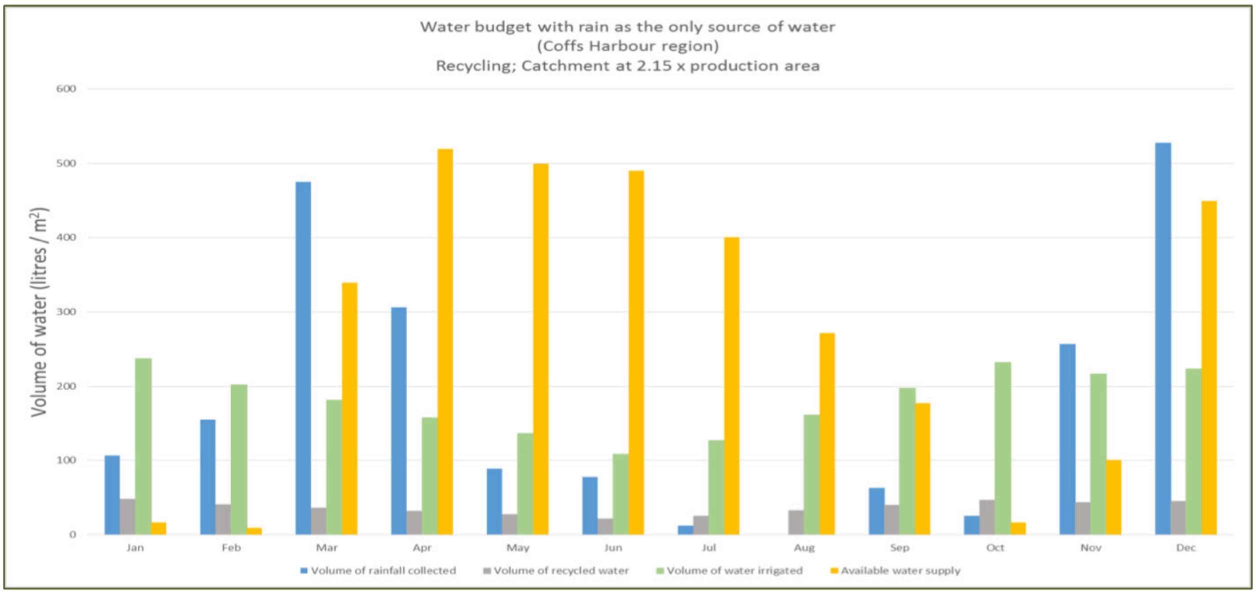


Figure 5: Example monthly water budget (Coffs Harbour region). The top budget shows that on a unit area basis, rainfall is insufficient to meet the water needs of a high production greenhouse crop. The lower budget includes recycling of the nutrient run-off and illustrates that a water catchment area just over twice that of the production area would supply just enough water for the crop.

A 1000m² greenhouse would need a storage capacity of 0.5ML and a water catchment of at least 1000m² in addition to the roof of the greenhouse.

[Note, this water budget assumes an average year of rain with 100% of rainfall collected and that the dam is 20% full at the start of the year.]

5.2 WATER – RE-USE AND RECYCLING

In most hydroponic systems, generating nutrient solution run-off is an important management strategy. This water and the fertiliser in it is a valuable resource. Wherever possible, water and especially hydroponic nutrient solutions should be re-used.

Water disinfection

Nutrient run-off and any water that may have come into contact with soil or plant material can be contaminated with plant pathogens. Municipal (town) reticulated water is already treated and is generally suitable for hydroponics without further disinfection as long as it has not been stored in an open tank or dam. Similarly, underground water is generally considered to be pathogen free and can be used without disinfection as long as it has not been stored in an open tank or dam. All other water sources such as surface run-off (dam water), roof catchment (rain water) and recycled nutrient solution need to be disinfected before use[6].

There are several methods of water disinfection including chemical treatment, ultrafiltration and biofiltration, thermal (heat) treatment and ultraviolet radiation (UV).

Selecting a method of water disinfection needs to be based on (1) efficacy, (2) cost and (3) practicality. This means that the disinfection system must reliably remove the target pathogens and must be cost effective. The maintenance and servicing of the treatment system cannot be too onerous and the volume of water that can be treated needs to match or exceed your peak water use demand.

Other factors to consider in disinfecting and in re-using water are the EC and pH of the water and whether the nutrient profile in the water has been affected by the disinfection process. Levels of disinfectants such as chlorine or ozone can be reduced by aerating the water prior to use.

Additionally, if the water source contains sodium (for example the water has been treated with sodium chloride, such as town water), the level of sodium must be monitored and the nutrient solution replaced when the level of sodium gets too high. Typically, the critical maximum level of sodium or chlorine in irrigation water is around 70mg/L.

6: A suitable hydroponic system

Principle: The hydroponic system must be manageable, cost effective and uniform, easy to clean and maintain and provide a good balance between moisture and air in the root zone. A closed system is the most efficient and sustainable form of hydroponics.

Hydroponics is the method of growing a plant without soil and providing a balanced supply of nutrients dissolved in water. There are three types of hydroponic systems: substrate, water and air.

Substrate culture is a system in which the plants are grown in containers in a substrate and are irrigated with nutrient solution typically by dripper, microspray or in a flood and drain set up. These types of systems are suited to growing any plant and are the most common system for growing fruiting vegetables such as tomato and cucumber.

Water culture is a system in which the plant roots grow directly in the nutrient solution in a channel or container. Examples of water culture systems include Nutrient film technique (NFT), floating tray and Flood & Drain. These types of systems are well suited to fast turnover crops such as leafy salad crops and many Asian vegetables.

Air culture is a system in which plant roots are contained within an enclosed chamber and misted with nutrient solution to keep moist. This type of system is very water efficient and has a lot of potential for specialty root crops as well as fast turnover crops such as leafy salad crops.

In all systems, it is important that both water and fertilisers are used efficiently as they are very valuable inputs. A substrate system is the most versatile and 'tolerant' method of hydroponics.

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[6] More information on water disinfection can be found online at https://sites.google.com/site/sustainablehydroponics/ and in J Badgery-Parker (2009) Keep it Clean – Reducing the costs and losses in the management of pests and diseases in the greenhouse, NSW Dept. of Primary Industries.

6.1 COMPONENTS OF A HYDROPONIC SYSTEM

All hydroponic systems have the same key components. The main differences between systems are in the level of automation and the set up for delivering the nutrient solution to the crop.

A hydroponic system (see figure 6) will contain:

- A clean water supply (and storage tank).
- A dosing station where nutrients are added to the water to create a balanced nutrient solution of a target concentration. Nutrients are generally supplied from at least two stock (concentrate) tanks. These are typically named the 'A' and 'B' tanks. An acid (or sometimes an alkali) tank is also used to balance pH of the nutrient solution.
- An irrigation system (including pumps, filters, pipes and emitters). It might also include containers and substrate.
- A nutrient run-off (drain) monitoring station.
- Nutrient run-off drain and collection point (drainage and sump tank).
- Run-off water that is discarded: a constructed wetland, reed bed or retention pond to remove nutrients before disposal.
- Run-off water that is reused: a 'dirty' water tank.
- A disinfection system.
- A clean recycled water storage tank.
- EC and pH meters.

6.2 OPEN / CLOSED HYDROPONICS

An important classification in hydroponics is whether the system is **OPEN** or **CLOSED**. An open hydroponic system only uses the nutrient solution only once. The excess nutrient solution (containing fertilisers and water) that drains from the crop is discarded (or used elsewhere).

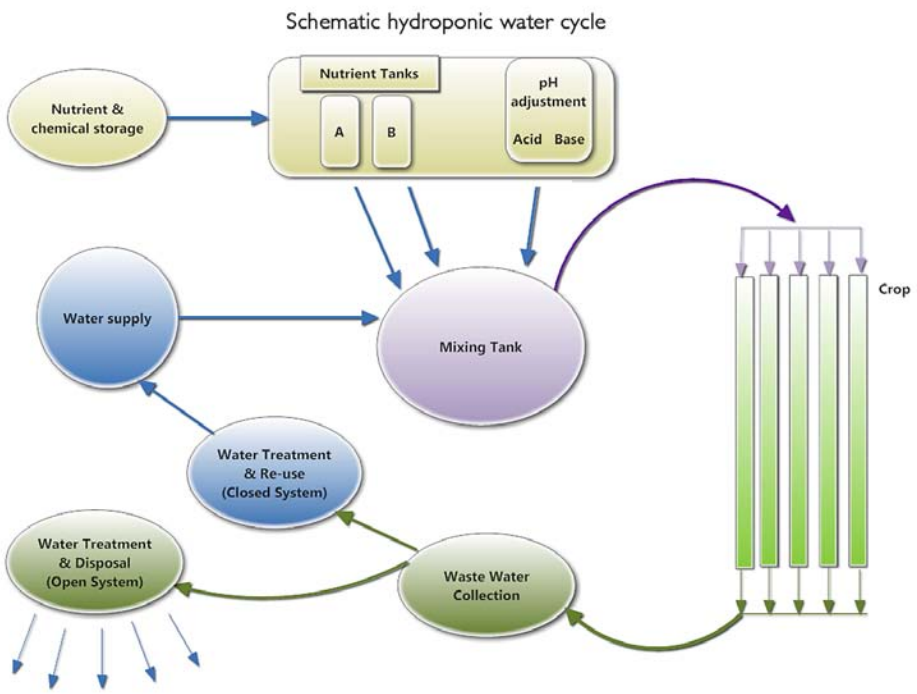

Figure 6: Diagram showing the generic components of a hydroponic system

A closed system is more efficient and sustainable. In a closed system, the nutrient solution is reused several times. The run-off from the crop is recycled which significantly – even completely – reduces the waste of fertiliser and water. There are two forms of closed hydroponics: In a *recirculated* system, the excess nutrient solution is returned straight back to the supply tank from which the crop is irrigated. In a *closed flow-through* system, excess nutrient solution that drains from the crop is collected, disinfected and then re-used.

6.3 SUBSTRATES / GROWING MEDIA

There are many different substrates that are used in hydroponics including sand and gravel, perlite, pine bark/compost, sawdust, cocopeat (coir), rockwool and purpose made synthetic materials. A substrate must provide a good balance between moisture and air in the root zone. It must also wet up evenly.

Selecting a substrate is mostly a case of cost, durability, consistency, availability, climate, crop and container. A relative comparison of some common substrates is provided in table A.

Different substrates are managed differently according to

(1) how much they interact with the nutrient solution,

(2) the water holding capacity (WHC), the air filled porosity (AFP) and the cation exchange capacity (CEC),

(3) how rapidly the material degrades.

▶ **TIP** The more consistent a substrate is, the easier it is to manage so crop production is better and there is less waste.

In a hydroponic substrate, 30 – 40% of the volume should be solid material, the remainder is space. The space is called porosity. At least 10% and up to 30% of the volume should be filled with air. This is called the Air Filled Porosity (AFP). One-third to two-thirds of the volume should be available for water. This is water holding capacity (WHC).

The cation exchange capacity (CEC) is a measure of how much a substrate will interact with nutrients. Organic materials will generally have a higher CEC than mineral based materials. A high CEC means that the grower has less capacity to fine tune the crop nutrition but a high CEC can be helpful for less experienced growers by providing a nutrient reservoir or buffer in the root zone.

Target substrate qualities

1. Uniform – consistent throughout
2. Durable – medium to slow rate of decomposition; slow to compact
3. Pest, disease and weed free
4. 60 – 70% total porosity (space within the solid material)
5. 30 – 60% water holding capacity (WHC)
6. 10 – 30% air filled porosity (AFP)
7. Known cation exchange capacity (CEC)
8. Free from salts (low soluble salt level)
9. pH within the range 5.5 – 6.5 and/or can be adjusted easily
10. Easy to transport, handle and available locally

The final factor that needs to be considered is the cost of the substrate.

Note: if a substrate is planned to be used for more than one crop:

a) Be especially vigilant about diseases. If you get a high disease load in your crop, you must discard the substrate.
b) Be aware of compaction – as a material compacts and decomposes, it may become limited in air space and overly wet.

Common substrates

Sawdust is a common and useful short-term, single-use substrate. It is generally one of the cheaper substrates; it is lightweight and readily available in most areas. (Only sawdust from softwoods, for example, from plantation pine should be used).

Sawdust has a high WHC, which increases as the material decomposes and it has a moderate AFP, which decreases as the material degrades. Sawdust decomposes quite quickly and as a result can use up some of the nitrogen in the nutrient solution, reducing the amount available to the crop. Sawdust is only suitable for a single crop. It has a high CEC, which means it interacts a lot with the nutrients in the root zone.

New sawdust is generally fairly uniform and as long as it is clean and has not been contaminated with soil or mud, it is usually free from pests and diseases. Sawdust can become hydrophobic if allowed to dry out and can be difficult to rewet or wet up evenly.

Sawdust is a renewable resource and can be readily composted after use making it a low impact substrate.

Cocopeat is a common and useful substrate. It is slow to decompose and can be used for longer crops or re-used for a second crop, provided there is no significant disease in the first crop. It is generally a medium cost substrate; is lightweight and readily available.

Cocopeat has a high WHC and a high AFP. As this material is slow to decompose, these qualities do not change significantly over a normal cropping period. With repeated use, WHC will increase and AFP will decline. It has a medium CEC, which means it interacts a little with the nutrients in the root zone.

Cocopeat is very uniform and when pre-packaged it is free from pests and diseases. Some low quality supplies can have high salt levels. If using a new supplier, flush some of the cocopeat with plain water and check the EC before use. Often fresh cocopeat should be pre-treated by flushing with a calcium-saturated solution to remove sodium. Cocopeat can be wetted fairly readily and has a high water infiltration rate.

Cocopeat is a renewable resource and can be composted after use making it a low impact substrate.

Compost is a common short-term, single-use substrate. It is generally one of the cheaper substrates, and is readily available in many areas. (Only properly composted material should be used, as the risk of plant diseases is high in this type of material).

Compost generally has a high WHC and it has a moderate AFP though these characteristics can change significantly depending on the source material of the compost and as this material decomposes. Compost decomposes quite quickly and as a result can use up some of the nitrogen in the nutrient solution, reducing the amount available to the crop. Compost is only suitable for a single crop. It has a high CEC, which means it interacts a lot with the nutrients in the root zone.

Compost is a renewable resource and can be readily composted after use making it a low impact substrate.

Perlite is a very lightweight and useful substrate. It is very slow to degrade so can be used for multiple crops – provided there is no significant disease in the previous crop. Perlite can be steam sterilised to reduce disease risk. It is generally one of the more expensive substrates.

Perlite has a high WHC and a high AFP. As this material is very slow to degrade, these qualities do not change over several cropping periods. It has a low CEC, which means it has very little interaction with the nutrients in the root zone, giving a grower a high level of control. Perlite can be wetted readily and has a high water infiltration rate.

Perlite is very uniform and when pre-packaged it is free from pests and diseases. Poor handling can degrade the material. Perlite is a renewable resource though requires energy in its manufacture. It cannot be composted after use but can be incorporated into soil, potting mixes and composts to improve them.

Rockwool is a very lightweight and high quality substrate. It is very slow to degrade so can be used for multiple crops – provided there is no significant disease in the previous crop. It is particularly good for long crops. It is generally one of the more expensive substrates.

Rockwool has a high WHC and a high AFP. As this material is very slow to degrade, these qualities do not change over several cropping periods. It has a low CEC, which means it has very little interaction with the nutrients in the root zone, giving a grower a high level of control. Rockwool can be wetted readily and has a high water infiltration rate. It has a high pH and needs to be flushed with nutrient solution prior to use.

Rockwool is very uniform and is free from pests and diseases. Rockwool is a renewable resource though requires energy in its manufacture. It cannot be composted after use but can be shredded and incorporated into soil, potting mixes and composts to improve them. Some suppliers recycle this material into new substrate.

Sand is a heavy, though readily available substrate. It is very slow to degrade so can be used for multiple crops – provided there is no significant disease in the previous crop. It is generally one of the less expensive substrates.

Sand has a low WHC and a moderate AFP and as this material does not degrade, these qualities do not change. It has a low CEC, which means it has very little interaction with the nutrients in the root zone, giving a grower a high level of control. Sand can be wetted readily and has a high water infiltration rate. The pH can vary depending on the source and type of sand. Coarse river sand should be used.

Sand is very uniform and is free from pests and diseases. Sand is a renewable resource though requires energy in its transport. It cannot be composted after use but can be incorporated into soil, potting mixes and composts to improve them.

Table A: Comparative qualities for common substrates

	WHC	AFP	CEC	pH	Uniformity	Durability	Cost
Sawdust	✓✓	✓✓	✓	✓✓✓	✓✓	✓	*
Cocopeat	✓✓✓	✓✓✓	✓	✓✓✓	✓✓✓	✓✓	**
Compost	✓✓✓	✓✓	✓	✓✓✓	✓	✓	*
Perlite	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	***
Rockwool	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓	***
Sand	✓✓	✓✓	✓✓✓	–	✓✓✓	✓✓✓	*

Other substrates that can be used include gravel, scoria, expanded clay pellets, peat and foam.

6.4 CONTAINER SYSTEM

The container holds the substrate (in substrate culture) or the nutrient solution (in water culture) and is an important component of any set up. In water and air culture systems, the container must ensure that the roots have access to a sufficient quantity of nutrient solution and adequate air exchange. The dimensions of a container in these systems need to be sufficient to ensure that as the root mass increases, access to water, nutrients and air are not limited. Some means of holding the plant is also essential, while in substrate culture, the plant can support itself in the substrate.

In a substrate system, the dimensions of the container also have an impact. The height of a container affects the air filled porosity – a taller container has more air space when it drains than a flatter container (Figure 7). As the height of a container increases, for a particular substrate, the air filled porosity increases and the water holding capacity decreases.

The dimensions and the volume of a container determine how much root zone volume is available per plant. A smaller volume will mean a smaller root mass and subsequently the plant will require a more frequent supply of nutrient solution. A large container volume can be inefficient and more difficult to irrigate evenly.

▶ **TIP** Generally, in a substrate system, aim for 3.5 – 4.0 litres of substrate per plant.

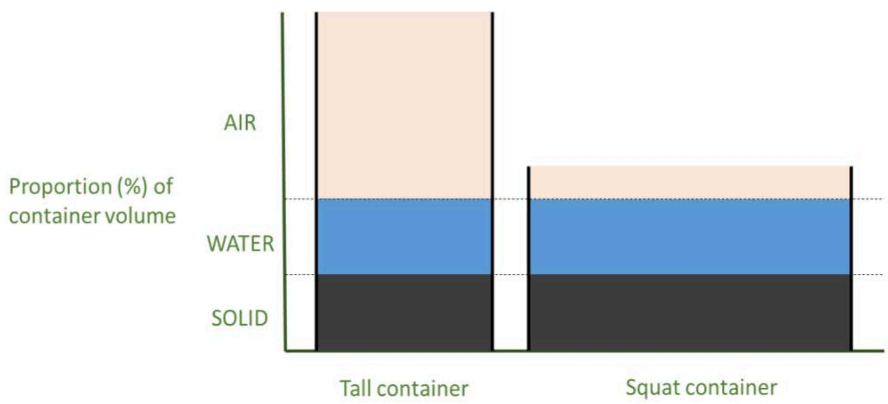

Figure 7: Two containers or bags of the same volume, filled with the same substrate will have different proportions of air and water depending on the height of the container or bag.
A taller container will have more drainage. A squat container will hold relatively more water.

6.5 SET UP AND ARRANGEMENT OF A SUBSTRATE SYSTEM

In a substrate system, the supply of nutrient solution and the removal of drain water are key considerations.

The irrigation system

As long as the irrigation system can deliver the required volume of water evenly to each and every plant at a rate that does not flood the container or channel through the substrate, there is no definitive design for a hydroponic irrigation system except that within an irrigation zone, all containers, emitters and substrate must be the same to ensure the system is uniform.

In a simple drip and substrate irrigation set up, plants are positioned in rows. A main irrigation line (for example 40mm polypipe) carries water from the nutrient dosing area to the greenhouse. A filter is included in the irrigation line to reduce the risk of emitters in the greenhouse becoming blocked. Secondary lines (for example 19mm polypipe) extend down each row of plants. A single spaghetti line

(4mm) with a pressure compensating emitter (dripper) is taken off the secondary line for each plant. The length of each spaghetti line should be the same and only as long as necessary to comfortably reach each plant (for example 500mm). Using small stakes or suspending the emitters just above the substrate can prevent plant roots from growing into and blocking the emitters.

The emitters must be able to discharge enough water to meet the peak demand in summer. The whole system must be able to supply a sufficient and timely volume of water to all irrigation zones (and plants) to meet the peak demand in summer.

Include an additional spare emitter (one with no plant) in each irrigation zone to use in the run-off monitoring station (see page 26).

The drainage system

An effective drainage system is required to make sure that excess nutrient solution (run-off) is moved away from the root zone of each plant. The container or bag must not sit in a pool of water. The roots of any plant should not be able to access this drain water. A simple and common strategy is to place each container on top of an object to keep it out of the drain water. Any object can be used as long as it can be disinfected and reused (or is disposable) and that it does not allow drain water to pool at the base of the container.

An effective low cost method is to suspend the containers above the drainage channel. This creates 'perfect' drainage and ensures that no plant can access drain water. This method also increases airflow around the plant which improves root zone temperatures and general growing conditions in the greenhouse.

A common and effective set up uses two tensioned parallel wires along each row (see below). The plant containers are placed on top of these wires. A drainage channel is installed on the ground under these wires.

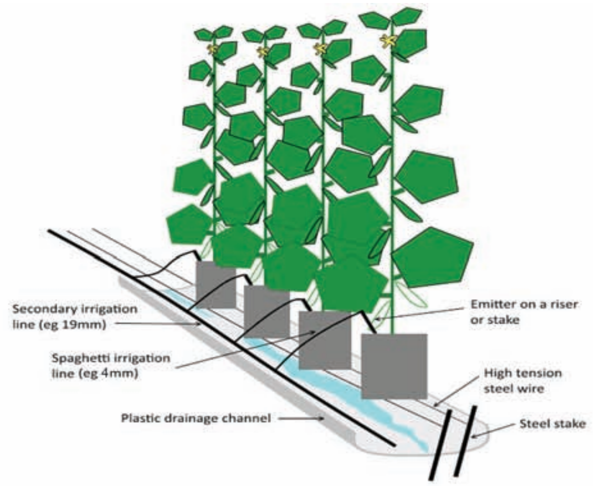

Figure 8: Two high tension steel wires are an effective way to suspend containers above the drainage channel

In a water culture system, for example 'NFT', drainage is achieved by gently sloping the channels so that nutrient solution flows past the roots of each plant. At the bottom of each channel, the water drains into a return pipe that diverts the water back to the supply tank. Nutrient solution is delivered to the top of each channel via an emitter or open ended pipe. Best practice is to use two emitters/tubes per channel to provide a backup in case of a blockage.

6.6 THE HYDROPONIC CLEAN UP[7]

Before a new crop is planted, the hydroponic system needs to be cleaned and disinfected. This should be done as part of the greenhouse clean up.

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1. Remove pH and EC and any other sensors from the hydroponic system.
2. If nutrient concentrate tanks are empty, wash them with a high-pressure hose and detergent and rinse with clean water. Wash with an appropriate disinfectant (for example, a 0.5 – 1 % chlorine solution[8]), then rinse with clean water.
3. Flush irrigation lines with an appropriate cleaning agent (for example phosphoric acid (pH of 1.5-1.8). Hold solution in irrigation lines for 12-24 hours if possible.

BE SAFE: Keep greenhouse vents open when acid washing irrigation lines and always wear appropriate personal protective equipment when using chemicals.

4. Rinse irrigation lines with clean water.
5. Soak all dripper stakes and emitters overnight in an appropriate disinfectant (as above)
6. Rinse dripper stakes and emitters with clean water, return them to the greenhouse and refit.
7. Conduct an irrigation distribution uniformity test on the system.

7: The irrigation system distributes water uniformly to all plants

Principile: To grow a productive crop efficiently and minimise waste and costs of growing, you need to keep the crop growing evenly – every plant has to get the same amount of water.

If irrigation is uneven, some plants will get too much water and other plants will not have enough. This will reduce yield and increase pest and disease problems. It wastes both fertilisers and water.

Distribution Uniformity (DU%) is a way of testing the hydroponic irrigation system. For an efficient hydroponic system, you need to have a DU% of more than 90%.

The Distribution Uniformity should be checked before planting each crop. Additional checks should be made during the cropping period if problems are evident. Each section (zone) of your hydroponic system needs to be checked separately.

Grade	DU%
Excellent	90 – 100 %
Good	80 – 90 %
Okay	70 – 80 %
Not good	< 70 %

[7] Adapted from J Badgery-Parker (2009) Keep it Clean – Reducing the costs and losses in the management of pests and diseases in the greenhouse, NSW Dept. of Primary Industries.

[8] When using chlorine to disinfect a closed hydroponic system, use calcium chloride, not sodium chlorine.

METHOD

A. Calculate the average water application rate for all the sampled emitters

(The application rate is the amount of water (in litres) that each emitter puts out in one hour.)

1. You need to collect at least 28 samples. Three or four emitters should be selected from each crop row. One sample needs to be taken from an emitter near the beginning of the lateral pipe and one sample from an emitter near the end of the row. The other samples should be from emitters somewhere along the row.

▶ **TIP** If you have 7 rows in a greenhouse and test 4 emitters in each row, you will end up collecting 28 samples. If you have more than 7 rows, select the row nearest the junction with the incoming irrigation line and the row furthest away. Select at least 5 more rows spread across the irrigation zone.

2. Place a cup or small container under each emitter (3 or 4 per row) that you will sample.
3. Turn on the irrigation system for 60 seconds (1 minute) then turn off the water.
4. Use a measuring cylinder to measure the amount of water (in millilitres, ml) in each cup. Record the amount of water for each emitter on a data sheet[9].
5. Calculate the amount of water that comes out of each emitter in millimetres per hour (mm/hr).

Amount of water per hour (L/hr) = Water collected (ml) x 60 / 1000

6. Record these numbers on a data sheet.
7. Add up the numbers for all the emitters. Divide this total volume by the number of emitters sampled to get the average.
8. Record this number on the data sheet.

B. Work out the average water application rate for the lowest quarter of the sampled emitters

1. Rank the emitters in order of how much water they put out.
2. Mark which ones make up the lowest quarter (25%) of emitters.
3. Now, add up the numbers for the lowest 25% of the emitters. Divide this total volume by the number of emitters to get the average.
4. Record this number on the data sheet.

C. Calculate the distribution uniformity (DU%)

1. Divide the average application rate of the lowest 25% of the emitters by the average application rate of all the emitters. Multiply this number by 100.

$$DU(\%) = \frac{Average\ application\ rate\ of\ the\ lowest\ 25\%\ of\ sampled\ emitters}{Average\ application\ rate\ of\ all\ the\ sampled\ emitters} \times 100$$

[9] A data sheet template is provided at the back of this guide and can be downloaded from www.primaryprinciples.com.au

▶ **TIP** If one or two emitters have very different amounts of water compared to the rest, for example twice as much or none at all, clean or replace these emitters and empty all the containers and repeat the test.

There are several ways to improve the uniformity of the irrigation system.

1. Make sure the capacity of the pump is sufficient for the size of the irrigation zone[10].
    a. Split the irrigation zone into a couple of smaller zones
2. Check that the water pressure is appropriate for the type and number of emitters.
3. Clean and flush all the irrigation lines.
4. Keep filters clean and in good condition.
5. Avoid high and low points (undulations) in the cropping area.
6. Check that all the emitters in an irrigation zone are the same.

If the system has a DU% less than 70% and you cannot improve it with these checks, the design of the irrigation system is likely to be wrong. Consult an irrigation specialist.

8: A balanced nutrient solution is used for every irrigation

Principle: Hydroponics is a means of providing plants with the nutrients that they require, when they require them with minimal waste and minimal stress. Never flush a hydroponic crop with plain water.

The nutrient needs of a plant change over the course of a day and over the whole cropping cycle. Nutrient needs are also affected by the growing conditions. With good irrigation and EC management, it is possible to produce a decent crop with a single, standard nutrient recipe. Higher yields and lower costs can be achieved with more precise management that separates nutrient needs according to stage of growth and plant balance.

The nutrient solution is a dilute mix of nutrients and water. The nutrient solution is what feeds and irrigates the crop. The nutrient solution must contain all the nutrients needed by the plant in specific amounts or concentrations. The specific amount of fertilisers used in a set volume of water is known as the nutrient recipe. Nutrients are purchased as separate fertilisers or as premixed formulations.

▶ **TIP** Premixed formulations can be more convenient and time saving, but they are difficult to adjust for individual needs or to address a specific problem.

> The Nutrient recipe specifies the amounts of each fertiliser (for example, calcium nitrate) used in a set volume of water.
>
> The Nutrient formula specifies the concentration of each element (for example, nitrogen or calcium) used in a nutrient solution.

[10] An irrigation zone is a discrete section of an irrigation network in which all the plants are irrigated together at the same time.

A stock solution is the mixture of nutrients in a concentrated form before it is diluted to make the nutrient solution. Some nutrients become insoluble if mixed in concentrated forms. Calcium should never be mixed with either a sulphate or a phosphate when making up stock (concentrate) solutions. Stock solutions are therefore typically split into 'A' and 'B' tanks. The division of nutrients into 'A' and 'B' tanks when making stock solutions is done to avoid fertilisers forming non-soluble compounds.

> ▶ **TIP** If a layer of sediment appears at the bottom of a nutrient (or stock) tank, it is likely that you (1) are trying to dissolve too much fertiliser in the volume of water or (2) you have mixed calcium with sulphates or phosphates at a concentrated rate (in the stock tank) or (3) the pH of your water is too high.

The 'A' tank will contain the calcium (for example calcium nitrate). Any fertiliser that contains phosphate or sulphate is put in the 'B' tank.

Iron and most of the trace elements can come in either a 'chelate' form or as a 'sulphate'. A chelate can go in either tank, but a sulphate must only go in the 'B' tank. For example, iron EDTA can be put in the 'A' tank but iron sulphate is put in the 'B' tank.

Table B: Common range of target nutrient concentrations in typical formulae and sources of fertilisers

Nutrient	Concentration (mg/L or ppm) *Range of typical nutrient formulae*	Fertiliser *Source of nutrient*
Nitrogen (N)	150 – 250 (2 – 10% as ammonium[11])	Calcium nitrate Potassium nitrate Ammonium nitrate Ammonium sulphate
Phosphorus (P)	25 – 50	Mono-potassium phosphate Mono-ammonium phosphate Di-ammonium phosphate
Potassium (K)	150 – 300	Potassium nitrate Mono-potassium phosphate Potassium sulphate
Calcium (Ca)	150 – 200	Calcium nitrate
Magnesium (Mg)	25 – 45	Magnesium sulphate
Iron (Fe)	2 – 3	Iron chelate (EDTA) Iron chelate (DTPA) Iron sulphate
Manganese (Mn)	0.3 – 0.5	Manganese chelate Manganese sulphate
Zinc (Zn)	0.2 – 0.5	Zinc chelate Zinc sulphate
Boron (B)	0.2 – 0.4	Boric acid Borax
Copper (Cu)	0.05 – 0.3	Copper chelate Copper sulphate
Molybdenum (Mo)	0.01 – 0.05	Sodium molybdite Ammonium molybdate

[11] Changing the proportion of nitrogen that is in the ammonium form can be used to manage pH in the root zone. As plants take up ammonium ions, the pH is lowered. With the legal restrictions on the use of ammonium nitrate, it can be substituted with ammonium sulphate – use approximately 0.83g/kL ammonium sulphate for each 1g/kL of ammonium nitrate. Ammonium sulphate must be put in the 'B' tank.

Potassium fertilisers can also be put into the ‘A’ tank provided they do not include phosphate or sulphate. Most recipes that use potassium nitrate commonly divide this fertiliser evenly between both the ‘A’ and ‘B’ stock solutions to even up the amount of fertiliser being dissolved in the respective tanks. This is to make sure that the amount of fertiliser added in each tank can be dissolved in the available volume of water.

Table C: Example nutrient formulae showing target concentration of key nutrients

Nutrient	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
Pre-fruiting: Target concentration (mg/L)	200	40	208	190	35	46	2.5	0.3	0.2	0.3	0.2	0.03
Fruiting: Target concentration (mg/L)	190	40	250	160	40	53	2.5	0.3	0.2	0.3	0.2	0.03

Table D: Example nutrient solution recipes based on the target nutrient concentrations shown in Table C

	Pre-fruiting			Fruiting		
Fertiliser			Amount of fertiliser in grams			
“A” TANK						
Calcium nitrate		94887			79236	
Ammonium nitrate		0			0	
Potassium nitrate		20537			25698	
Iron EDTA		2551			2551	
“B” TANK						
Potassium nitrate		20537			25698	
Mono Potassium phosphate (MKP)		19025			18866	
Magnesium sulphate		35672			40426	
Manganese chelate	300	or		300	or	
Manganese sulphate			122			122
Zinc chelate	200	or		200	or	
Zinc sulphate			88			88
Borax	283	or		283	or	
Boric acid			167			167
Copper chelate	200	or		200	or	
Copper sulphate			89			89
Sodium molybdate	7.56	or		7.56	or	
Ammonium molybdate			6.14			6.14
K:N ratio		1			1.3	
Ca:N ratio		0.95			0.85	
K:Ca ratio		1.1			1.5	
Approx. EC		1.8			1.8	
Approx. pH		5.9			5.9	
Proportion of nitrogen as Ammonium (NH^{4+})		4.7%			4.2%	
Volume of each stock solution	1000 litres		Dilution rate		X 100	

8.1 ELECTRICAL CONDUCTIVITY (EC)

Electrical Conductivity (EC) measures the strength (saltiness) of the nutrient solution. EC is measured with an EC meter and should be measured in milliSiemens per centimetre (mS/cm).

There are two other ways to measure the strength of the nutrient solution:

1) Conductivity factor (cF) is an older way but is still used. An EC reading of 1 mS/cm ≈ 10 cF.
2) Total dissolved solids (TDS) is measured in parts per million (ppm). An EC reading of 1 mS/cm ≈ 640 ppm TDS.

It is important that you know what unit of measurement you are using. For example, a cF of 10 is a weak solution, but an EC of 10 mS/cm is very strong.

▶ **TIP** Only ever make small changes (< 0.2mS/cm) in the EC of a nutrient feed solution in a 24-hour period. Don't irrigate or flush a hydroponic crop with plain water.

You need to have an EC meter and calibrate it regularly. It should have a range of at least 0 – 6 mS/cm and accuracy of at least 0.1 mS/cm. This is in addition to any EC meter that is installed as part of an automatic system.

The target EC of a nutrient solution is based on the type of crop being grown. Some crops, for example tomato, tolerate a higher EC. Other crops, for example lettuce, have a low salt tolerance so need a nutrient solution with a lower EC. A third group of crops, for example cucumber, sit in the middle.

If the EC is too high, plant roots can be damaged and some nutrients may become toxic to the plant. If the EC is too low, the plant may become deficient in some nutrients. Leaves and fruit can become soft and flavourless. The run-off EC needs to be checked at least daily.

▶ **TIP** Avoid growing crops with different target ECs in the same hydroponic system.

8.2 THE pH

Measuring the pH of a nutrient solution or substrate shows you how acid (< 7) or alkaline (> 7) it is. A pH of 7.0 is considered neutral.

The pH will affect how easily particular nutrients are dissolved in water. This in turn affects how available the nutrients are to the plant. If the pH is too high or too low the plants can't take up some nutrients properly. If the pH is below about 4, plant roots will be damaged.

The target pH in hydroponic systems is generally between 5.5 – 6.5. (The feed pH to achieve this may be between 5.0 – 6.0. The root zone pH can be affected by the nutrient recipe, the growth of the plant and the growing conditions. The pH of the run-off needs to be checked at least daily.

You need to have a pH meter and calibrate it regularly.

This is in addition to any pH meter that is installed as part of an automatic system.

Calibrating EC and pH meters

Calibration means reading a solution of known conductivity (or pH) and adjusting your meter to read the same. You need to calibrate your EC and pH meters regularly to make sure that they are giving you the correct measurement. EC and pH meters get less accurate over time. EC and pH meters should be calibrated every couple of months.

Before calibration

1. Check the batteries
2. If the meter has not been used for a long time place the probe in tap water for about five minutes before calibrating

The EC meter

An EC meter will have an adjustment screw or knob. The standard solution commonly used for calibrating EC meters is 1.413 mS/cm potassium chloride (KCl) solution.

1. Pour a small volume of calibrating fluid into a clean container and place the probe into the solution.
2. Wait for reading to become constant (may take up to 30 seconds)
3. Using the adjustment screw, set the value to 1.4
4. Discard the used solution and rinse the probe with clean water.

The pH meter

A pH meter has two set screws, and it must be adjusted to two values. You will need 2 different calibrating fluids – ph 7.0 and 4.0.

1. Pour a small volume of calibrating fluid with a pH value of 7.0 into a clean container and place the probe into the solution. Using one of the adjustment screws, set the value to 7.0
2. Discard the used solution and rinse the probe well with clean water.
3. Pour a small volume of the second calibrating fluid with a pH value of 4.0 into a clean container and place the probe into the solution. Using the other adjustment screw, set the value to 4.0.
4. Discard the used solution and rinse the probe well with clean water.

Keep the pH meter probe moist when not being used. Depending on the type of pH meter you have, it may be stored in ordinary tap water or in a special fluid supplied by the manufacturer.

9: The EC, pH and run-off volume is measured at least daily

Principle: To grow a healthy and productive crop and to minimise waste, the nutrition and irrigation has to reflect the actual needs of the crop.

In hydroponics, the irrigation is used to give the crop water and nutrients. To grow a healthy and productive crop while minimising waste and reducing the costs, the nutrition and irrigation has to reflect the actual needs of the crop.

▶ **TIP** Always think of irrigation in terms of **volume of water** applied, not on the basis of the time the irrigation system is running.

In a substrate system, the amount of irrigation to give the crop is based on the EC and volume of the run-off. The run-off is used as an approximation to the root zone solution.

In each irrigation zone (for example, one greenhouse) you need to set up a monitoring station.

- A spare dripper is placed into a measuring container to record the feed (irrigation) volume.
  CHECK: Is the volume of water in this container equal to the amount of water you are aiming to apply?
- A tray or other device is placed under a plant to collect all the run-off from that plant and drain it into another measuring container.

The EC, pH and the volume of irrigated water and the volume of drain water are measured and the run-off percentage (RO%) is calculated. These measurements need to be checked at least daily but for best results there are 3 points in the day when it should be checked. The run-off percentage is calculated from the water volume measurements.

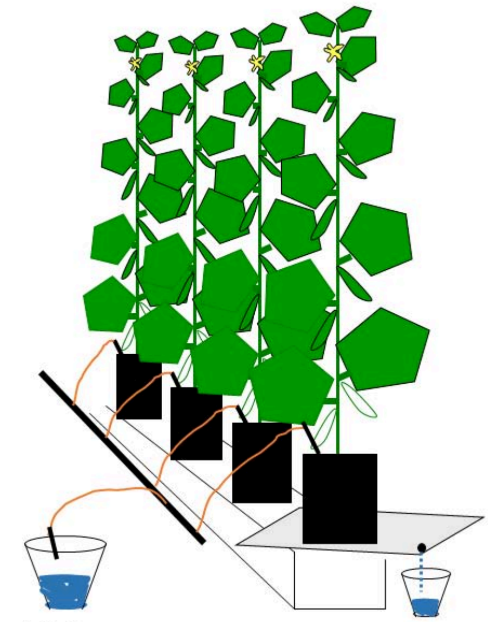


Figure 9: Simple hydroponic run-off (drain) monitoring station

$$RO(\%) = \frac{Volume\ of\ run\text{-}off\ (drain\ solution)}{Volume\ of\ irrigation\ (feed\ solution)} \times 100$$

The daily run-off percentage (RO%) is calculated over the whole day so if your daily target run-off percentage is 10%, you would expect to collect a total of 100ml after the last irrigation of the day for each litre of nutrient solution you apply to a plant.

Example calculation

If you irrigated the plant with 1 litre (1000ml) of feed solution and the run-off volume is 100ml, the run-off percentage is:

$$RO(\%) = \frac{100}{1000} \times 100$$

$$RO(\%) = 10\%$$

▶ **TIP** Record the EC, pH and RO% on charts so you can easily see the trends. There is more information on charting the data on page 32 of this guide[12].

[12] Example charts are provided at the back of this guide and can be downloaded from www.primaryprinciples.com.au

10: Irrigation is based on growing conditions and plant needs

Principle: For good crop management and efficient use of fertilisers and water, the day is divided into irrigation periods.

The nutrient and water needs of a crop not only change with different weather conditions, but they also change over a 24-hour period. To optimise crop management in a substrate system and make more efficient use of fertilisers and water (and create less waste), the day is divided into irrigation periods and each period can have different run-off targets. Typically there are four periods in a day (24hrs) – early, middle, late and night.

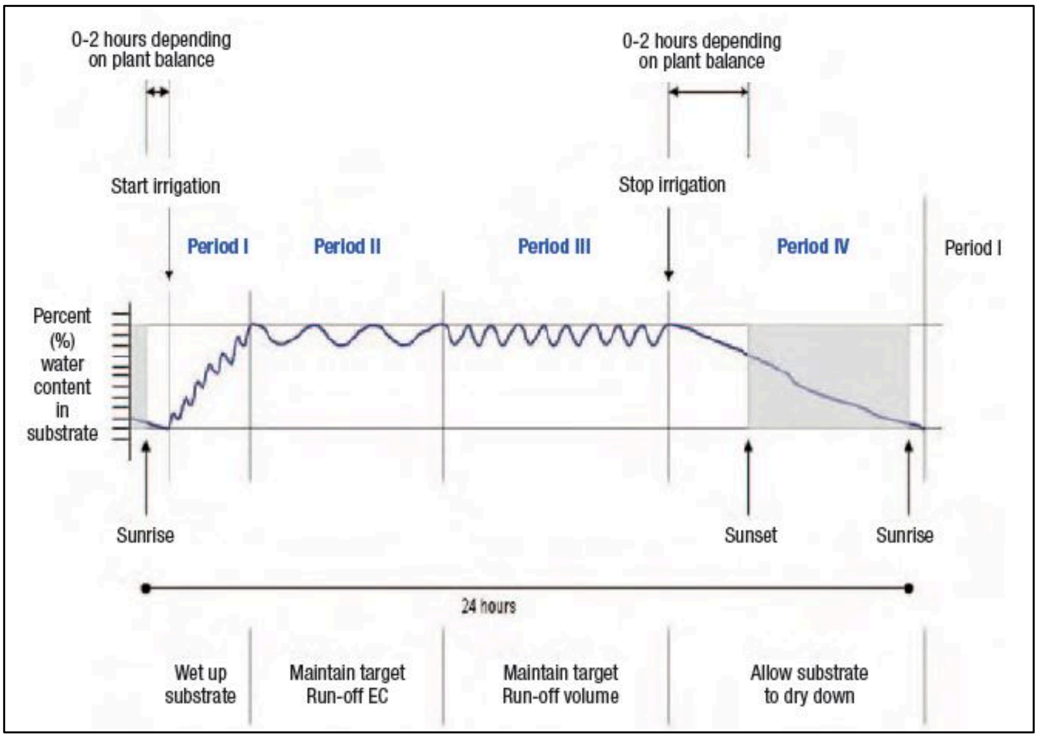
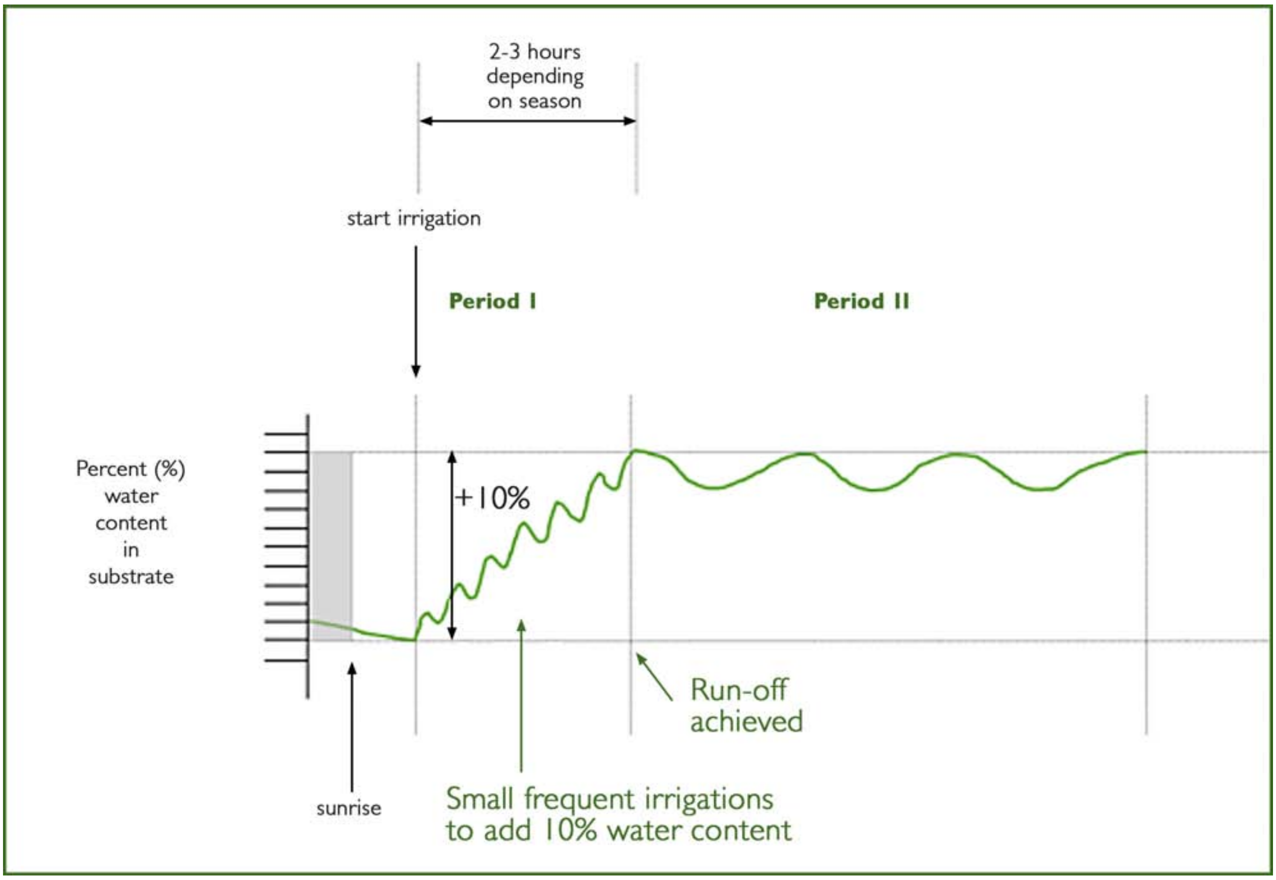


Figure 10: Representation of the four irrigation periods in a day and showing the relative water content (%) in the substrate

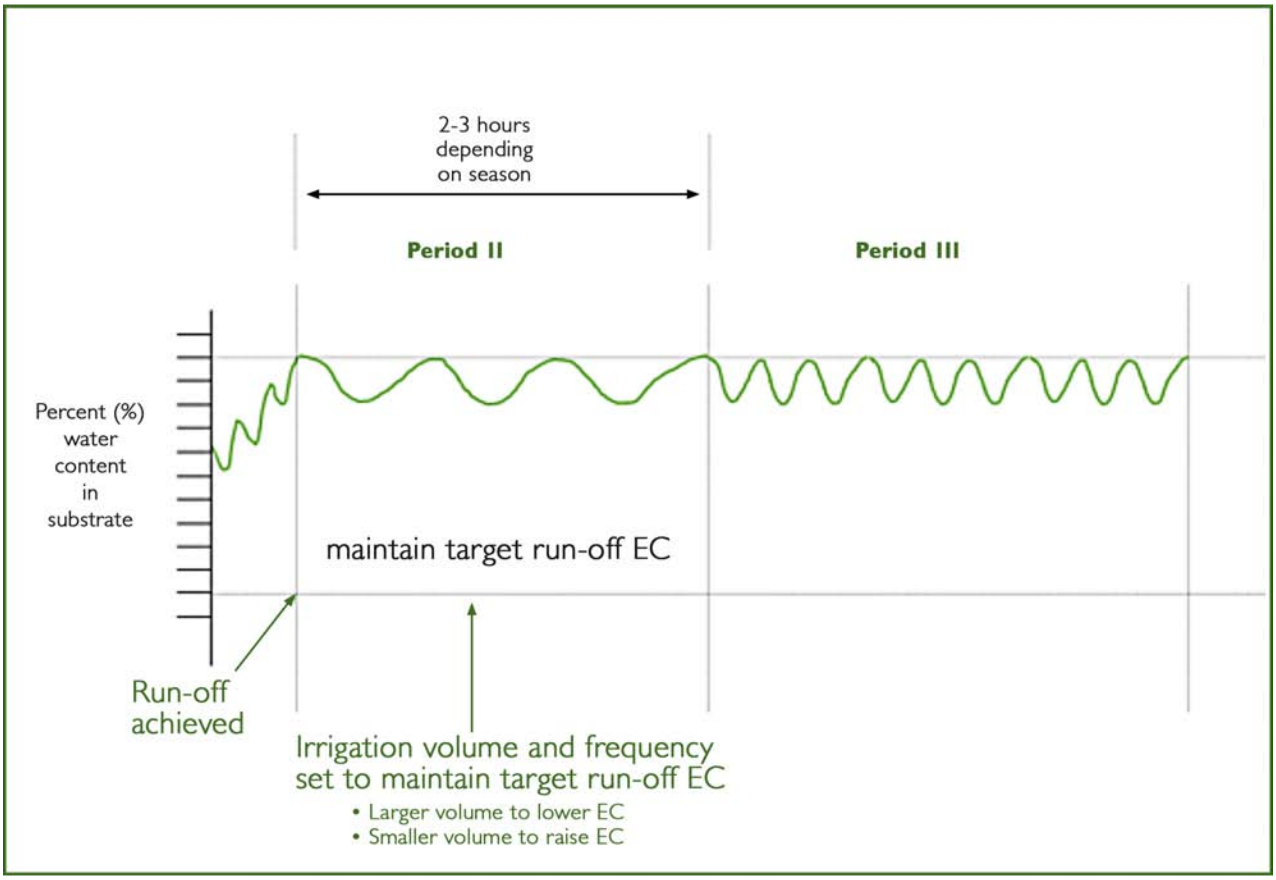
The water content is the proportion (%) of the water holding capacity (WHC) that is filled with water at a point in time. In summer, the target water content of a substrate is in the range 75 – 85%. During winter, a lower water content is desirable and the target water content is in the range 50 – 60% of water holding capacity.

The individual irrigation periods are shown in more detail on the next page:
Period 1 (morning) starts with the first irrigation of the day and continues until first run-off. Small, frequent irrigations are used to wet up the substrate.
Period 2 (mid-morning) extends for a few hours after first run-off and is focussed on maintaining the target EC in the run-off. The target EC will vary with the crop and the growing conditions. For example, a lower run-off EC is used in hot sunny conditions, compared with cooler, cloudy conditions.
Period 3 (afternoon) is during the middle of the day and into the afternoon when the plant needs the most water. This irrigation period is focussed on maintaining the target volume of run-off, as a percentage of the irrigation volume.
Period 4 (night) starts after the last irrigation. During the night, the substrate is left to dry down, that is, the water content is reduced. When nights are cool, for example in winter, it is very important to make sure the plant can use up some of the water in the bag before sunset.

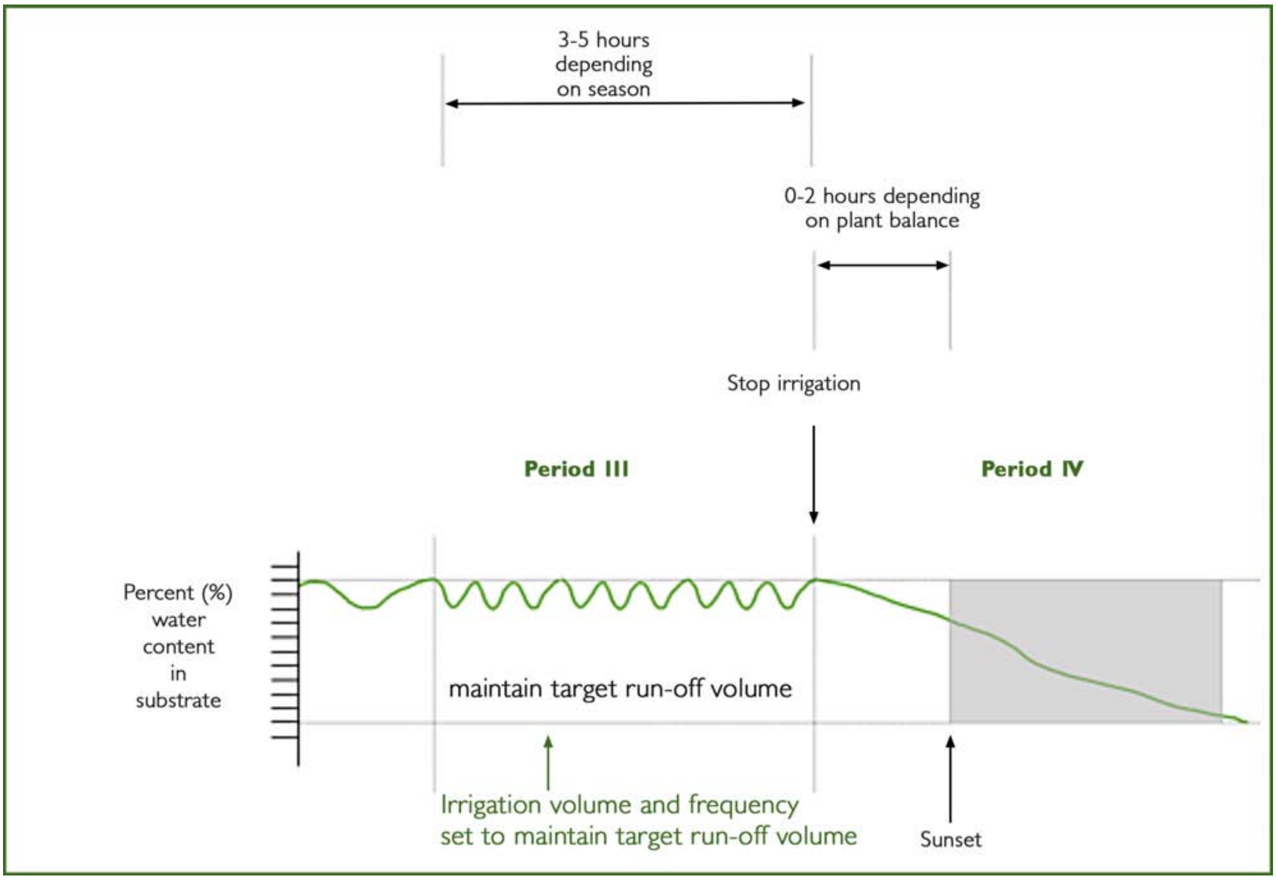
Period 1 (early morning) – add 10 % water content



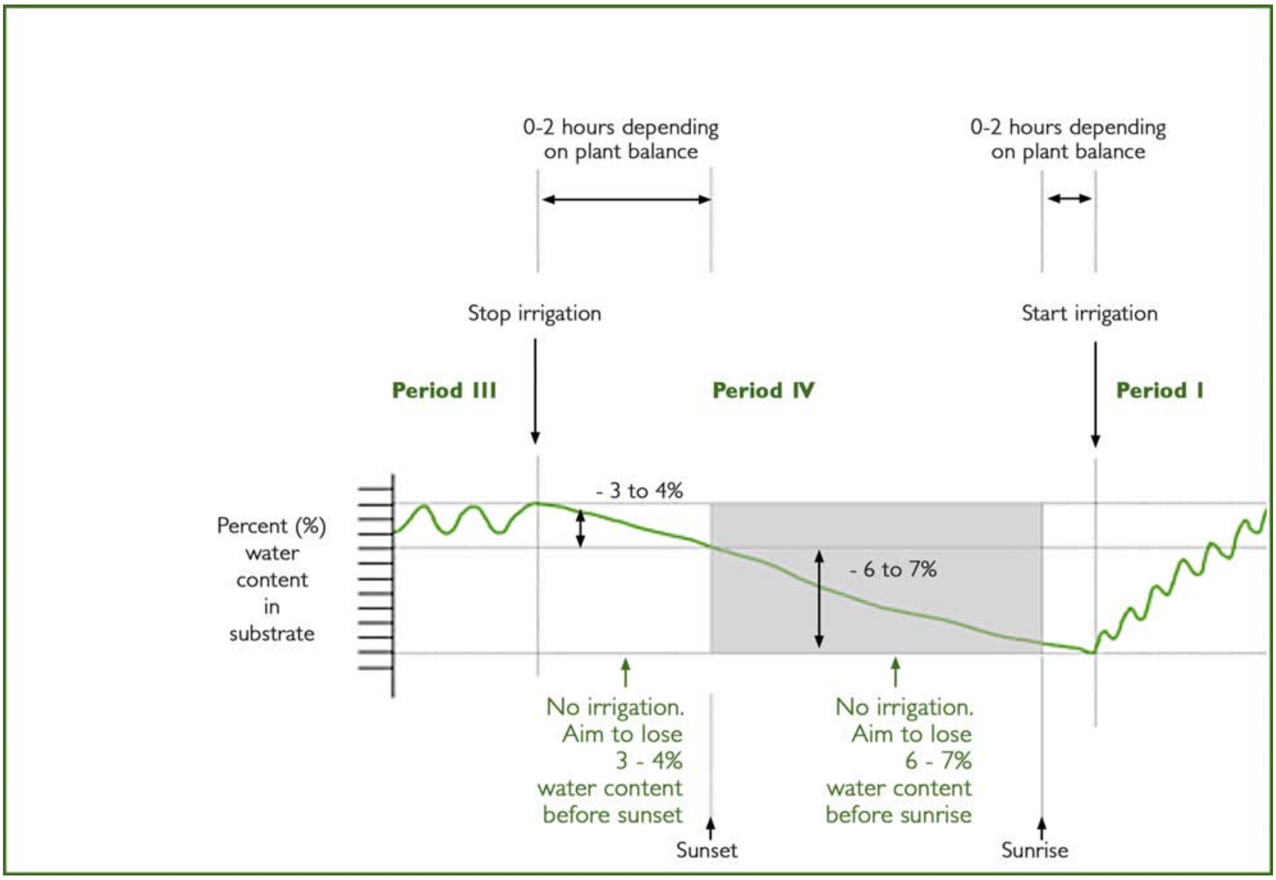
Period 2 (mid-morning) – maintain target run-off EC



Period 3 (afternoon) – maintain target volume



Period 4 (night) – lose 10% water content



11: Recognise and act on crop issues quickly

Principle: Protected cropping is an active management system – with more control, there is more responsibility.

It is important to know how and where problems can occur. Tracking conditions in the greenhouse, the hydroponic system and the crop helps to highlight changing patterns or potential problems. Records also provide a way to backtrack to the cause or start of any issues. This improves management decisions and builds skills and experience. Management targets are a means of setting direction. As a grower's experience increases, targets can be refined to generate higher yields at lower cost.

11.1 GROWING CONDITIONS – CROP NEEDS

Protected cropping is an **active management system**. It enables you to exercise greater control over the growing conditions and the crop itself to get the most from the crop, as efficiently as possible. However, if you do not manage the system, it can become less productive than a cheaper, open-field production system.

Know what conditions the crop needs and what conditions must be avoided.

Common crop targets

Management targets are not fixed objectives. They are reference points. These targets are used to guide management decisions about the greenhouse environment, the hydroponic system and the crop. But, you need to adjust the targets based on how the crop is performing and on the actual growing conditions.

Table E: Common reference points for setting management targets

Feed EC	1.5 – 2.5 mS/cm
Feed pH	5.0 – 6.0
Drain EC	2.5 – 3.5 mS/cm
Drain pH	5.5 – 6.5
Run-off %	15 – 20%
Day temperature	22 – 26°C
Maximum	30°C
Night temperature	16 – 19°C
Minimum	15°C
24hr average	19 – 22°C
Humidity	70 – 80%
Water content (Summer)	75 – 85%
Water content (Winter)	50 – 60%

Feed and Drain EC and pH (Substrate culture)

The feed water (irrigated nutrient solution) may be adjusted in order to achieve the desired drain conditions. As a starting point, a target feed EC might be set in the range 1.5 – 2.5 mS/cm. The target feed pH will normally be in the range 5.0 – 6.0.

The drain (run-off) water is the most important reference for managing a hydroponic crop. The target drain conditions will vary with the type and age of crop being grown, as well as the growing conditions. A target drain EC for a moderate feeding crop (eg cucumber) might be set in the range 2.5 – 3.5 mS/cm and for a heavy feeding crop (eg tomato), the target drain EC might be 3.5 – 4.5 mS/cm. In winter or during low light conditions, the target drain EC might be increased by an extra 1.0 – 1.5 mS/cm. The target drain pH will normally be in the range 5.5 – 6.5.

The target daily run-off percentage[13] (RO%) will vary with the type of substrate and the growing conditions. A target daily run-off might normally be around 15 – 20% but can be set in the range 10 – 40%, with the higher run-off being used in hotter conditions and with freer draining substrates.

The target water content of a substrate also varies with the growing conditions. The target water content in summer will normally be in the range 75 – 85% and in winter the target is in the range 50 – 60% of water holding capacity.

[13] Note, the run-off percentage is used not the run-off volume. The run-off percentage (RO%) is calculated by dividing the volume of run-off by the volume of feed (irrigation) and multiplying the answer by 100 to get a percentage.

- **TIP** Irrigation decisions are based on a combination of both the drain EC and the run-off percentage.

Water culture system
A water culture system that uses a continuous (for example, NFT) or periodic (for example, flood and drain) irrigation schedule requires a different management process. The nutrient solution is monitored and regularly adjusted to the target EC and pH. In these systems, the temperature of the nutrient solution and the flow rate must be suitable to provide enough oxygen to the plant roots.

The greenhouse climate

The target greenhouse temperatures will vary with the crop but for common crops such as cucumber and tomato, the target daytime temperature is in the range 22 – 26°C. The maximum temperature for most crops is 30°C. The night-time temperature is in the range 16 – 19°C. The 24 hour average temperature (24T)[14] is important and the target for this is around 19 – 22°C.

The target relative humidity in a greenhouse is in the range 70 – 80%.

The light transmission in a greenhouse should generally be maximised – but excess heat must be removed. The venting capacity of a greenhouse should be at least 30% of floor area, and more in warm climates.

Plants need carbon dioxide. During the day, always make sure there is some air exchange (open venting) with the outside, even if conditions are cool. This is especially important soon after sunrise if the greenhouse has been closed up overnight.

Setting targets

Management targets are reference points to use in making decisions. You should review and adjust targets throughout a cropping period depending on crop growth, balance[15] and health. You will also need to adjust your targets as you gain experience with (1) the type of crop, (2) how the greenhouse performs, (3) how the hydroponic system performs and (4) the specific environmental conditions on your farm.

Your starting targets can be based on previous experience, or advice from other growers, consultants and resellers. It is important to have a starting point and then refine your targets over time. The values in table E can be used as baseline targets from which to start.

If you have a persistent problem in a crop, always review your settings and your targets.

11.2 CONDUCT REGULAR PEST AND DISEASE CHECKS

Be biosecure in your greenhouse. A key advantage of a greenhouse is the opportunity to minimise the entry of pests and diseases into the crop. Greenhouse and farm hygiene is fundamental but you cannot rely on it alone to protect from pests and diseases. You must monitor regularly.

Figure 11: Downy mildew on cucumber leaf

[14] The 24 hour average temperature (24T) is a way of assessing not just the temperature the crop is exposed to, but how many hours the crop experiences this temperature – both of which will influence how the plant makes and uses sugars.
[15] Plant balance is the relationship between vegetative growth and generative growth. A plant that is in balance is healthier and more productive.

A pest and disease check[16] is one of the simplest ways to monitor for problems. A check should be done in each greenhouse at least two times per week in summer and at least once per week in the cooler periods of the year.

For pests and diseases, you also need to set and frequently review targets. These are called action thresholds. With action thresholds, the aim is to determine the economic threshold for your farm. The economic threshold is the level of a pest or disease that you can tolerate before it causes a loss that is more than the cost of a control.

If the action threshold is too low, you will waste money implementing controls (for example pesticides) that are unnecessary. If the action threshold is too high, the pest or disease might get out of control and cause significant damage or loss to the crop. An inexperienced grower should start with a lower threshold and increase it as experience is gained. You should have at least two levels of action for each pest or disease.

▶ **TIP** It is not possible to arbitrarily set an appropriate action threshold for your farm. You need to choose a starting point and then you must refine your action thresholds over time. Specific greenhouses can sometimes require different action thresholds for certain pests or diseases.

11.3 CHART YOUR DATA – WRITE IT DOWN & RECOGNISE TRENDS

Charts also make the keeping of records fast and simple. You need separate charts for each crop and irrigation zone. For hydroponics, you need to measure EC, pH and the run-off percentage at least every day but monitoring these parameters more often throughout the day will help to make better crop and irrigation management decisions.

In the greenhouse, you should monitor the temperature, relative humidity and the average 24-hour temperature. Pests and diseases should also be monitored and charts can be used to quickly and easily make useful records.

When managing hydroponic irrigation, you need to set EC and run-off targets based on your crop and the growing conditions and use these with your measured values to guide your fertiliser and irrigation decisions.

It is important to make management decisions regarding the nutrient solution based on the trend, not *individual* measurements. Variations in water and nutrient uptake by plants occur throughout the day and are influenced by growing conditions.

Putting your daily measurements into graphs or charts makes it much easier to see the trends and changes.

▶ **TIP** Make yourself familiar with the most common pests and diseases and disorders, including symptoms of nutritional problems so you can recognise them quickly.

[16] More information on greenhouse hygiene and conducting a pest and disease check can be obtained from J Badgery-Parker (2009) Keep it Clean – Reducing the costs and losses in the management of pests and diseases in the greenhouse, NSW Dept. of Primary Industries.

Table F: Example action threshold (management target) plan

Pest	Action threshold (management target)	Action (management strategy)
Greenhouse Whitefly	Level 1: 5 adults per plant in defined area of crop	• Release biological control into greenhouse • Check buffer area and clean zone are free of broadleaf weeds • Conduct an additional pest check (monitoring)
	Level 2: 15 adults per plant in defined area of crop	• Apply spot application of appropriate pesticide to target area • Release biological control into greenhouse • Check buffer area and clean zone are free of broadleaf weeds • Conduct an additional pest check (monitoring)
	Level 3: 10 adults per plant throughout crop	• Apply general application of appropriate pesticide to target area • Release biological control into greenhouse (subject to chemical residues) • Check buffer area and clean zone are free of broadleaf weeds • Conduct an additional pest check (monitoring)

Using charts to record the daily monitoring makes it very quick and simple and easy to see the trends. For example, in figure 12 below the daily drain EC results are drifting above the target from the 10th of the month. This might have been due to a few days of bright hot weather causing the crop to take up more water. As a result the drain EC rises. On a chart, the trend is very easy to see. In this situation, the feed EC was reduced slightly giving the plants more water and less salts. The root zone EC begins to move back towards the target value (shown by the red line). The grower could also have left the feed EC the same and increased the volume of irrigation.

▶ **TIP:** This simple chart record only needs a couple of coloured markers and takes a few seconds to make the record for the day. Make sure the crop and dates are marked on every record sheet and fill in the legend at the bottom with the same coloured markers you will use for the chart.

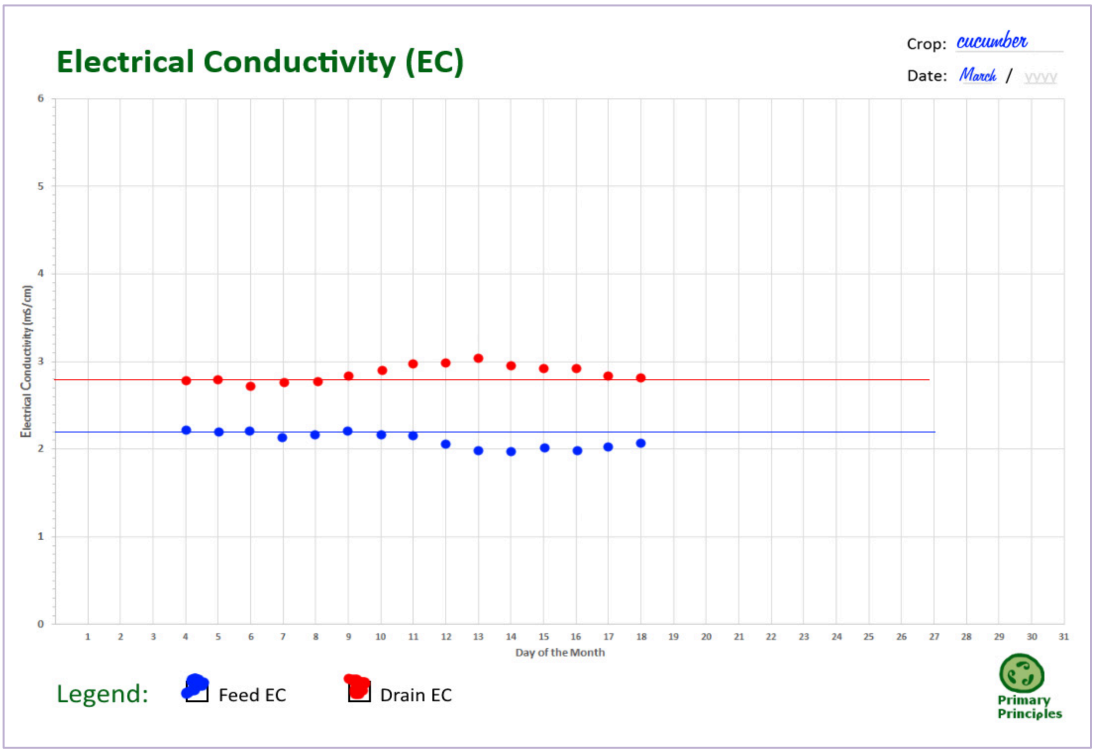


Figure 12: Example EC chart monitoring record showing a drift in drain EC and an adjustment in the feed (drip) EC to correct the drain

12: Plan your farm layout and prepare farm and greenhouse work procedures

Principle: To grow healthy and productive crops, focus on how your farm operates day to day.

Time management

In protected cropping systems, more hands-on management is required than in an equivalent soil production system. This is because the system is designed to drive the crop at its best *all* of the time. This requires active management. Crops will grow faster so you need to manage labour – your time – well. If you get behind or miss critical activities, crop losses and reduced yields will result.

Every day

- Monitor and record the drain EC, pH and run-off percentage.
- Review run-off records – look for trends and deviance from targets.
- Assess plant balance.
- Adjust irrigation volume and frequency (and/or feed EC) to deliver target drain, if required.
- Consider adjusting volume and frequency of irrigation to match crop growth and growing conditions.
- Summer: check for blocked drippers – clean drippers and filters if required.
- Monitor and record the temperature and humidity in each greenhouse. Calculate 24-hour average temperature and record.
- Adjust venting and/or heating, if required. Always open a vent in the morning to refresh carbon dioxide levels and remove humidity.

Every week

- Check that irrigation settings (volume and frequency) are delivering target drain EC and runoff percentages.
- Check and clean filters.
- Conduct at least one pest and disease check (twice per week in summer) in each greenhouse crop.
- Maintain buffer area – keep free of all plants, substrate, equipment and waste materials.
- Maintain grassed areas in clean zone – keep mown and free of broadleaf weeds.
- Check and maintain water disinfection system.
- Winter: check for blocked drippers – clean drippers and filters if required.
- Check that greenhouse settings (venting and/or heating) are delivering target conditions to match crop growth and growing conditions.

Before every crop

- Clean up and disinfect greenhouse.
- Clean and disinfect hydroponic system.
- Set up greenhouse and hydroponic system for new crop.
- Check the distribution uniformity of irrigation in each irrigation zone.
- Calibrate all EC and pH meters.
- Set up run-off monitoring station within each irrigation zone.
- Check water supply, storage and review with expected peak demand

After every crop

- Clean out greenhouse.
- Remove (clean or discard) all equipment and materials in the greenhouse.
- Review farm activities and farm layout. What worked well and what could you improve?

13: Contain and manage wastes

Principle: Nutrients and water are two of the most valuable resources and inputs in your protected cropping system. You need to ensure that waterways are not polluted and that you make the most efficient use of inputs and available resources. Poor management of wastes in and around the greenhouse increases potential problems with weeds, crop diseases and some pests.

The high input, high output protected cropping system will generate a moderately high level of 'wastes', per unit of production. These systems are much more efficient than open field horticulture. In hydroponic systems, because the crop residues are not incorporated back into the ground, they must be removed from the greenhouse. Plastics (such as bags and twine) need to be separated from the biodegradable materials. For short term crops, biodegradable twine made from sisal can be used which can simply be shredded and composted with the crop residues.

13.1 NUTRIENT SOLUTION RUN-OFF (DRAIN WATER)

A simple hydroponic nutrient solution can be worth (in water and fertilisers) as much as $6 per kilolitre. This is equivalent to $10,000 – $20,000 per hectare per year in run-off. Nutrient loaded waste water must be prevented from discharging into water courses.

A. The most cost effective and productive means of managing nutrient loaded waste water is to disinfect[17] and reuse the nutrient run-off in the hydroponic system. This option is the cheapest to implement, requires the least area of land and makes the most efficient use of expensive fertilisers. It also ensures excess nutrients are not discharged into the environment. This is a *closed* hydroponic system (see page 13).
B. An effective, though increasingly costly option (as it wastes expensive fertilisers) is to contain and treat nutrient loaded waste water in a constructed wetland or reed bed to remove the nutrients prior to releasing the cleaned water into the environment. At a minimum, this type of waste water treatment system needs to be able to retain the nutrient loaded water for at least 7 days. This requires a wetland capacity of around 140,000 litres per hectare of production.
C. The least suitable option is to contain nutrient loaded waste water and use it to irrigate soil grown crops and gardens. The high nutrient load of this waste water and the general mismatch with crop and soil requirements means that regular soil tests need to be conducted if this waste management strategy is used. Sufficient storage of the nutrient solution is also required for periods of rain when soil-based crops are not irrigated. This could require a storage capacity of more than 200,000 litres per hectare of production.

13.2 WASH-DOWN WATER AND NUTRIENT SOLUTION DISCARD

When a greenhouse and hydroponic system is cleaned and disinfected, wash down water must be contained and prevented from entering the environment. A retention tank or small dam can be used to manage this waste water. The waste water needs to be exposed to sunlight and aerated.

If a batch of nutrient solution is made up incorrectly and cannot be remedied, it may have to be discarded. This nutrient loaded waste water is not suitable for reuse. It can be contained in the wash-down retention pond. After a period of detention, this water can be filtered and disinfected and used again.

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[17] More information on disinfection options and closed system hydroponics can be found online at https://sites.google.com/site/sustainablehydroponics/

13.3 RAIN / STORMWATER

Stormwater needs to be managed. At a minimum, surface run-off must be prevented from entering the greenhouse. Good drainage is essential. Surface run-off should be slowed to minimise erosion and diverted through a sediment trap before leaving your property. However, stormwater should be considered a low cost and high value source of water on your farm. Where permissible, this water should be collected, cleaned and disinfected and used as irrigation and wash-down water.

13.4 PLANT RESIDUES AND SUBSTRATES

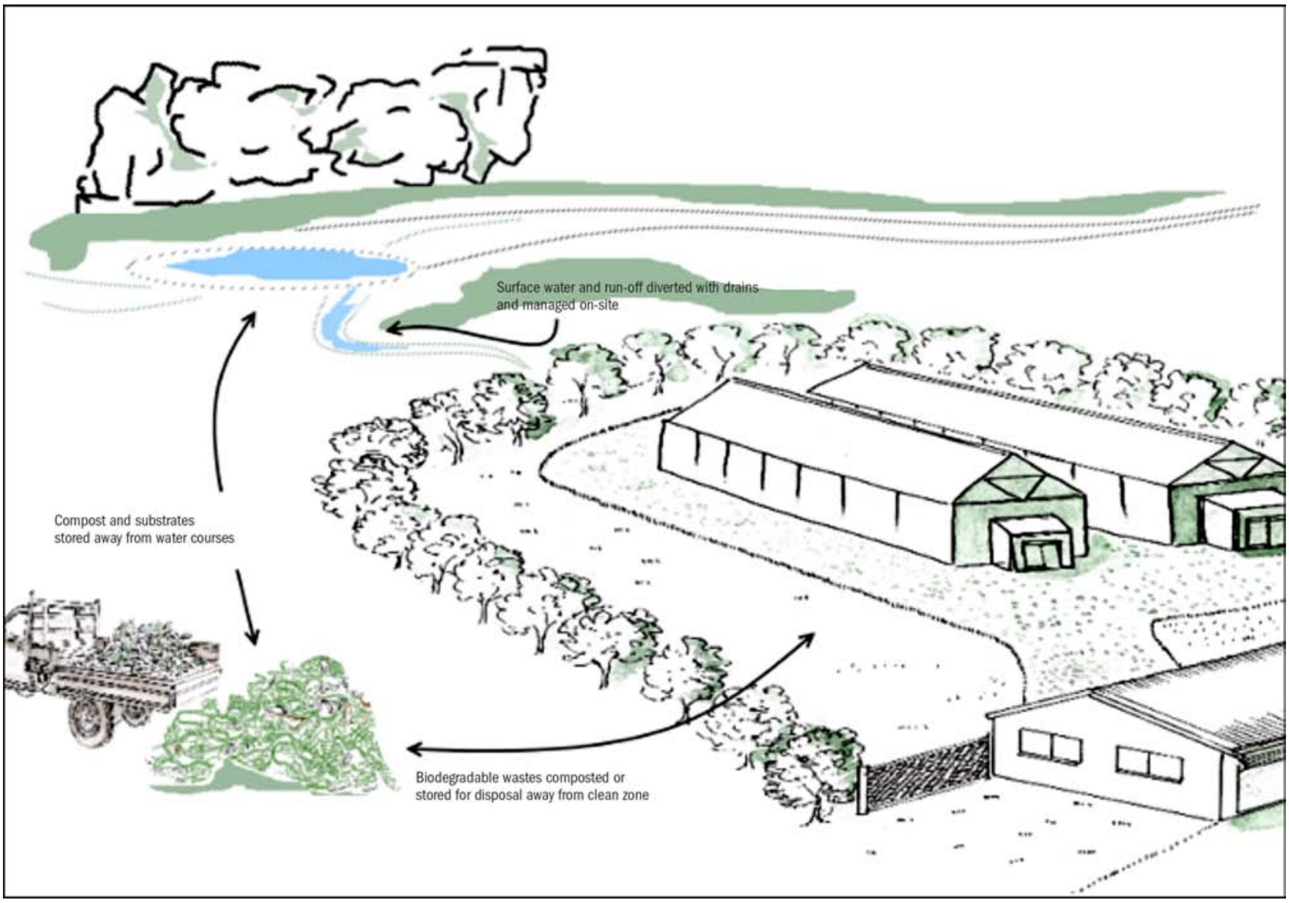
Plant residues and many substrates can be shredded and composted. Most substrates will be replaced with every new crop. Organic materials such as sawdust and cocopeat can be readily incorporated with plant residues for disposal. Some inorganic substrates that are derived from mineral sources such as rockwool, sand and perlite can also be managed with crop residues. On-farm composting is relatively simple and the end product can be used elsewhere on the property (in soil cropping or landscaping) or could be used to generate another income stream.

Key management tasks:

1. Plant residues and used substrates need to be stored (and composted) away from the production area and outside of the clean zone of the farm.
2. If composting materials on-site, plant residues need to be free from plastics (bags, clips and twine) and shredded to speed up decomposition.
3. The composting area needs to away from water courses and be bunded to prevent stormwater run-on and to contain run-off water as this will contain high levels of nutrients.
4. If materials are being stored temporarily prior to periodic collection and removal for off-site disposal, they need to be kept well away from the production area and outside of the clean zone and away from water courses. These materials should be stockpiled downwind from the cropping areas and covered.

Crop & substrate waste poorly managed

Crop waste contained for removal



13.5 PLASTICS AND GENERAL RUBBISH

Plastics and redundant equipment or machinery need to be stored securely and disposed of regularly. These materials can harbour pests and diseases and make weed management difficult. They need to be stored away from the cropping area and outside of the clean zone until they can be collected for off-site disposal. Check for recycling options. Plastic waste generated on the farm will likely include old plastic covering materials, used bags and containers, fertiliser and chemical bags and containers and occasionally polypipe and irrigation fittings that have been replaced.

Cardboard boxes and paper waste can be shredded and incorporated with the crop residues for composting.

▶ **TIP** The simplest way to contain and manage the risks from waste is to just focus on maintaining a tidy farm. By doing this, you will naturally achieve effective waste management.

Glossary

Air Filled Porosity (AFP) is the proportion of space filled with air in a substrate after it has been saturated and allowed to drain. A hydroponic substrate should have an AFP of at least 10%, and up to 30% of total volume.

Bunding or a 'bund wall' is a constructed containment system such as a low wall, which is designed to prevent spills of chemicals or fuel getting into the environment.

Closed hydroponic system reuses the nutrient solution several times. The excess nutrient solution (containing fertilisers and water) that drains from the crop is collected, disinfected and reused.

Disease is any condition in a plant that interferes with its normal function. Sometimes for simplification, the word 'disease' is used to refer to both the pathogen and the disease it causes.

Distribution Uniformity (DU%) is a measure of how evenly the irrigation system is working.

Drain solution (also called 'run-off') is the excess nutrient solution that drains away from the roots of the crop.

Drip (also called 'feed') is the nutrient solution that is irrigated to the crop.

Electrical Conductivity (EC) is a measure of the strength of a nutrient solution. It should be measured in mS/cm.

Feed solution (sometimes called 'drip') is the nutrient solution that is irrigated to the crop.

Flow-through hydroponic system is a closed system in which excess nutrient solution is collected and used later as a water source in the hydroponic system.

Open hydroponic system only uses the nutrient solution once. The excess nutrient solution (containing fertilisers and water) that drains from the crop is discarded.

Pathogen is an organism that causes a disease. Fungi, bacteria and virus are three different groups of pathogens and often require different management strategies so they need to be identified properly.

Pest is an organism that causes damage or loss, or poses a risk to your crop.

Photosynthetically Active Radiation (PAR) refers to the proportion of light that is used for plant growth. PAR is measured in $\mu mol.m^{-2}.s^{-1}$ and is approximately 50% of the global radiation levels. Under high temperatures, many crops perform better with higher light conditions.

Plant balance is the relationship between vegetative growth (leaves and roots) and generative growth (flowers and fruit).

Recirculated hydroponic system is a closed system in which excess nutrient solution is returned straight back to the supply tank from which the crop is irrigated.

Relative humidity (RH%) is the proportion of moisture (water vapour) in the air at a given temperature compared with the maximum amount of moisture that the air could hold at that temperature. For most crops, the optimum relative humidity is around 70 – 80%.

Temperature is the main influence on plant growth and development. **Air temperature** will affect relative humidity. **Leaf temperature** will affect vapour pressure deficit. In direct sunlight, the leaf temperature can be as much as 10°C warmer than the air. The **average 24hr temperature (24T)** affects the rate at which the plants make (photosynthesis) and use (respiration) sugars and how they are distributed in the plant. For common greenhouse crops, air temperatures within the range of 16 – 28°C are suitable. Optimum temperatures vary between crops and developmental stages. Suitable average 24hr temperatures within the range of 19 – 22°C are typical. Under high light conditions, many crops perform better under higher temperatures.

To calculate the 24-hour average temperature, multiply the number of hours at each temperature by the temperature to get "hour degrees" (eg 10 hours at 20°C = 200 hour degrees). Add up all the hour degrees for a whole day (24 hours) and divide this by 24 to get the 24T. (eg 10 hours at 20°C and 14 hours at 25°C = 550 hour degrees. Divided by 24, equals 22.9°C so 24T = 22.9°C)

Vapour Pressure Deficit (VPD) is a measure of how much water is lost from the plant. The optimum vapour pressure deficit is around 3 – 7 grams/m^3.

Water Holding Capacity (WHC) is the proportion of space filled with water in a substrate after it has been saturated and allowed to drain. A hydroponic substrate should have a WHC of around 30 – 60% of total volume.

Weeds are unwanted plants which can harbour pests and diseases or compete with your crop.

Useful references

The NSW DPI website has much information for greenhouse horticulture. As well as fact sheets and manuals, the charts attached to this manual can be downloaded electronically for printing.

www.dpi.nsw.gov.au/agriculture/horticulture/greenhouse – Publications and factsheets on structures, irrigation, management of waste water, pest and disease.

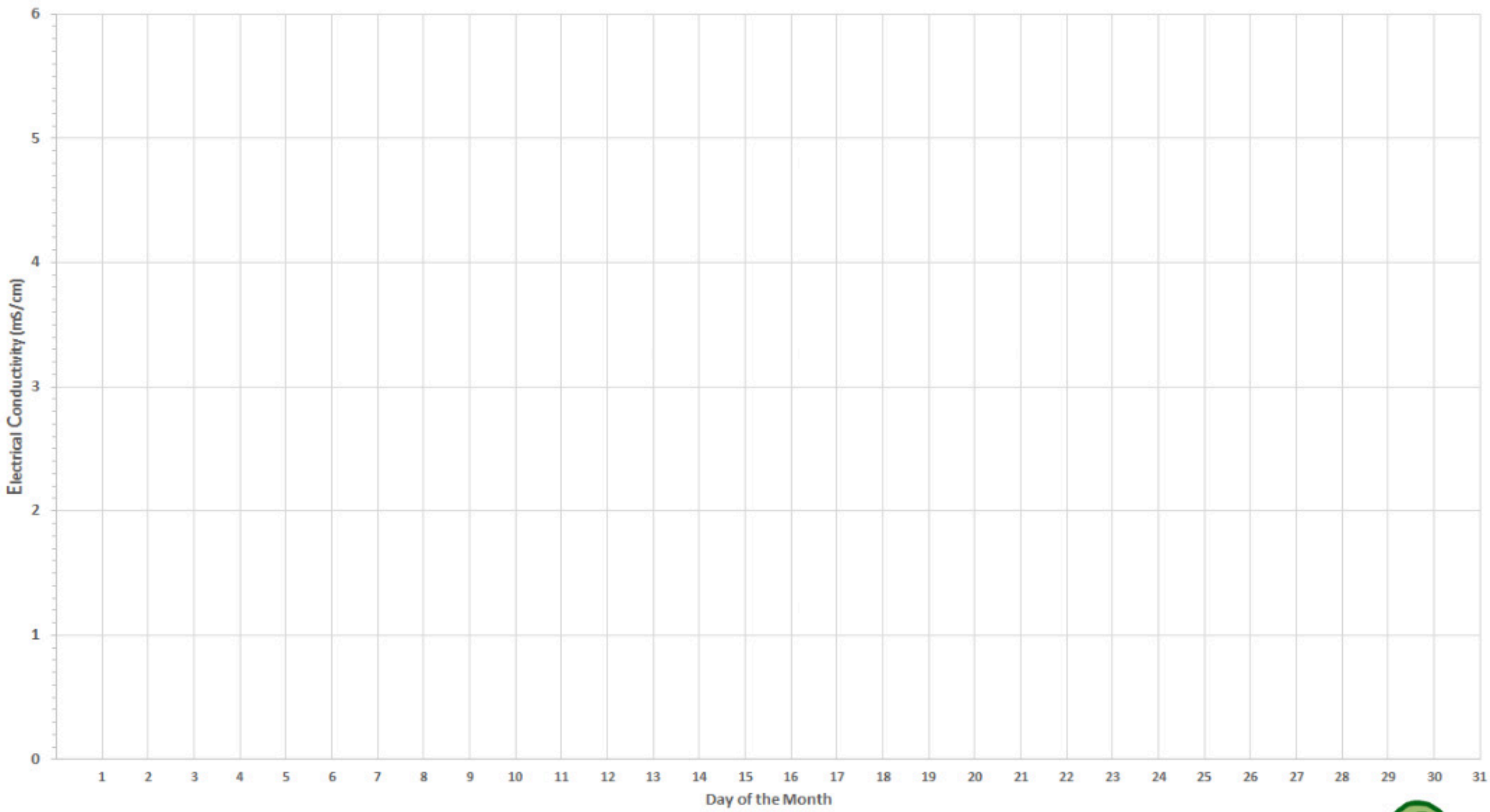
The 'Keep it Clean' booklet by Jeremy Badgery Parker referred to in this publication can be downloaded in total.

www.dpi.nsw.gov.au/primefacts – Primefact 1005: On-farm hygiene and sanitation for greenhouse horticulture, NSW Industry & Investment, 2010

Electrical Conductivity (EC)

Crop: ____________

Date: mm / yyyy



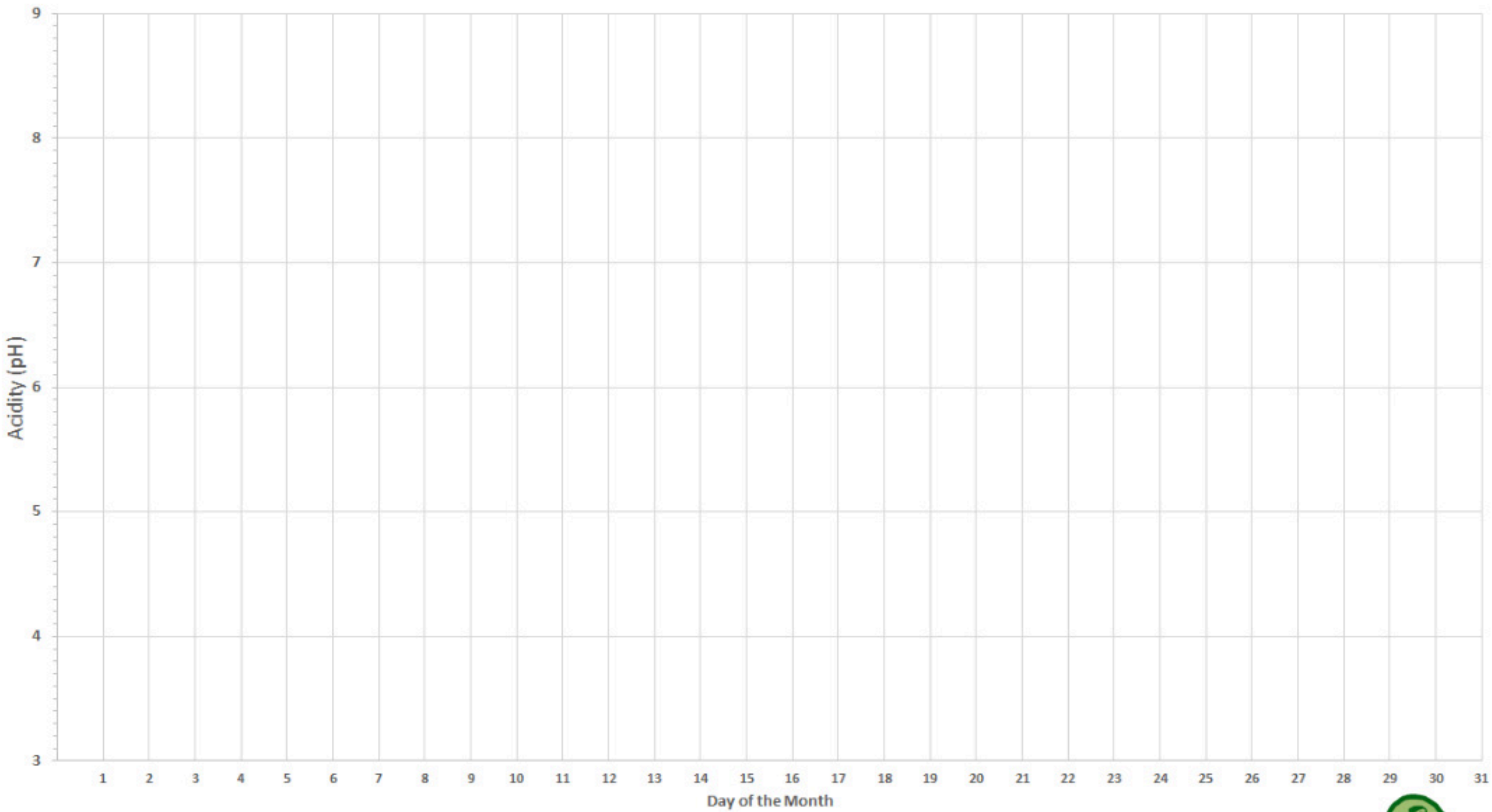
Legend: ☐ Feed EC ☐ Drain EC

Primary Principles

Acidity, Alkalinity (pH)

Crop: ____________

Date: mm / yyyy



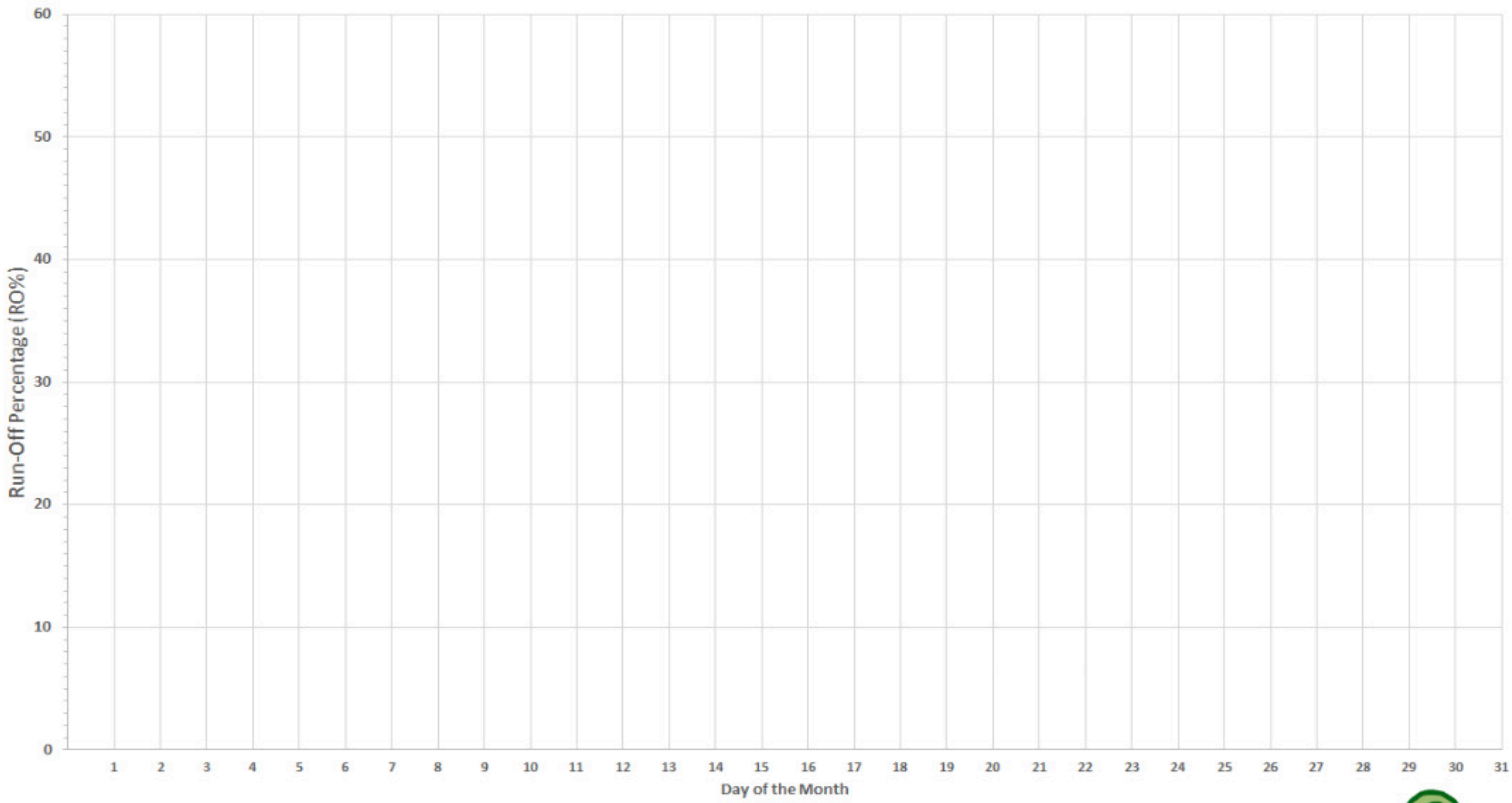
Legend: ☐ Feed pH ☐ Drain pH

Primary Principles

Run-Off percentage (RO%)

Crop: ______

Date: mm / yyyy



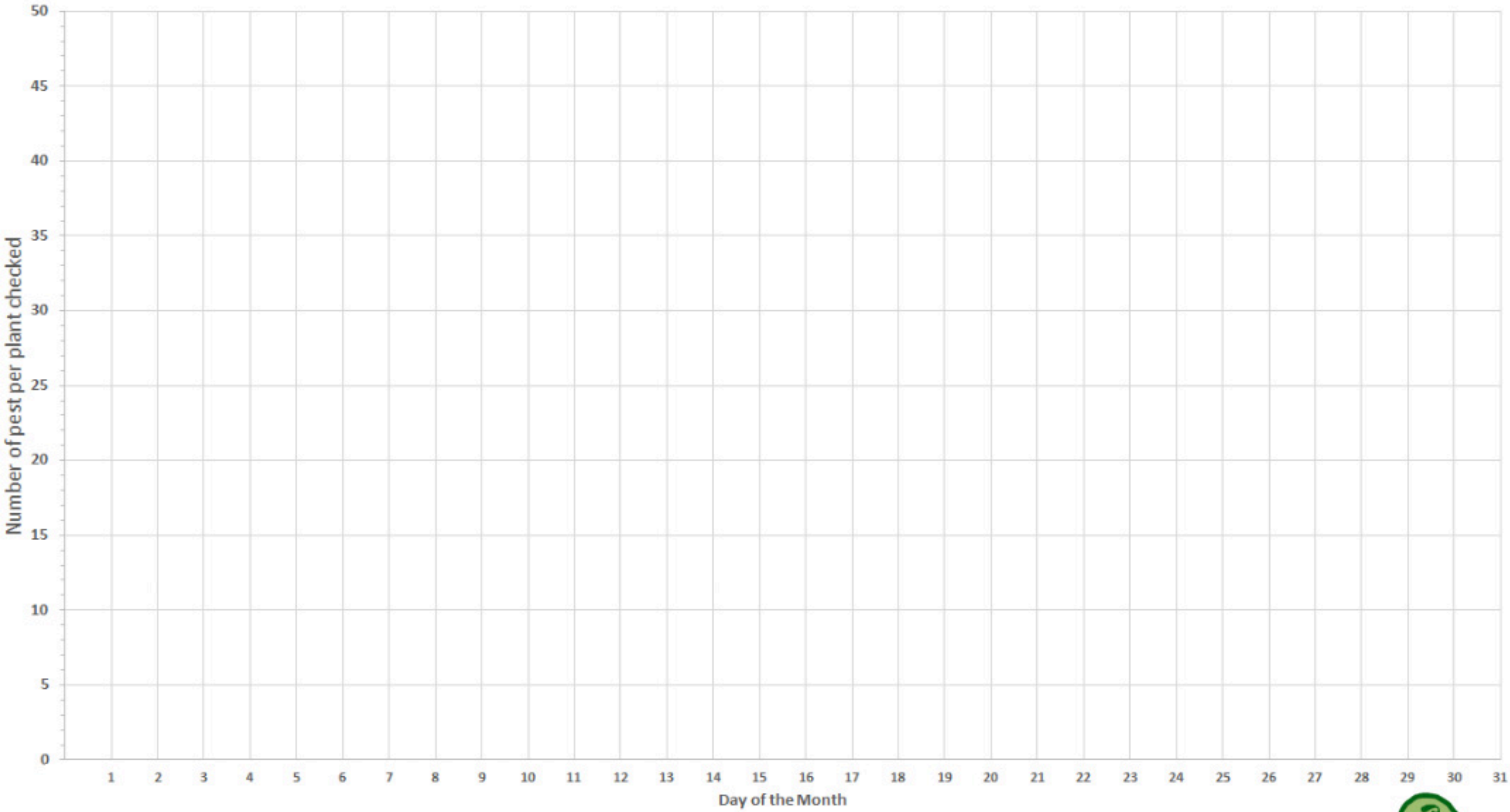
Legend: ☐ Daily RO% ☐ Period 1 RO% ☐ Period 2 RO% ☐ Period 3 RO%

Primary Principles

Pest check

Crop: ____________

Date: mm / yyyy



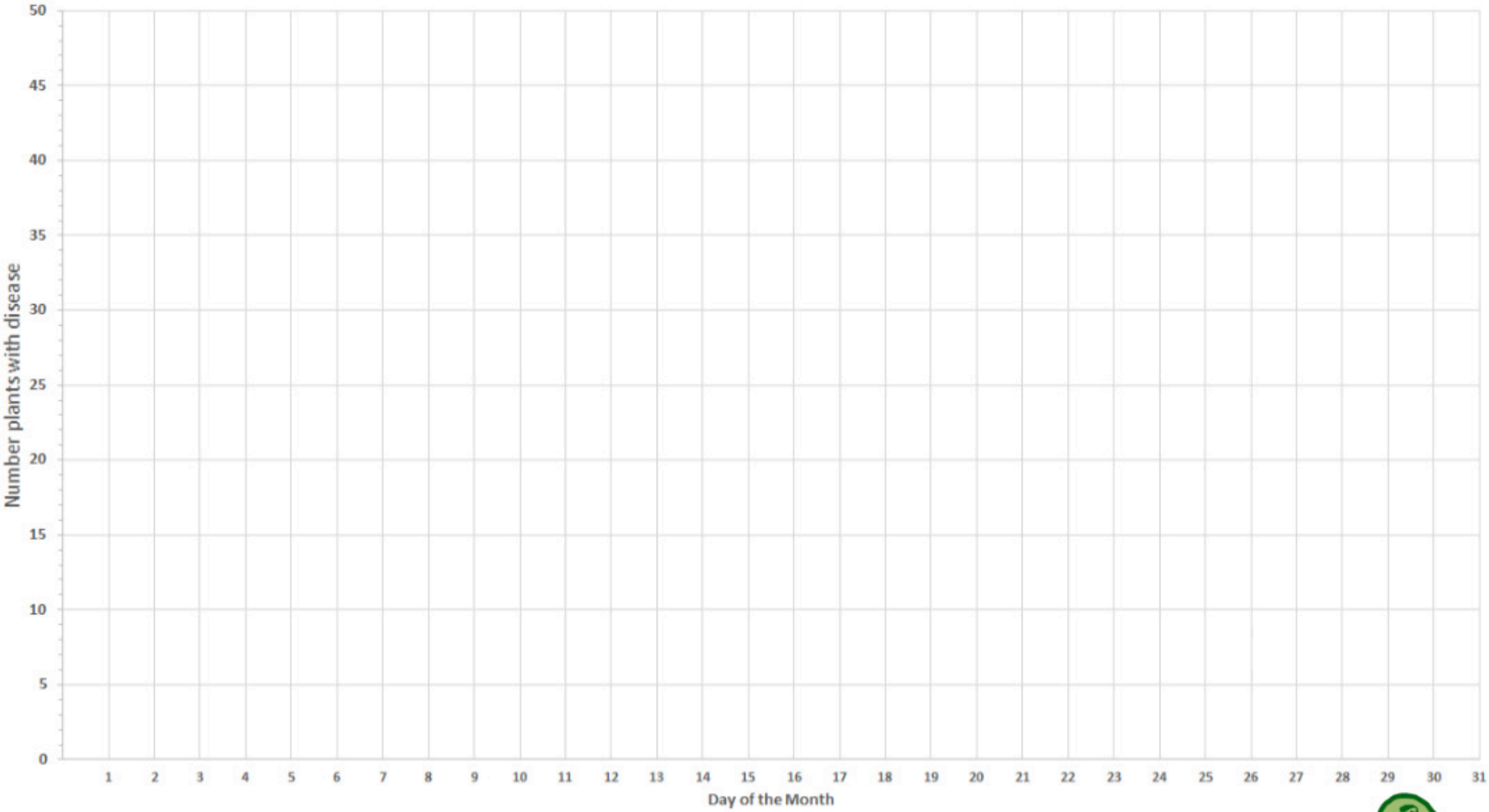
Legend: ☐ Pest 1 ☐ Pest 2 ☐ Pest 3 ☐ Pest 4

Primary Principles

Disease check

Crop: ______

Date: mm / yyyy



Legend: ☐ Disease 1 ☐ Disease 2 ☐ Disease 3 ☐ Disease 4

Primary Principles

Irrigation Distribution Uniformity (DU%)

Primary Principles

Irrigation zone: ____________

Date: mm / yyyy

Emitter number	Water collected (ml in 1 minute)	Application rate (L / hr)	Lowest 25%
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			

All emitters	Total :		
	Average :		
Lowest 25% of emitters	Total :		
	Average :		

13 Basic Principles for Greenhouse Management

NSW GOVERNMENT

Local Land Services
North Coast

Coffs Harbour
Regional
Landcare