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Sustainability of sprinkler- irrigated horticulture on sandy soils at Binningup - Swan Coastal Plain, W.A.

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CHAPTER 4. METHODS AND MATERIALS

The investigation site at Binningup was chosen because of the nearby automatic, online weather station at Myalup maintained by the Department of Agriculture and Food, Western Australia (DAFWA), together with having a substantial history of groundwater measurements on and adjacent to the site.

4.1 Myalup weather station

This agricultural facility is situated 6.5 km north of the horticultural property under investigation at Myalup (33°5.695S, 115°43.136E) at an altitude 10 m and at the same distance from the coast. Operated by DAFWA, it provides real time and historical weather data for the immediate area including:

- air temperature
- relative humidity
- rainfall
- pan evaporation
- wind speed and direction
- soil temperature
- solar radiation (W/m^2).

Reference evapotranspiration is also available through the automatic weather station.

The tipping bucket rain gauges employed in this research did not distinguish between sprinkler water and rainfall so subtraction of Myalup rainfall data from the tipping gauge was used to calculate sprinkler delivery rates. The weather station was also used to identify rainfall events at the study site and provided local data for pan evaporation, temperature and relative humidity. An example of a live weather output provided by the weather station is given in Figure 4-1.

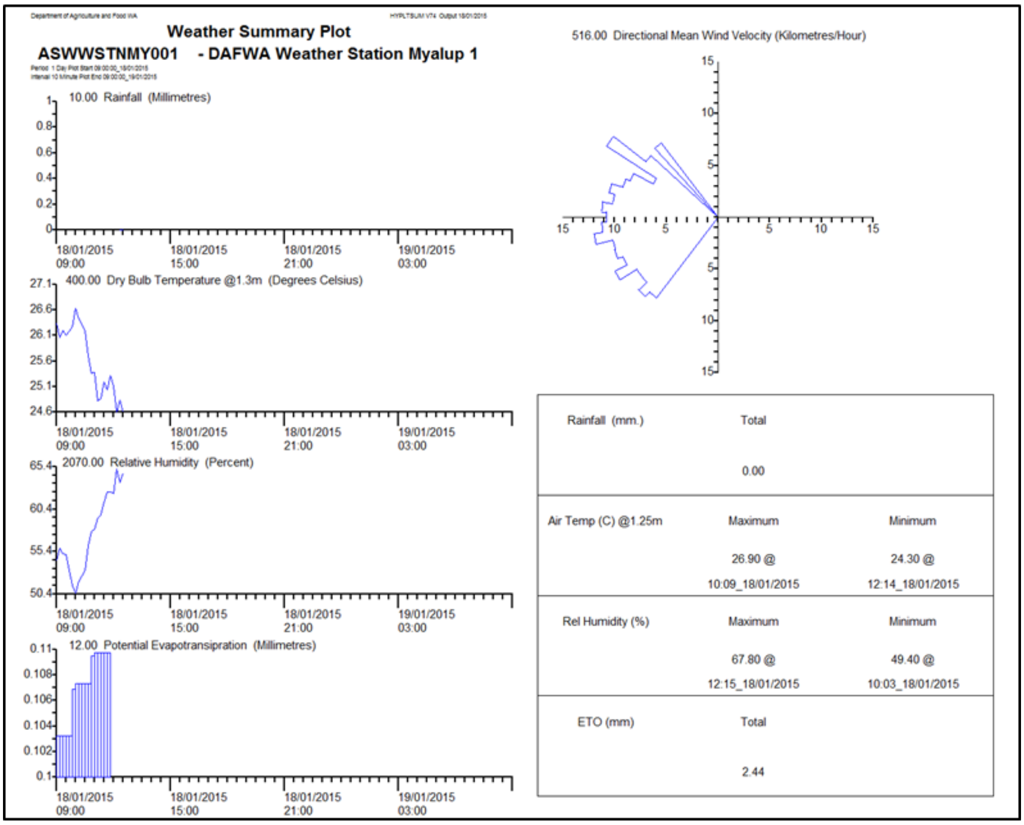

Figure 4-1: An example of the output provided by the Myalup automatic weather station (DAFWA 2015c).

4.2 Fieldwork observations

Three sets of data were examined for this investigation:

- Soil moisture (soil water content)
- Soil water salinity (electrical conductivity (EC) and total dissolved solids (TDS))
- The combined volume of sprinkler irrigation and rainwater application.

These were then considered in relation to parameters such as evaporation, temperature, humidity and rainfall provided by the weather station. Recording equipment was installed in vegetable crops over both the winter and summer growing seasons as outlined in Chapter 3.

Samples of soil were collected down the profile at representative intervals to ground truth the soil moisture recording equipment and determine the TDS in the free water available to the crop. The field visit schedule is given in Table 4-1.

Table 4-1: Field visit schedule for the duration of the research.

Date	Investigation	Activity
02/04/2011	P001	Site reconnaissance Collect soil samples Test W1,W2 and W3 water quality
09/04/2011	P001 P002 C001	Install monitoring equipment Soil sample collection Data retrieval Test W1,W2 and W3 water quality
15/04/2011	P001 P002 C001	Soil sample collection Data retrieval Test W1,W2 and W3 water quality
06/05/2011	P001 P002 C001	Retrieve equipment from P002 and C001 for maintenance Soil sample collection Data retrieval
28/05/2011	P001 P003 P004	Retrieve equipment from P001 Deploy crop and control equipment in P003 and P004 Soil sample collection
01/07/2011	P003 P004	Soil sample collection Data retrieval
20/08/2011	P003 P004	Retrieve monitoring equipment for maintenance Soil sample collection Test W1,W2 and W3 water quality
08/10/2011	P005 C002	Deploy equipment in P005 and C002 Soil sample collection
10/10/2011	P005 C002	Soil sample collection
05/11/2011	P005 C002	Soil sample collection Data retrieval Equipment maintenance Test W1,W2 and W3 water quality
04/12/2011	P005 C002	Retrieve monitoring equipment from P005 and C002 Retrieve data

	C003 O001	Collect soil samples Redeploy monitoring equipment in O001 and C003 Collect soil samples Test W1,W2 and W3 water quality
11/12/2011	C003 O001	Retrieve data Collect soil samples Collect laboratory water samples
20/12/2011	C003 O001	Retrieve data Collect soil samples
27/01/2011	C003 O001	Retrieve monitoring equipment from P005 and C002 Retrieve data Collect soil samples

The location of each investigation, as well as vegetable type and date are given in Figure 4-2 and detailed in Table 4-2.

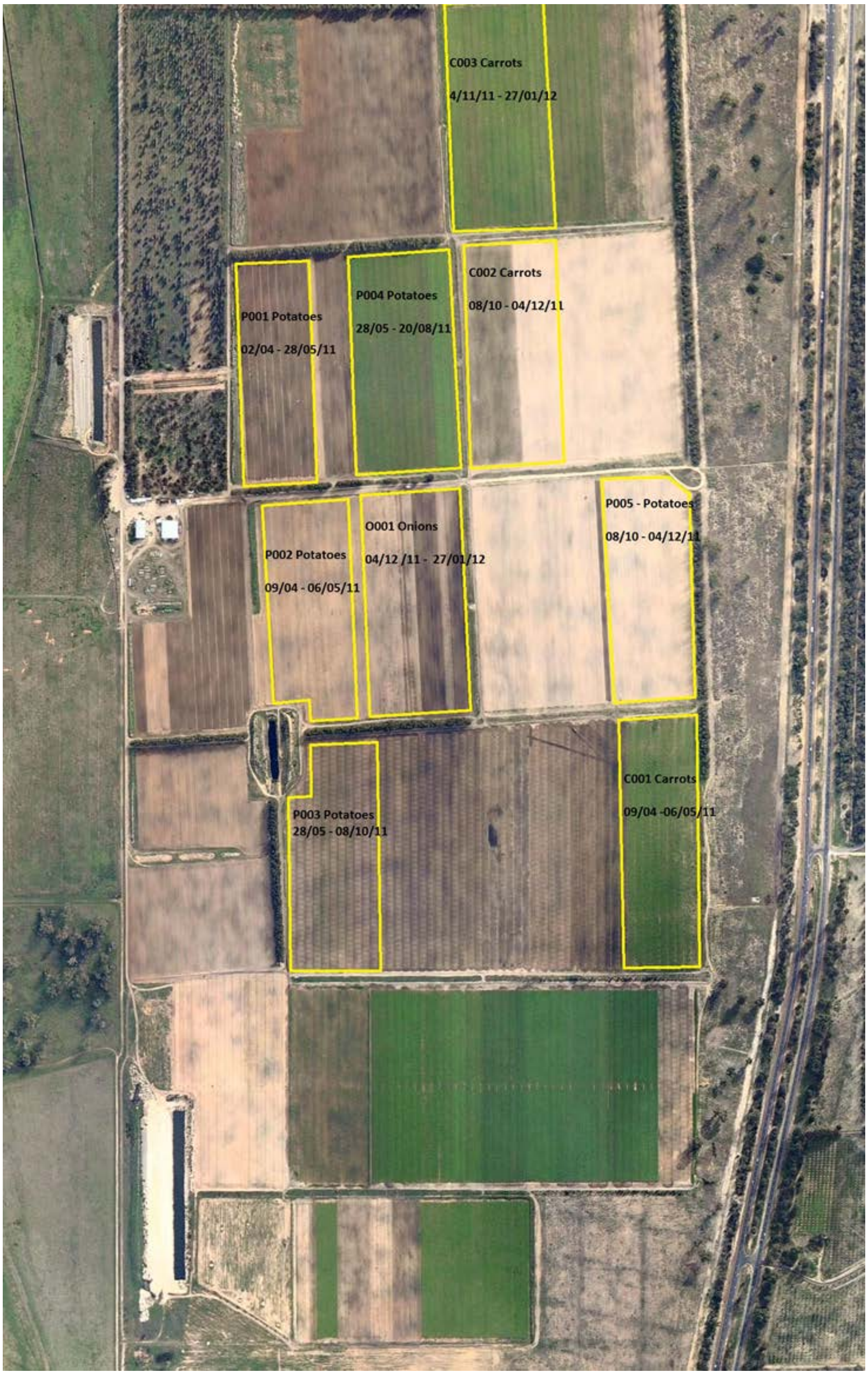

Figure 4-2: Location of investigations during the research period.

Table 4-2: Summary of investigations during the research period.

Investigation	Date		Crop type	GPS	
	Start	End		South	East
P001	02/04	28/05	Ruby Lou potato	33° 09′ 21.6″	115° 42′ 37.4″
P002	09/04	06/05	Potato	33° 09′ 34″	115° 42′ 36.2″
P003	28/05	08/10	Ruby Lou potato	33° 09′ 38.4″	115° 42′ 38.7″
P004	28/05	20/08	Potato	33° 09′ 11.2″	115° 42′ 44.2″
P005	08/10	04/12	Carisma™ potato	33° 09′ 22.2″	115° 43′ 01″
C001	09/04	06/05	Carrot	33° 09′ 37.5″	115° 42′ 55.2″
C002	08/10	04/12	Carrot	33° 09′ 21.6″	115° 42′56.9″
C003	04/12	27/01/2012	Carrot	33° 09′ 08″	115° 42′ 56″
O001	04/12	27/01/2012	Onion	33° 09′ 23.5″	115° 42′ 43″

As noted in Table 4-2, the data from two investigations were used for this research: P003, a winter potato crop and C003, a summer carrot crop.

4.3 Soil water content measurement

Three methods were used to measure soil water content: the thermogravimetric method, to obtain definitive results at a known time; measurements of soil water suspensions using electrical conductivity; and the dielectric method, to obtain a continuous indication in relation to irrigation, rainfall weather conditions and crop maturation. These are briefly outlined below.

4.3.1 Thermogravimetric method

Soil sample collection and analysis

Soil sample cores were collected down the soil profile within rows adjacent to the vegetables using a 120 cm long, 10 cm diameter polyvinyl chloride (PVC) tube with a serrated edge at intervals of (cm) 0–10, 10–20, 20–30, 30–40 and 40–50 - chosen to correspond with 80% of the depths recorded by the capacitance probes. Soil intervals are hereafter referred to as 10–¬, 20–, 30– and 50 cm and there is an offset in the measurements because the capacitance sensor effectively recorded at the base of each interval. While the sensor only measured the four intervals, the 30–40 cm interval was retained and analysed.

The coring tube easily penetrated the soil profile in the first three intervals to approximately 30 cm, thereafter clockwise rotation was applied using a 2 cm diameter steel tube, inserted through two 2.5 cm predrilled holes at the upper end of the tool in the same manner as that of a manual auger tool (Figure 4-3).

Upon extraction, soil samples within the core were removed at each 10 cm interval, split into halves and placed into sealed and labelled polythene bags. Samples were weighed on site and placed in a sealed plastic bucket for transport to Perth for soil moisture and salinity determination.

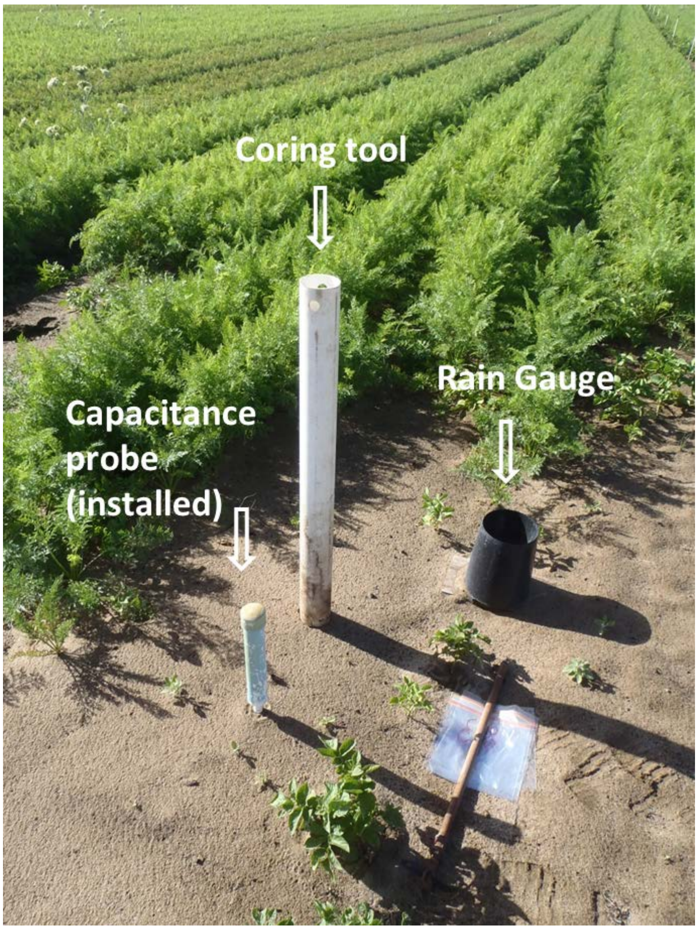

Figure 4-3: Coring tool shown *in situ* with the Odyssey capacitance probe and Odyssey tipping bucket rain gauge, sample bags and coring tube handle.

Gravimetric water content (θ_g) is the mass of water per mass of dry soil. It is measured by weighing the soil sample (m_{wet}), drying it to remove the water and reweighing the dry soil (m_{dry}) (Black 1965; Bilskie 2001). The following procedure described in Black (1965) and Smith and Mullins (2000) was followed:

- Weigh aluminium tin, and record its weight (tare).
- Place a soil sample in the tin and record the weight (wet soil + tare).
- Place the sample and tin in an oven at 105°C overnight to dry.
- Weigh the sample and record this weight as weight of (dry soil + tare).

The advantages of this method are that it ensures accurate measurement and is not dependent on salinity and soil types (Zazueta and Xin 1994). The following equation was then used to determine the soil water content:

$$\theta_g = \frac{m_{water}}{m_{soil}} = \frac{m_{wet} - m_{dry}}{m_{dry}}$$

The gravimetric water content (θg) was also used to calibrate values recorded by the Odyssey capacitance probes.

4.3.2 Soil water salinity

Soil water salinity was measured on duplicate samples via the electrical conductivity (EC) of a suspended soil solution. The sample was placed into a container and rinsed with a measured volume of distilled water at an approximate ratio of 1:5, taking into consideration soil water content and thoroughly mixed. The EC was then measured using a calibrated handheld meter (YSI EcoSense EC300) and converted to TDS.

Standardising soil salinity

The times at which the collection of soil samples took place during field visits varied throughout the day and in relation to irrigation and precipitation. Assuming salinity of soil moisture varies substantially in response to daily irrigation and precipitation, and evapotranspiration, it is necessary to transform recorded moisture values to a common water content to calculate salt accumulation to gain relative values and provide a comparison across each sample.

A standard value was calculated for recorded values at three moisture percentages realistically representing the observed range of soil moisture content. These were 4, 6 and 8%, The calculation required for this was to divide the recorded soil water percentage by the required standardised percentage (i.e. 4, 6 or 8) then multiply by the recorded or actual TDS value.

4.3.3 Dielectric method (multisensor capacitance probe)

The Odyssey Soil Moisture Recording System (Odyssey 2014) was used to continuously monitor *in situ* soil water content at 15-minute intervals. It comprised a multisensor capacitance probe connected to a battery-powered data logger. A PVC access tube housed the sensor rod which enabled the assembly to be removed for maintenance and data to be downloaded without disturbing the soil profile.

Equipment installation

A central position within the crop row (Figure 4-6) was chosen for the probe installation using the following procedure. A hollow steel tube of slightly smaller outside diameter to the sensor was rotated and driven vertically through the soil profile to approximately 50 cm at the location within the crop chosen for the sensor. The soil being captured as the steel tube passed through the profile.

The steel tube, along with the captured soil core, was then removed leaving a hole in which to install the sensor assembly ensuring minimal compaction of the soil surrounding the sensor which would otherwise result in distorted measurements. A PVC access tube was then pushed into the hole and tapped firmly into position. After activation of the data logger, the sensor assembly was then inserted into the PVC access tube and proceeded to record (Figure 4-4).

Communication was continuously maintained with the horticultural property manager, who provided notification of when removal of the monitoring equipment was required due to harvesting or in the event of a crop failure.

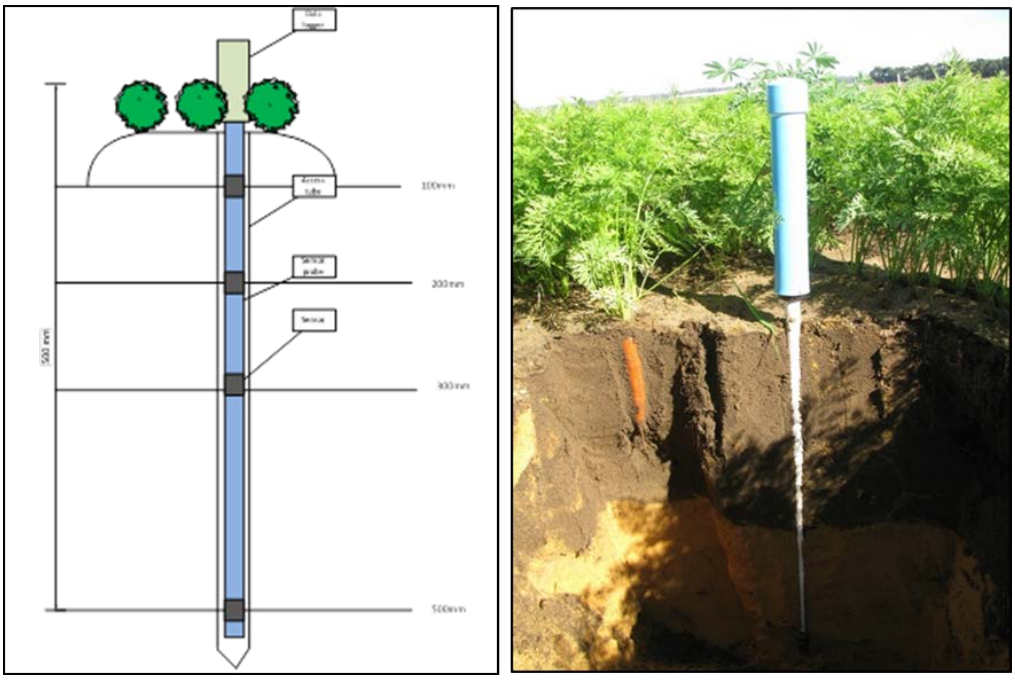

Figure 4-4: (Left) Cross-section of Odyssey capacitance probe illustrating components and (Right) its installation in a carrot crop demonstrating its relation to soil types and crop depth.

The capacitance technique measures the apparent dielectric constant of the soil surrounding the sensor, which reflects the water content of the soil-water-air mixture, to determine soil water content (Fares and Alva 2000). Sensor points along the probe measured soil water content every 15 minutes at four depths 10-, 20-, 30- and 50 cm and, for the purposes of the research described here, these sensor depths are reflective of the following soil intervals (cm): 0–10, 10–20, 20–30 and 40–50. The 10-, 20- and 30 cm intervals were representative of the root depth and the 50 cm interval represents the depth at which the soil water content (within undisturbed Cottesloe sand) indicates effective leaching past the root zone.

Soil moisture at each interval was time stamped and stored for subsequent download using the Odyssey software and exported to either Microsoft Excel™ or Stata™. An example of the Odyssey software graphical output illustrating soil moisture at each of the predetermined intervals is given in Figure 4-5.

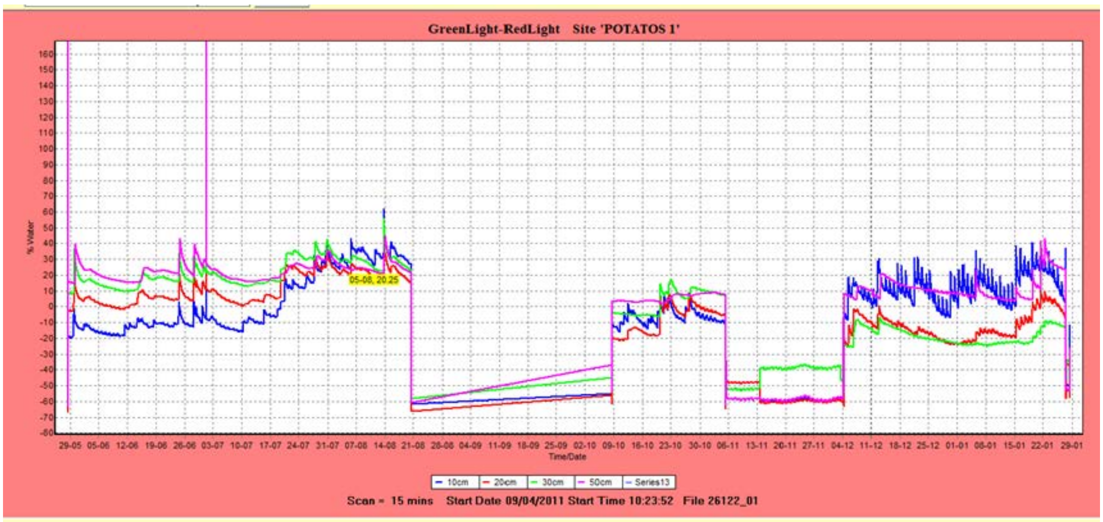

Figure 4-5: An example of the readout from the Odyssey software.

Potential limitations associated the soil moisture probes

With the exception of equipment maintenance and relocation, soil moisture data was recorded continuously over the 11-month investigation period. Relocation of the instruments across the horticultural property resulted in calibration errors occasionally resulting in data loss

The latter stages of fieldwork indicated that settlement of the tilled, humic soil, combined with the compaction of the growing crop, potentially adversely affected sensor readings. It was also discovered that vegetables adjacent to the sensors contributed to soil moisture readings. To combat this, soil samples were collected (as described above) on installation of the probes into a new trial and analysed gravimetrically to provide a control value for the soil moisture probe. Instrument data were subsequently transformed in an attempt to ensure their accuracy. However there were some flaws generating erroneous negative values that caused issues. In addition, low sample numbers for each short-duration investigation meant that the recalibrated values did not truly reflect the correct moisture reading when reverted. This was considered to be due to the changing structure of the soil and associated soil moisture content as the crop matured.

4.4 Sprinkler water volume and rainfall

Previous observations indicated that site infiltration was 100%, even in very heavy rain periods and runoff has never been observed. Thus tipping bucket rain gauges were installed in crop locations corresponding to the capacitance probes to measure the volume of irrigation water applied to the crop and rainfall events at ground level.

An estimation was also made of sprinkler water evaporation between the sprinkler head and the ground by measuring any changes in TDS. Collection dishes were used to obtain ground level samples and TDS measured using a handheld conductivity meter.

4.4.1 Tipping bucket rain gauge and data logger

Each collection bucket was 16 cm in diameter by 24 cm high and was calibrated by pouring a measured volume of water through the bucket and converting it to precipitation in mm. An Odyssey data logger was connected to a Davis Instruments gauge and fitted within each bucket (Odyssey 2014). Figure 4-6 illustrates the layout adopted for the equipment in the investigations.

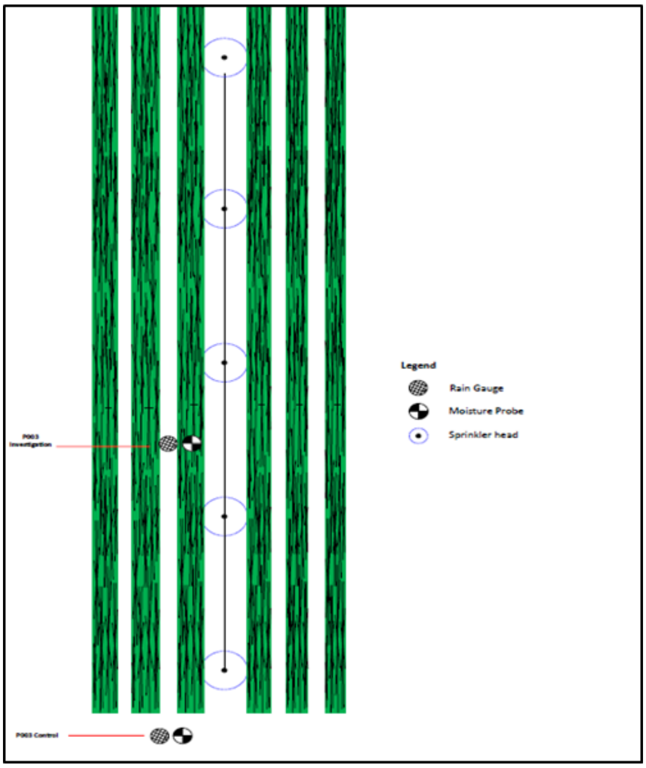

Figure 4-6: Plan view of instrument placement within the crop.

4.4.2 Investigation control

Control data were collected on a selection of the investigations and involved the installation of a soil moisture probe and rain gauge under the same environmental conditions outside of the crop-growing area. Control soil samples were also collected and analysed using methods described above.

4.5 Groundwater quality

TDS and nitrogen profiles from W1, W2, and W3 (Figure 3-1) which supply irrigation water to the vegetable crops, as well monitoring bore MB2, were recorded. Routine laboratory analyses of water samples from the sources were conducted by the horticultural station’s management staff and provided to support this research. In addition to these analyses, TDS readings were also collected from the same sites using handheld meter (YSI EcoSense EC300) as described in Section 4.3.2.