Horticulture Innovation Australia

# Final Report

## A focus on irrigation and fertiliser practices to improve production efficiency for LOTE strawberry growers

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Project Number: BS12025

**BS12025**

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# Summary


Project BS12025: *A focus on irrigation and fertiliser practices to improve production efficiency for LOTE strawberry growers*, had the primary aim of promoting the adoption of efficient nutrition and irrigation practices among the Vietnamese growing community, who are responsible for growing about 80% of the crop in Western Australia. Originally designed as a three-year project, it was terminated one year early due to lack of interest and cooperation by most growers.

The first year, 2013, concentrated on benchmarking several aspects of production within the target audience: fruit yield and quality, irrigation system design and scheduling, fertiliser practice, soil chemical and physical parameters, and water movement.

Year two established a demonstration site on a grower's property and intensively monitored soil moisture movement, soil conductivity and temperature. Another set of irrigation assessments was offered free of charge in 2014 but no growers accepted. Field days with a Vietnamese interpreter were held to communicate project activities and extension material was written and translated into Vietnamese.

The second year presented a very difficult operating environment. At the beginning of the strawberry season in Wanneroo a series of raids by the Australian Government was carried out on a property which operated a labour hire company using illegal labour. Although most of its operations impacted on the vegetable industry, there was a flow-on effect for the strawberry industry and labour was in very short supply over the 2014 season. Significant additional plantings meant an oversupply of fruit and poor prices. Several growers we worked with in 2014 are not growing in 2015. The overall downturn in profitability means less impetus for extra investment.

Growers who attended field days now have better awareness of the poor lateral movement of water, and hence nutrients, in WA sands as seen in the dye demonstrations. Whether this will translate to changes in grower practice is doubtful. An unintended outcome of the project was retraining in fumigation practice for all growers.

Many Vietnamese growers are over 50 years old. They have been growing for a long time and are set in their ways. Close to retiring, they see little point in investing in infrastructure, particularly when their properties are leased and likely to be rezoned 'urban' in the next five years. This has meant some growers are moving from Wanneroo and Carabooda to locations such as Bullsbrook and Muchea which are further north.

Power is concentrating in the hands of fewer, bigger players who have invested heavily in infrastructure including better irrigation design and soil moisture monitoring equipment. However, the more northerly growing areas mean colder night temperatures resulting in lower productivity per plant with current varieties.

The strawberry industry in Western Australia is unique in Australia in that export is viable although heavily influenced by prevailing exchange rates. Berry consumption is increasing due to perceived health benefits, but per capita consumption of strawberries is still well behind that of other countries.

## Keywords

Strawberry; Vietnamese; LOTE; irrigation design; nutrition; fertigation; fumigation.

# Introduction

A three-year HAL-funded project ran a demonstration farm on a grower consultant's property in east Wanneroo from 2005 to 2008 (Phillips et al. 2008). The project examined aspects of berry production under high tunnels, cloches and open fields, evaluating different varieties of strawberry, and comparing fertiliser programs, irrigation schedules and configurations.

That work showed that at Wanneroo, with good management, commercial scale plantings of strawberries could yield 1200 to 1500 grams of marketable fruit per plant over three consecutive growing seasons (Camarosa and Camino Real). This was achieved by fertigating once to four times a day with a nutrient solution that applied 2 kilograms of nitrogen per hectare per day in fixed ratio with other nutrients. This equates to about 450kg of nitrogen and 6.2 megalitres of water per hectare over a season (April to November).

Little of this work has been adopted by industry. Many growers are still using more water than needed and in doing so are leaching away much of the applied fertiliser. Given that most growers are on water licences and groundwater supplies are dwindling, it is important to maximise water efficiency. In addition, there are ongoing concerns about fertiliser leaching into the groundwater, particularly nitrogen. Growing more fruit with less water may enable growers to expand their production areas.

There is evidence that many irrigation systems are poorly designed and so irrigation and fertiliser application rates are likely to be uneven. Since most fumigation is applied through the driplines, poor system uniformity will also mean that fumigation is uneven and possibly suboptimal. It is often observed that early invasion of soil-borne diseases such as *Fusarium* crown rot is in single rows, indicating blocked nozzles during fumigation; or on the outside of beds, suggesting that fluctuations in soil moisture (and soil conductivity) may be facilitating entry of pathogens to plant roots and crowns. Pockets of soil that are not fumigated effectively will enable soil pathogens to carry over between crops and start new infection loci. Ineffective fumigation also enhances the likelihood of disease resistance.

While it is appreciated that current irrigation configurations work well in achieving good yields, it is possible that the perimeter of the drip zone, especially at the outer edges of the bed where soil salinity and moisture are likely to fluctuate more, provides stressors that weaken roots and enable the penetration of pathogens such as *Fusarium*, *Macrophomina* and *Rhizoctonia*. Excessive irrigation is also likely to contribute to disease, both above and below ground.

This project was established to assist growers better understand and implement irrigation and fertiliser practices expected to have wide-ranging implications for the productivity and quality of their crops. The methods encompass fundamental irrigation design and 'waterwise' principles applicable to any crop, together with the specific findings of the previous project, BS05001.

The project targeted the Vietnamese strawberry growing community who comprise about 80% of all growers (in terms of numbers) in Wanneroo/Carabooda/Bullsbrook, the main growing areas in Western Australia.

# Methodology

The project monitored and benchmarked the growing practices of a sample group of strawberry growers, for whom English was a second language, and was combined with demonstration and communication activities.

## Benchmarking

The project began in July 2013, the beginning of the financial year, which was after the start of the strawberry season (April) so it was not possible to work on some aspects in the first year (fumigation and nutrient leaching), as crops were already in ground and cropping. However, we were able to do a considerable amount of groundwork providing a good foundation and direction for the second year's work.

Our first task was an introductory letter in Vietnamese sent to all growers (Appendix 1). Prior to this, our grower consultant, Mr Gerry Verheyen, had already visited many growers to explain the project and obtain access to potential sites.

The monitoring sites used in 2013 are detailed in Table 1 but the identities of individual growers have been protected.

**Table 1. Monitoring sites used in 2013**

| Grower | Variety | Number of plants |
|---|---|---:|
| Grower 1 | Camarosa | 800,000 |
| Grower 2 | Festival | 200,000 |
| Grower 3 | Camarosa | 95,000 |
| | Fortuna | 50,000 |
| Grower 4 | Festival | 35,000 |
| | Camarosa, leaf-on | 35,000 |
| | Camarosa, leaf-off | 120,000 |
| | Palomar | 35,000 |
| | Fortuna | 500 (trial) |
| Grower 5 | Camarosa | 200,000 |
| Grower 6 | Camarosa | 90,000 |
| | Fortuna | 50,000 |
| Grower 7 | Camarosa | 130,000 |
| | Fortuna | 110,000 |

### Yield

Yield benchmarking was needed to demonstrate the effect of changes in grower practices over the project. This represented a significant workload since strawberries are harvested from approximately June to November at frequencies up to every two to three days. We could not commit to such an intensive schedule for the prolonged period, so sought the agreement of the growers to picking our plots only once a week and offered to pay them for the equivalent quantity of fruit that was lost to market from that exercise. In fact, that did not eventuate, as the growers were present mostly when we picked so the fruit was given back to them after grading and weighing.

We set up three replicate plots, of about 100 plants on each of three growers' properties. Each week, ripe fruit was picked, graded into extra special, special, medium and reject classes, counted and weighed.

## Soil and water testing

Baseline water (Appendix 2) and soil samples (Appendices 3 and 4) were taken from each of the growers listed in Table 1 to establish if there were any issues such as salinity or soil acidity of which we needed to be aware.

## Irrigation and fertiliser practice

At the beginning of the 2013 season we documented the irrigation configurations (Appendix 5) for each grower listed in Table 1 to assess their irrigation scheduling. This was repeated in 2014 as several growers changed aspects of their systems.

Moisture monitoring equipment was installed on each property (two sets for Grower 1 due to the diversity of his site) listed in Table 1.

All growers were visited weekly by the project leader, technical officer or grower consultant, to collect soil and sap samples for nitrate, electrical conductivity (EC) and pH monitoring and to pick fruit from the benchmarking plots. A summary of the soil and sap sampling results is attached in Appendix 6. Growers 4 and 6 were also visited weekly for soil and sap monitoring. Growers 5 and 7 who came to us later in the season were not included in soil and sap monitoring as we simply could not handle that many samples with our resources.

Each grower in Table 1 was interviewed to document and evaluate their fertiliser program (Appendix 7).

Plant tissue samples (Appendix 8) were taken from Growers 4 and 5, who appeared to be the two best growers.

In 2014 we restricted the installation of tensiometers to those properties where the irrigation design and uniformity were good enough for some scheduling. This meant only two sets of moisture monitoring equipment were installed (Growers 1 and 3) despite requests from others.

To evaluate the impact of blockages on the irrigation system, irrigation research officer Rohan Prince and technical officer Rob Deyl visited Grower 1 in late October to measure system pressures and compare them with those at the beginning of the season.

## Irrigation assessments

Irrigation assessments can involve some destructive practices and so were scheduled for the end of the season. Eleven irrigation assessments were completed for 2013 (Table 2). A further two growers had been approached, with one failing to respond and the other having a mainline failure the day prior to the scheduled assessment.

All properties were assessed for pressure variation within shifts as a guide to emission uniformity throughout the field. Where water meters and pressure gauges were installed some systems were assessed for hydraulic losses through mainlines, sub-mains and filters as a guide to efficiency of delivery. If pump makes and models were known, efficiency of operation was compared against the manufacturer's pump performance curves.

Another batch of irrigation assessments was scheduled for 2014. Towards the end of the season we sent letters to all growers inviting them to nominate for a free irrigation assessment (Appendix 9).

**Table 2. Irrigation assessments proposed for the end of 2013 and result**

| | **Area of site/ plant numbers** | **Status** |
|---|---|---|
| **Grower 1** | 800,000 plants | Completed |
| **Grower 2** | 3.5ha,<br>200,000 plants | Completed |
| **Grower 2 (2nd property)** | 3.5ha,<br>200,000 plants | Completed |
| **Grower 3** | 3.5ha,<br>145,000 plants | Completed |
| **Grower 4** | ~3.5ha | Completed |
| **Grower 5** | 4ha | Completed |
| **Grower 6** | 3.5ha,<br>140,000 plants | Completed |
| **Grower 7** | 4ha | Completed |
| **Grower 8** | 1.4M plants (2013) | Completed |
| **Grower 9** | 4ha | Completed |
| **Grower 10** | ~200,000 plants | Completed |
| **Grower 11** | 4ha | Not completed, grower failed to respond in time |
| **Grower 12** | 4ha | Not completed, mainline failure and system switched off |

## Disease incidence

The incidence of both *Gnomoniopsis* and crown rot was recorded in 2013 on the same three properties used for yield benchmarking using the sample three replicate plots.

Early in the 2014 season we visited the growers and selected one tray of fruit at random (variety Festival) to establish the rate of infection of *Gnomoniopsis*.

### Plant establishment

Due to the high number of complaints about plant establishment, each year surveys were carried out at three growers' properties.

Fortuna, in particular, has a record of poor establishment and in 2014 many growers complained about the first shipment of runners from interstate. However, one grower, despite receiving plants that were low in vigour, managed to nurse most of them through. We visited his property and recorded establishment over the different shipments and varieties. For each planting we counted four random plots each of 50 plants to make a total of 200 plants per plot.

We surveyed two other growers who appeared to have establishment issues relating to sprinkler coverage.

At Grower 4's property in Carabooda we counted three plots each of 100 plants (variety Festival) in selected rows on or between sprinkler lines. Sprinklers were on row 87 and between rows 96 and 97.

At Grower 7 we counted three replicates of 50 plants near or between sprinkler lines for both Camarosa and Fortuna varieties.

## Demonstration site

After the 2013 season we scrutinised the irrigation assessment results to shortlist possible growers for the demonstration site. We had a preference for a Wanneroo grower as they are more central and closer to more of the smaller growers. The selected grower had to be willing to participate in field days, that is, have other growers on their property. Grower 6 was our first choice and after some discussions with him, his wife and son, they agreed to participate.

An area was set up with an independent irrigation and fertiliser system servicing three beds. The adjacent three beds were used as the grower control. The variety on that part of the property was Fortuna – not our first choice as it is problematic for establishment and not one of the two main varieties grown.

The irrigation system consisted of:

- An SD Systems 48 valve/station 2-wire controller and accessories (pump start relay 24 VAC, 3G modem configured to the SD Systems server, 3 x 2 wire data valves, lightning protection, a Bermad 25mm data valve with flow control and level, a 25mm control valve (including ball and float) for tank filling and a data node for a water meter.
- Six CS650-PT-VS 30cm soil moisture/EC and temperature probes together with four tensiometers fitted with pressure transducers recording on Campbells Scientific CR200 loggers. Measurements were taken each minute and averaged over 15 minutes. Rain was recorded in the demonstration site using a tipping bucket rain gauge while the grower's irrigation was measured using a 10L pulse output water meter isolated to measure the three test beds.
- A 5000L water tank and two 180L drums for fertiliser tanks A and B.

Some pictures of the site are in Appendix 10, Figures A10.1–A10.4.

The demonstration ran from 18 April to 4 November 2014 with irrigation and fertiliser being controlled by DAFWA staff over three 1.2m by 61.0m beds. Three similar beds immediately adjacent and to the east, were controlled by the grower.

In the first two to three weeks of plant establishment (18 April to 3 May inclusive), overhead irrigation was applied, controlled by the grower. Water applied via drip irrigation was measured using a water meter read weekly.

Yield data was collected by the grower during the trial with the exception of the first couple of weeks when only very small amounts of fruit were harvested. Data collection ended after a storm damaged the crop in early October. Each area was colour-coded with flagging tape and a set of trays with coloured stickers was used to collect the harvested fruit. That fruit was kept separate for grading and packing and a final count of punnets recorded from each area.

Approximately 20 fruit from each of the grower and demonstration plots were sampled at 1–2 week intervals (depending on availability) from 27 August to 11 November. Each fruit was tested for Brix using a hand-held refractometer and for firmness using a hand-held penetrometer Model FT327 with 11.3mm tip.

## Intensive soil moisture, conductivity and temperature monitoring

Thirty probes (12cm CS655-PT-VS) were ordered for intensive monitoring at one site to investigate the possible correlation between soil temperature, EC, moisture, and disease incidence. A requirement of the site was that it needed to have distinct areas of high and low pressure. The chosen site was established in Carabooda (Grower 4) in May, at the beginning of the season. Two lines were selected, which by coincidence were next to each other, one line running at 100kPa, the other at 55kPa (measured at beginning of season).

We selected a short length of bed and installed a set of probes in each bed. The probes were installed at 15cm depth in three sets of five across the bed (western edge, under the dripline (west), centre, under the dripline (east) and eastern edge), each set of five being about 10cm from the last. We made sure to install probes both directly under emitters and between two emitters. These probes recorded soil moisture, EC and temperature at 15 minute intervals throughout the season (Appendix 11, Figures A11.1–A11.6).

## Dye demonstrations

Three dye demonstrations were planned, the first timed to coincide with the first project field day.

1. The day before the field day a system to inject water containing dye was set up at the grower consultant's property. A series of beds was set up with Netafim drip tape with 10, 20 and 25cm emitter spacings. Three beds were compacted as normal and one bed was left uncompacted and the irrigation run to achieve specified outputs.

2. The second dye test was set up at our intensive monitoring site at the end of the 2014 season. Dye was used to track the passage of water in each bed. The beds were deconstructed to gain an idea of root distribution and water movement.

3. We intended to do a third dye test before the end of the season at the demonstration site. On 5 November 2014 we were assured the crop would be in for several more weeks. Then, on 13 November we received a phone call to say the crop was being pulled out at that moment and could we come and take our moisture monitoring gear out so we had no possibility of doing the dye work that needed to be run over two days.

# Fumigation survey

Because there was a great deal of debate about the efficacy of shank injection versus inline fumigation to control disease, and given the issues of poor irrigation design and lateral spread of water which would also affect gas diffusion and spread, we planned to survey gas levels at two growers' properties after fumigation, one using inline fumigation and a second using shank injection.

We were not skilled in this type of work so employed Dr Scott Mattner from the Victorian Strawberry Industry Certification Authority (VSICA) who was experienced in this field. Dr Mattner was also funded by SGAWA for research on runner establishment and cold storage, and undertook periodic visits to WA for that project. We planned to coordinate the fumigation work with one of those visits and the field day.

Trying to find growers willing to participate and to arrange dates and times for fumigation, proved extremely difficult. A grower was contracted to fumigate two beds using shank injection at our grower consultant's property. A videographer was engaged to record both the fumigation process and the gas sampling procedure afterwards. The technique is relatively simple so that growers could learn and use to evaluate the efficacy of their fumigation and to check that gas levels had dropped sufficiently to plant.

The procedure uses specialised gas sampling tubes that we obtained from Gastech Australia Pty. Ltd. and Airmet Scientific. Two tubes are required for Telone-C35® or for Rural Inline® as the products are a mixture of two chemicals – 1,3 dichloropropene and chloropicrin. The sampling procedure was done three times post-fumigation in three positions – at the point of application (POA), at the shoulder of the bed, and in the middle of the path between the beds. As this was the first time we had done this in Western Australia on our coarse sands it was hard to judge the best time intervals and these did change as we gained more experience.

A second survey evaluated inline fumigation and also collected data from three replicate plots. A third partial survey (shank injection) was done after concerns about the low gas levels in the first survey of shank injection. The gas sampling tubes used for this process have to be ordered well in advance and although we budgeted for breakages and some extras, we did not have enough tubes for three full surveys.

# Field days

Three field days were held during the project. For the first two, a Vietnamese interpreter was employed through Australian Multi-Lingual Language Services (AMLS), but after some comments about the literal nature of his translation (not being a grower himself), it was suggested we use one of the industry people who had good bilingual language skills for the final field day.

# Outputs

All grower contacts during the project were logged and are summarised in Appendix 12.

## Extension material

A range of material for growers has been revised and translated into both Vietnamese and English and is listed below:

### Pesticides

Information on pesticides using registered chemicals and permits for use on strawberries was provided on the DAFWA website in both English and Vietnamese, and updated as minor use permits changed (Appendix 13).

### Plant establishment, irrigation and fertiliser guidelines

Web pages based on the information gained in the project have been written in English (Appendices 14 and 15) and are being translated into Vietnamese and uploaded to the DAFWA website (June 2015). They are expected to be available in Vietnamese by July 2015.

### Gnomoniopsis

An earlier English version of notes about this disease is available on the DAFWA website at https://www.agric.wa.gov.au/strawberries/gnomoniopsis-fruit-rot-and-leaf-blotch-strawberries or use the search engine.

A new set of notes on this disease has been written, translated into Vietnamese and distributed to growers (see Appendix 16 for the English and Vietnamese versions).

### Fumigation

A video with voiceover of the fumigation work is in preparation and will be completed and made available to growers (expected by August 2015).

## Reports

Two reports on project progress have been written and presented to the APC Strawberry Producers Committee, through which the industry provided funding.

An update on the project with photos was provided to Horticulture Australia Limited for the Annual Report on 18 September 2014.

## Media articles

A media release organised by project staff was picked up and featured in *The Countryman Newspaper* (4 July 2013) and the *Joondalup Weekender* (15 August 2013) and shown in Appendix 17.

# Outcomes

This project was terminated one year early due to the lack of interest and cooperation from the Vietnamese growing community as a whole. It can be seen from the activities undertaken that we did work successfully with a small number of growers, but most of the fundamental changes we hoped to achieve during the course of the project were not possible. Some growers did make changes but they were often piecemeal or unsustained.

The demonstration site was one example where the data from the soil moisture monitoring equipment we installed was used to schedule irrigation and the suggested fertiliser program was followed. However, the dynamics of the father/son relationship on the grower property meant that some critical elements were not followed – such as the application of pre-plant compost, which set in place many things that worked against us.

Many of the Vietnamese growers are over 50 and even 60 years of age. Almost without exception they have been growing for a long time and are set in their ways. Many are close to retiring age and see little point in investing extra money in infrastructure, particularly when their properties are leased and likely to be rezoned for urban use in the next five years.

When we planned the project we discussed investing in a Vietnamese development officer to assist with industry liaison. We were advised against this, but in hindsight I believe there may have been benefits in that approach.

The 2014 season presented a very difficult operating environment. Significant additional plantings caused a glut of fruit and poor prices, so several of the growers we worked with in 2014 were not planning to grow in 2015. The overall downturn in profitability meant even less impetus for extra investment.

In May 2014 at the beginning of the strawberry season in Wanneroo there was a series of police raids on a local property which operated a hire company using illegal labour. Although its operations impacted mostly on the vegetable industry there was a flow-on effect for the strawberry industry and labour was in very short supply over 2014.

It is hard to predict what the future holds for the strawberry industry in Western Australia. We are unique in Australia in that export sales are viable. One grower is trialling a robotic harvester. If mechanisation is able to relieve the labour issues, there are good prospects for industry expansion, especially for export. Berry consumption is increasing due to the focus on their health benefits. The Hepatitis A outbreak in February 2015 allegedly due to imported frozen berries only temporarily increased demand for local frozen product.

As with other horticultural industries we are seeing a concentration of power into the hands of fewer, bigger players. Given that many of the smaller growers are in east Wanneroo which is likely to be rezoned as urban in the near future, plus their age, the whole sector may disappear and the industry could become centred on Bullsbrook, further north, with only two to three main players.

Recent expansion into the south-west of the state is spreading strawberry availability throughout the year, potentially taking the pressure off prices caused by peaks in supply.

The bigger growers have invested heavily in infrastructure and technology including proper irrigation design and soil moisture monitoring equipment. The proximity of at least one to sensitive groundwater areas has meant that nutrient and irrigation monitoring is a condition of his water licence and more efficient irrigation practices are now in place.

Remarks on specific project activities follow.

## Benchmarking

Because most picking is done by labour hire companies, pickers change from day to day and week to week. Even though we had our plots flagged with fluorescent tape and bamboo stakes we would frequently find them already picked when we went to harvest. At one grower's property this was so frequent we abandoned the exercise within the first month. At another we found plots picked or partially picked only occasionally at first, but as the season progressed it became worse. We were left with only one grower with reliable data which showed a total yield per plant of about 720g (average of three plots) for Camarosa (Figure 1). The other grower showed about 746g for the one reliable plot (variety Festival).

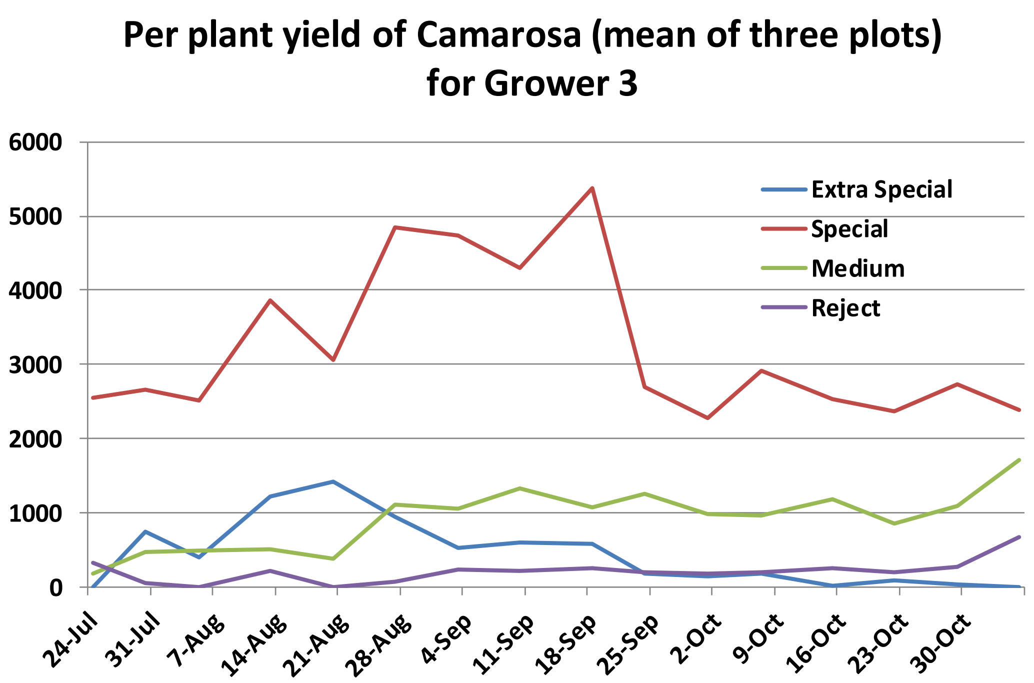



**Figure 1. Example of fruit yield and size benchmarking for Camarosa from Grower 3**

It is commonly reported that around 750g per plant is average yield. Our best grower reported 1kg per plant. In previous commercial-scale trials in the same area DAFWA achieved more than 1kg.

Prices dropped during September 2013 to around 70–80c/250g punnet which had most growers threatening to pull crops out, however prices recovered and ended the season on about $1.10.

The first grower stopped production at the end of October. Most others finished by mid-November but one continued into the first week of December.

## Irrigation system design and scheduling

Appendix 5 details the irrigation configurations used by each grower. Apart from variability in soil type (despite largely being sand, behaviour of applied water varies), plant spacing, tape type and emitter spacing all varied greatly with the result that the amount of water applied by each grower varied from about 10 to 20 millimetres per day. Two growers used magnets to treat their water.

All irrigation assessments in 2013 showed major design flaws to the extent that we chose not to proceed with dye tests until these were resolved.

While pressure variation should not exceed 20% for flow variation to be within 10%, most properties exceeded this level. One property had acceptable pressure loss within laterals within an irrigation shift, but was exceeding the recommended operating pressure provided by the manufacturer. Other properties had acceptable pressure loss along the length of a single lateral, however laterals from one end of the shift to the other almost always exceeded recommendations. Most of the variation was a result of either topographical changes that had not been considered when the system was designed or installed, or emitter line lengths exceeding the manufacturer's recommendations to maintain flow variation within 10%. From the assessments, it appears there has been little consideration of hydraulic principles and limited input by qualified irrigation designers.

Lack of maintenance of filters was common. Pressures tested on lines before and after the filters often showed pressure losses of 80 to 100kPa, resulting in insufficient pressure to supply lateral lines. There was little or no use of flushing valves and lines were often linked to an adjacent line or simply terminated. This results in build-up of material at the end of the lateral lines and potential for blocked drippers with irregular output (Figures 2 and 3).

**Figure 2. Sludge from the end of driplines without or inoperative flushing valves**

**Figure 3. Sludge blocking a flushing valve and preventing its operation**

Appendix 18 contains a selection of moisture monitoring graphs from 2013. We used time domain reflectometers (TDRs) installed to calculate soil moisture over 0–15, 15–30 and 30–60cm. It can be seen that the 30–60cm TDR in virtually all graphs showed that each irrigation was penetrating beyond the root zone, so significant improvements could be made once system uniformity was improved.

**Grower 1**: This property was by far the most complex with changes in contour and soil type, and required significant input. We agreed to help fund some design as the grower was willing to invest money in his system as well as pay for liming and earthworks. He intended to bring in sand to raise the level of a low peaty area in which soil sampling showed a clay layer at about 40cm. He also planned to bring in a contractor to invert the profile to a depth of about 70cm over the rest of the block. However, at the conclusion of the project only the liming had been done.

We had several meetings to familiarise him with the irrigation design compiled by Netafim. He also undertook some major works himself, replacing a poorly designed mainline with a larger one and putting in a 150mm line between two bores to serve as a backup in case one failed. Twenty-two millimetre Netafim dripline was put in for the 2014 season and reduced the pressure loss along his rows to acceptable limits (previously it was 16mm). Two Dosatrons were to be installed with A and B tanks for constant fertigation, but at June 2015 this had still not happened. When we visited him at the end of the 2014 season he said his yields had improved especially on the low yielding, low pH peaty soil.

Despite the system upgrades there was still an issue with iron bacteria clogging filters after only one day. After discussions with the project team he decided to try dropping 20L of chlorine down the bore. This helped considerably, extending the time between filter cleans to several days.

Pressures on the system arising from the southern bore were well below expectations so Grower 1 was advised to have the pump examined. A leaking joint was found and repaired.

**Grower 2**: When we visited in 2014 his pump was not operating properly and system pressures were even worse than in 2013. We are not aware if the pump was fixed during that season.

**Grower 3**: This grower moved properties (three blocks down) for 2014. He modified the irrigation design and the resultant pressures were much better.

**Grower 4**: The main changes needed to improve his system uniformity were to move filters so they were in the middle of each shift. He claimed he ran out of time to do that before the 2014 season as he was installing artificial windbreaks. His crop suffered in a 2013 storm that ripped plastic from his cloches and bent frames, so we have to accept that excuse. He is not growing in 2015.

**Grower 5**: Several factors worked against us achieving any changes. He only irrigated once a day in the morning as he had a manual system and had to pick his children up from school in the afternoon, allowing no time to do an afternoon watering. He was one of the best growers in terms of yield despite that, so had little incentive to change. He was also likely retire in the next year or two as the property was leased and likely to be sold for development.

**Grower 6**: This grower hosted the demonstration site. The family modified the layout and changed filter positions and sizes, following our suggestions.

**Grower 7**: His dripline was changed from 1.6 to 1.2 litres per hour, unbeknown to us, for the 2014 season which he thought should enable it to cope much better with the flow requirements of his shifts. However, because the line lengths were unchanged, the pressures at the ends were still very low. Grower 7 was another who was happy with his crop and did not see the need to change practices. He was close to retirement and not growing for the 2015 season.

**Grower 8**: The system on this property was new and overdesigned in anticipation of expansion in 2014. We have not been back to retest the system.

**Grower 9**: This grower did not grow strawberries in 2014.

**Grower 10**: This grower could make some simple changes that would markedly improve his system. The main one would be to increase the size of a mainline which runs up a hill. He had no flushing valves, but connected the two driplines at the end of the rows. Over the season sludge built up and blocked the drippers towards the ends of the rows. We tried working with him over two seasons (including prior to this project) but he showed no sign of wishing to make changes.

**Growers 11 and 12:** These are not included as assessments were not completed.

**Grower 13**: We visited this grower expecting to find a system performing well because it had been professionally redesigned not long before, but the pressures at the end of his lines were low and typical of what we had found elsewhere in the industry. There was no ability to schedule his irrigation and no equipment was installed. We tested pressures on one shift only. Row lengths were 125 metres with some shorter rows of 110m. Pressures at the start of rows ranged from 75 to 98kPa while at the ends it was 30–32kPa except for the shorter rows where it was 40–50kPa.

## Demonstration site

During the project, the original grower's son took over management of the property and instead of the usual practices, the son tried to follow our practices as much as he was able. This meant the "grower practice" was changed. Figure 4 shows how the grower's water use matched more closely with the demonstration site and evaporation as the season progressed.

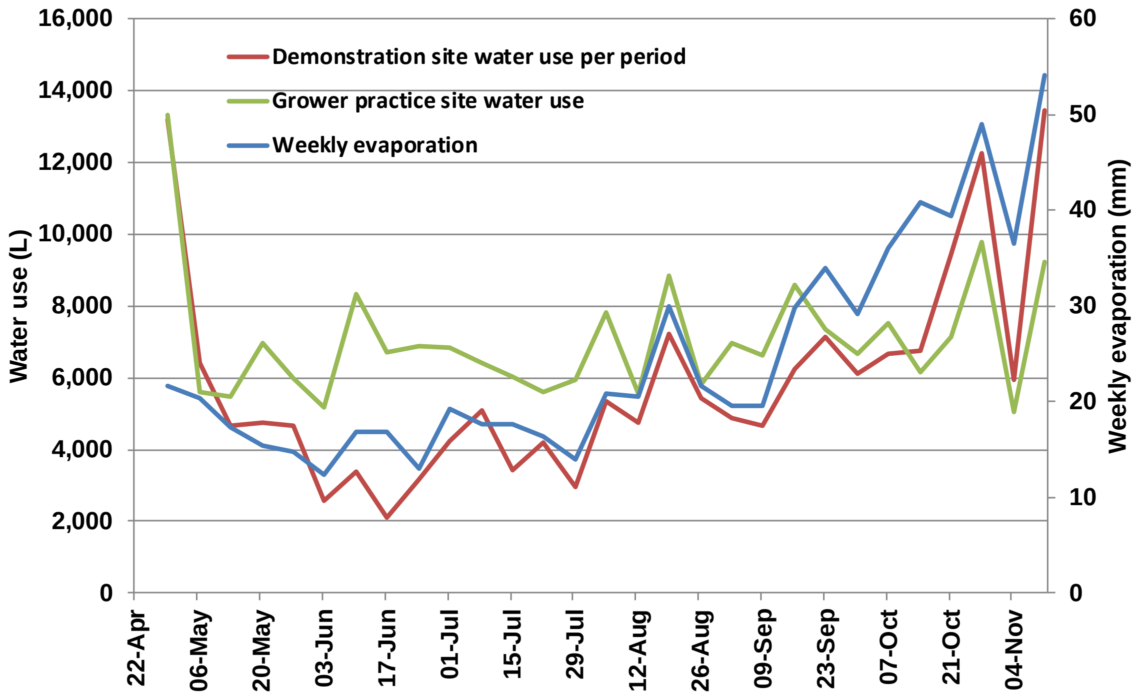



**Figure 4. Weekly evaporation compared to water use for demonstration and grower sites**

Irrigation for the demonstration site was intended to be scheduled using evaporation replacement and fine-tuned using soil moisture monitoring equipment. A target crop factor for evaporation replacement from previous work was initially suggested at 0.7. This proved unsatisfactory and was increased to close to 1.0 for most of the trial.

From planting to crop removal, 195,194 litres and 157,807 litres were applied to the grower practice and demonstration sites, respectively. This was the equivalent of 826mm applied by the grower and 657mm applied by DAFWA staff, over the same bed area, a difference of 26%.

Over the same period, evaporation (667mm) and rainfall (570mm) were recorded at the Wanneroo weather station.

Drainage below the crop was intercepted using three catch-can bag lysimeters 0.83m x 1.2m (1m$^2$). The catchment, to 1 metre below the crop, averaged 692mm in the grower-managed area and 495mm in the demonstration area.

## Fertiliser application

The intention for the demonstration site was that no base dressings would be used and that fertigation would be started at planting. However, we were informed, after the fact, that a load of a composted chicken manure product (Fabfert™) had been applied. It took us some time to establish exactly what had been used in the pre-plant treatment. The grower was not forthcoming and it was only after a chance encounter with the supplier, that we were able to discover that about 50 tonnes of Fabfert™ at 30% moisture was applied over the 2.65ha property (1.75ha bed area). According to the manufacturer's analysis (4.2:2.0:2.0) this contained 554.7kg nitrogen (N) and 264.2kg each of phosphorus (P) and potassium (K) per hectare, of which we were informed only 25% of the N and 10% of the P was water soluble.

The fertiliser applied through irrigation over the duration of the trial is detailed in Table 3.

**Table 3. Major nutrients applied to demonstration site in 2014 season**

| Site (kg/ha) | N | P | K | Mg | Ca |
|---|---|---|---|---|---|
| **Demonstration site fertigation** | 518.3 | 129.9 | 744.4 | 73.5 | 312.2 |
| **Grower practice site fertigation** | 415.4 | 73.9 | 492.5 | 64.2 | 246.2 |
| **Base dressing** | 554.7 | 264.2 | 264.2 | NA* | NA* |
| **Total demonstration site (including base dressing)** | 1073.0 | 394.1 | 1008.6 | NA* | NA* |
| **Total grower practice (including base dressing)** | 970.1 | 338.1 | 756.7 | NA* | NA* |

NA* - data not available

The pre-plant manure application roughly doubled the amount of nutrient applied, well beyond plant requirements. This was a most unsatisfactory outcome and made leaching inevitable.

Nitrate concentration multiplied by drainage volume was an indication of nitrogen (N) leaching below the crop. We only monitored nitrogen and electrical conductivity (EC) in the trial so have no data on phosphorus leaching. In the first few weeks the leachate indicated very high nitrogen content with the quantity of nitrogen leached in the first two weeks being triple that of subsequent weeks as shown in Table 4. Apparently the compost supplier recommended no fertiliser application in the first six weeks. We understand the grower held off feeding for the first four weeks and then fed at half strength for another two weeks. We fed at half strength for the first four weeks.

**Table 4. Nitrogen leached (kg) in first three weeks after planting**

| Week ending | Demonstration | Per hectare equivalent | Grower practice | Per hectare equivalent |
|---|---|---|---|---|
| **22/04/2013** | 24.81 | 1128 | 22.27 | 1012 |
| **29/04/2014** | 19.50 | 886 | 26.67 | 1212 |
| **06/05/2014** | 6.88 | 313 | 9.65 | 439 |

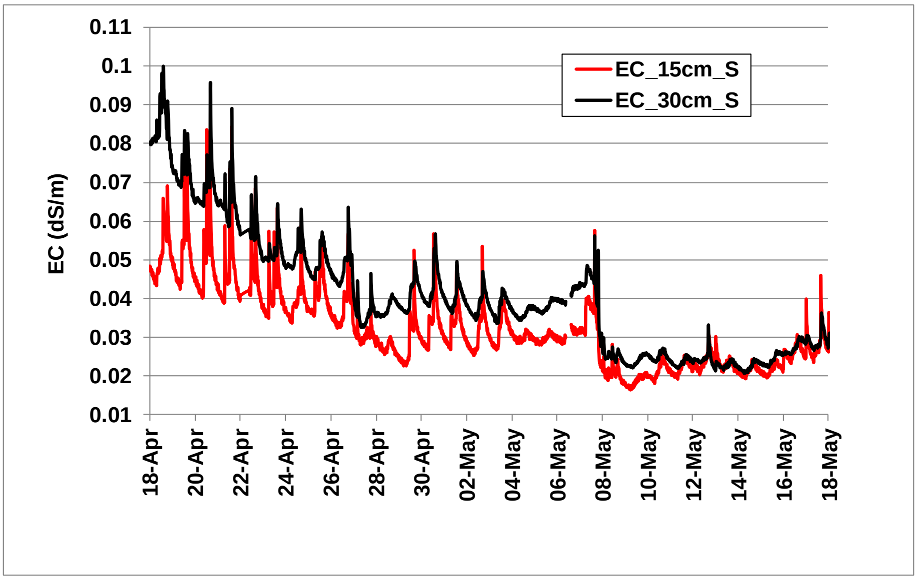



**Figure 5. Trend in EC at demonstration site for the first month**

Over the whole cropping period, 284kg of N was leached below the grower-run treatment while 374kg was leached below the demonstration treatment. In each case the figure was the mean of three lysimeters, however the variability between the three on our site was a concern – 348, 263 and 511kg compared to the relatively more consistent 260, 257 and 335kg from the grower site. We do not know the reason for this, but it may relate back to the chicken manure-based compost application and its possible uneven distribution.

The EC levels as shown in Figure 5 also were a concern in those early weeks, and together with the fragility of the particular cultivar (Fortuna) and uneven soil moisture, it is likely this combination of factors contributed to the plant losses experienced.

Yields were complicated by several factors. Although each area had the same plant spacings there were significant numbers of plant deaths in the first few weeks after planting and unbeknown to us, those plants were replaced, in part by another variety, Camarosa. Despite this, there was also considerable variation in plant vigour. Approximate final plant counts are detailed in Table 5.

Final per plant yields (9 July–20 October) adjusted as well as possible for plant number, were 371g (extra large) and 45g (medium) for the demonstration site and 412g and 36g for the grower plots respectively.

**Table 5. Demonstration site plant counts (percentages in brackets)**

| Treatment plot | Plant numbers as at 25 August 2014 | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Dead** | **Low vigour** | **Diseased** | **Subtotal** | **Healthy (by difference)** | **Total** | **Camarosa (estimate)** |
| Demonst-ration | 89 (3.9%) | 268 (11.8%) | 81 (3.6%) | 437 (19.2%) | 1843 (80.8%) | 2280 | 156 (6.8%) |
| Grower | 122 (5.4%) | 247 (10.8%) | 83 (3.6%) | 452 (19.8%) | 1828 (80.2%) | 2280 | 172 (7.5%) |

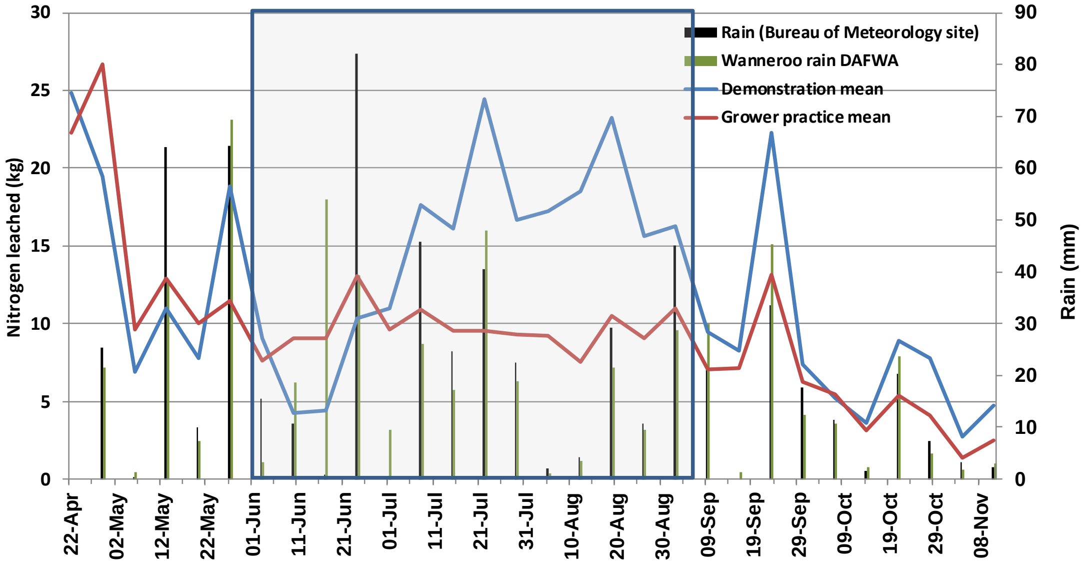


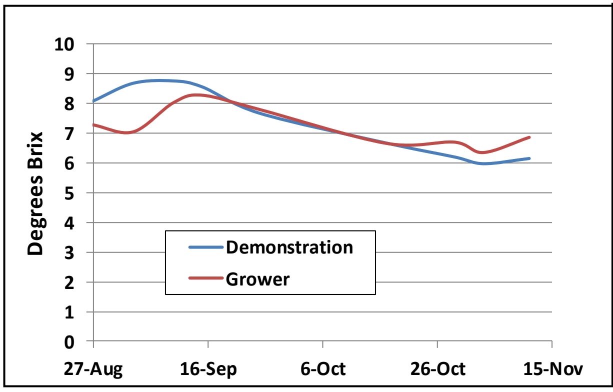

**Figure 6. Graphical presentation of precipitation and nitrogen leaching for demonstration site where the area enclosed signifies when the crop was under cloches**

Figure 6 shows the very high initial levels of nitrogen leaching over the first few weeks and also how closely nitrogen leaching correlated to rainfall in the periods where cloches were not used. While cloches were in use there was less correlation. We know from the soil moisture monitoring that rainfall which accumulates in the pathways does infiltrate into the beds at the level of the paths and therefore is capable of leaching nitrogen in the soil profile at 15cm and below, into the lysimeters whose tops are at 40cm to avoid problems when growers use rotary hoes. The amount of precipitation was also magnified when cloches were used, as it shed off the cloches and into the pathways, potentially increasing it threefold.

The results were virtually identical for Brix. The grower fruit was marginally firmer (Table 6). Figure 7 shows a slight trend towards softness and lower sugar content as the season progressed.

**Table 6. Comparison of firmness and sugar levels at demonstration and grower sites**

| | Demonstration | Grower practice |
|---|---|---|
| **Mean °Brix** | 7.26 | 7.25 |
| **Mean firmness ($kg/m^3$)** | 1.10 | 1.23 |



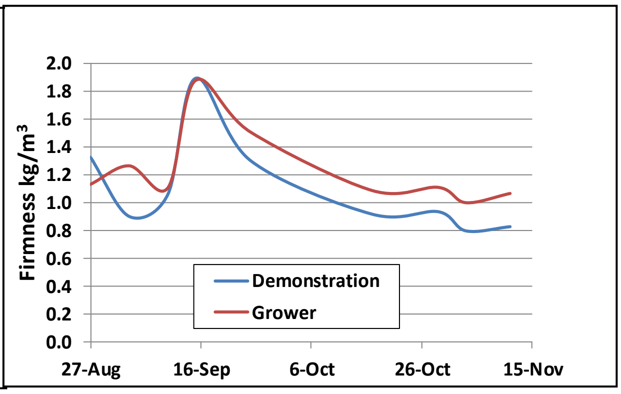




**Figure 7. Trends in Brix (left) and fruit firmness (right) over the season for each site**

Grower 6 also changed his fertigation system. He installed A and B tanks early in the season but we were able to pinpoint some problems through soil nitrate testing which showed his nitrate levels to be extremely low, as though the fertiliser was not getting through. Our grower consultant was able to establish some problems with dilution rates. By the end of the season soil nitrate levels were gradually improving.

## Disease management

In three replicated plots (strawberry cultivar Festival) on the property belonging to Grower 2, the disease was recorded on 60% of plants in Plot 1, 52.5% in Plot 3 but only 13% in Plot 2. However, the low incidence of *Gnomoniopsis* was not a positive outcome in Plot 2, as there was variability in plant growth in that area and several times, on soil sampling, we found patches of soil to be dry as a result of possibly blocked emitters. The final yield for that plot was about 25% less than for Plot 1. The incidence of *Gnomoniopsis* was found to be 50% higher in the outer rows than the inner rows, which seemed to be the result of water dripping from the edges of the plastic cloches onto the crop.

In conversation we found the grower did not spray for *Gnomoniopsis* as he had been advised it made no difference, but we heard of other growers who sprayed and found it useful.

After gaining an overview of the operations of several growers, it became apparent that the design of some cloches/beds was better than others. One Festival grower had no issues with *Gnomoniopsis* but his cloches came well down over the sides of the beds so there was no dripping onto the edge plants. However, he was using only three-row beds and a slightly different, higher design of cloche. It may be possible to decrease bed width slightly, but even so, the cloches used by most growers are comparatively low and the outer rows of plants would probably become squashed.

The incidence of Gnomoniopsis at the other two properties (Growers 1 and 3) where the variety being monitored was Camarosa, was negligible.

**Table 7. Early season counts of *Gnomoniopsis* on fruit of strawberry cultivar Festival at three properties**

| Infection rate | Grower 1 | | Grower 4 | | Grower 14 | |
|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % |
| **Nil** | 53 | 51.0 | 40 | 38.5 | 11 | 10 |
| **Mild** | 19 | 18.3 | 40 | 38.5 | 30 | 25 |
| **Moderate** | 19 | 18.3 | 19 | 18.3 | 44 | 3 |
| **Severe** | 13 | 12.5 | 18 | 17.3 | 27 | 23 |
| **Total** | **104** | | **117** | | **112** | |

Table 7 shows the results for early season disease counts of Gnomoniopsis on fruit from the first flush. A significant proportion of fruit in this first flush of Festival is usually affected. Grower 14 had an especially high infection rate and told us he irrigated three times a day for 30, 40 and 30 minutes compared to the other two growers who were only watering for 20–30 minutes twice daily. We decided that given Grower 14's age and limited future in the industry he was not a good investment of our time in the project.

The incidence of crown rot was complicated by the fact that there appeared to be a high incidence of disease coming in on the runners. While not every plant was tested, we did find *Fusarium* and *Phytophthora* in many cases. Without being able to confirm that the disease came in on the runners, or whether it was left in the soil as a result of poor fumigation, we suspect the earliness of the deaths points to the former. Plant death from crown rot early in the season then provides a source of inoculum for others and more deaths can be expected regardless of irrigation or fumigation practices. Adjacent plants in the same row as other infected plants are more likely to die first.

**Figure 8. Driplines joined together at the ends of rows instead of flushing**

One grower in 2013 was complaining of numerous plant deaths, especially in the outer rows. We found his trickle irrigation was not buried, but placed on top of the bed (under the plastic). Instead of being between the two pairs of rows it was hard up against the inner row, leaving the outer row of plants subject to moisture stress. We advised the grower to bury the tape slightly next year. That grower also had 5–10m of plants at the end of several rows that were dead or dying. He had simply looped the tape around the ends of the beds so no flushing of the lines could occur (Figure 8). He was advised to terminate the two lines separately and use flushing valves.

The grower had not taken up any of our recommendations in 2014

## Plant establishment

### *Variety issues*

There were distinct differences in plant health and survival between Fortuna plants of differing origin.

**Victorian Fortuna:** No dead plants in three of four plots. Five plants over the four 50-plant plots were apparently diseased (lethal yellows 1, crown rot 1, nearly dead 1 or very small 2).

**Queensland Fortuna, early shipment**: 14 dead (7%) over the four 50-plant plots and 15 plants small/stunted.

**Queensland Fortuna**, **late shipment**: Five plants (2.5%) dead over the four 50-plant plots and 12 plants small/stunted.

This grower did not consider his losses to be particularly high, but other growers experienced up to 15% losses. On the demonstration site losses of Fortuna were between 11 and 13% and there were also 23 times that number of plants significantly lacking in vigour, as well as about 3.5% that appeared diseased.

## Sprinkler effects

Table 8 and Figure 9 show the effect of poor sprinkler coverage (Naan 5022 at 15m x 11m offset) on plant establishment, in terms of plant losses and low vigour for Grower 4. Row 93 is intermediate between sprinklers and the proportion of healthy plants was only 60%.

**Table 8. Effect of poor sprinkler design on establishment of Festival for Grower 4; from four 50-plant plots at various positions along the row**

| Row no. | Dead | Low vigour | Healthy |
|---|---|---|---|
| 87 | 1 | 0 | 49 |
| | 1 | 1 | 48 |
| | 1 | 1 | 48 |
| | 1 | 2 | 47 |
| **Total** | **4 (2%)** | **4 (2%)** | **192 (96%)** |
| 90 | 6 | 8 | 36 |
| | 2 | 6 | 42 |
| | 6 | 6 | 38 |
| | 4 | 9 | 37 |
| **Total** | **18 (9%)** | **29 (14.5%)** | **153 (76.5%)** |
| 93 | 10 | 18 | 22 |
| | 1 | 9 | 40 |
| | 9 | 12 | 29 |
| | 8 | 12 | 30 |
| **Total** | **28 (14%)** | **51 (25.5%)** | **121 (60.5%)** |
| 96 | 6 | 4 | 40 |
| | 2 | 2 | 46 |
| | 2 | 4 | 44 |
| | 3 | 5 | 42 |
| **Total** | **13 (6.5%)** | **15 (7.5%)** | **172 (86%)** |

**Figure 9. Visible differences in plant establishment due to poor overhead sprinkler design**

Disease counts were planned at this property but the effect of the poor sprinkler coverage on plant establishment and vigour were so great that they outweighed any effect of drip irrigation pressure on plant health.

The effects of poor sprinkler design (Naan 5022 at 12m x 11m offset) at Grower 7's property were not as clear. Camarosa, a more robust variety, seemed to tolerate this better than Fortuna.

**Table 9. Plant counts from Grower 7 (means of three 50-plant replicates)**

| Variety | Distance from sprinkler row | Healthy | Low vigour | Diseased | Dead |
|---|---|---|---|---|---|
| | | | % | | |
| **Camarosa** | Close | 92.0 | 2.7 | 0.7 | 4.7 |
| | Between | 94.0 | 2.7 | 1.3 | 2.0 |
| **Fortuna** | Close | 90.7 | 4.0 | 0.7 | 4.7 |
| | Between | 86.7 | 7.3 | 0.7 | 5.3 |

## Intensive soil moisture, conductivity and temperature monitoring

Figure 10 shows the lack of movement in soil moisture at the edges and centres of the beds. The peaks were due to infiltration of rain from pathways between the beds into the beds. The soil moisture readings are essentially dry, that is, sub-optimum, and did not differ between the 110kPa and 55kPa pressures in the beds.

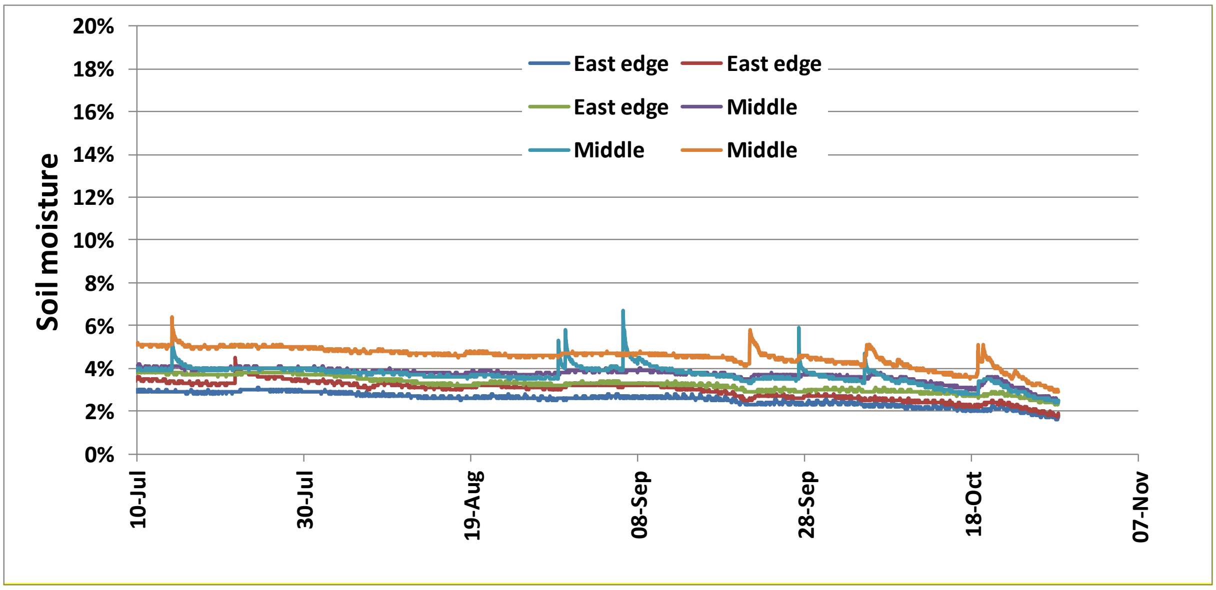



**Figure 10. Soil moisture readings typical of edges and middle of strawberry beds**

For the sensors situated under an emitter line we saw huge variation in soil moisture content over only a very small area. The sensors between two emitters hardly moved at all whereas those under an emitter showed drastic changes in soil moisture with every irrigation. The vertical nature of the lines shows that it is drainage not plant water use. So we have three quite contrasting lines all within 10 cm of each other. In the 100kPa bed (Figure 11) the soil moisture content increases to 16% with each irrigation but settles to about 7–8% between irrigations. In the low pressure bed (Figure 12) soil moisture varied between peaks of about 12% and 4–4.5% between irrigations. Again, this was dry for WA coarse sands.

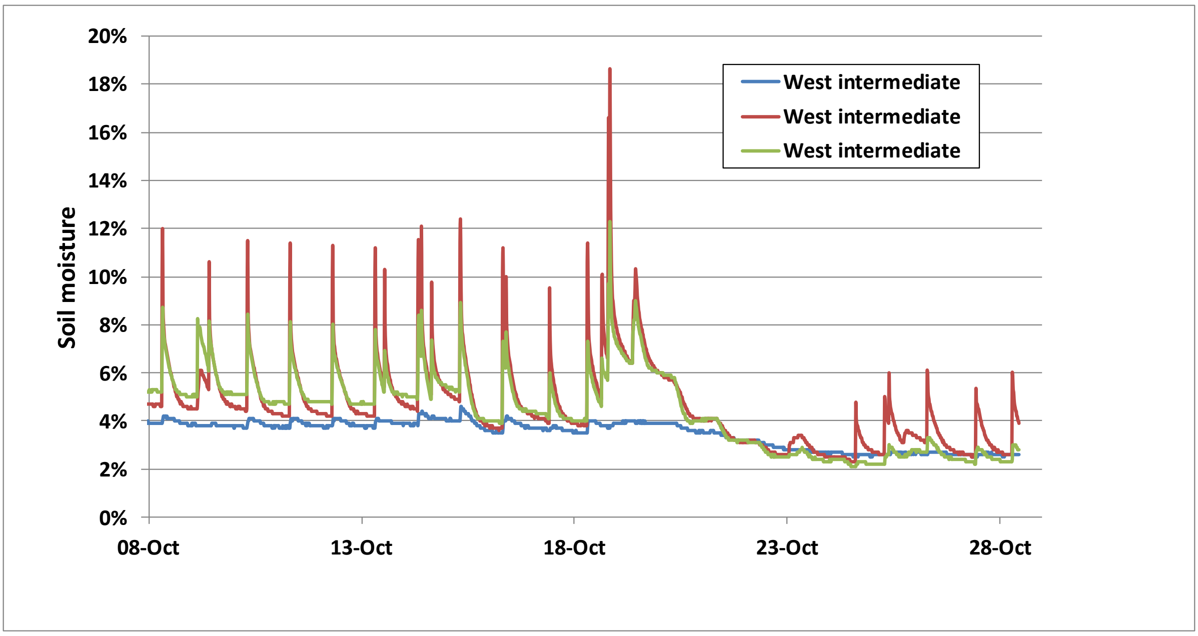



**Figure 11. Soil moisture readings below the dripline for the 110kPa line**

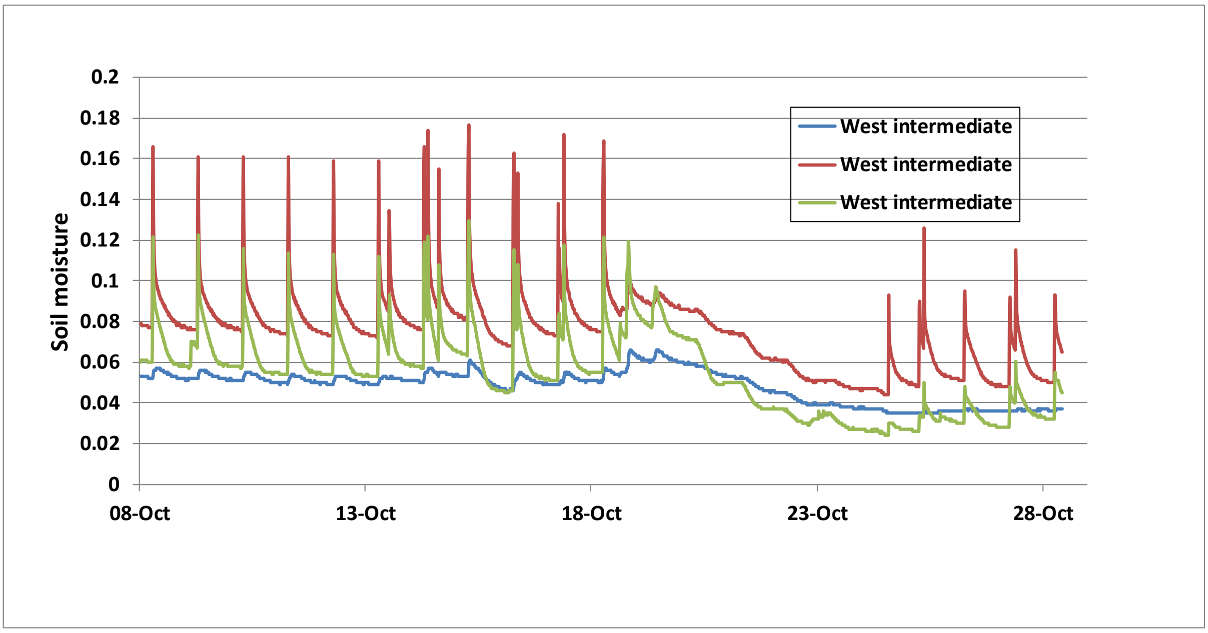



**Figure 12. Soil moisture readings below the dripline for the 55kPa line**

Figures 13 and 14 show the soil conductivity readings followed a very similar pattern to soil moisture. In both cases the baseline EC was roughly the same, but the peaks with each irrigation varied markedly between the two pressures.

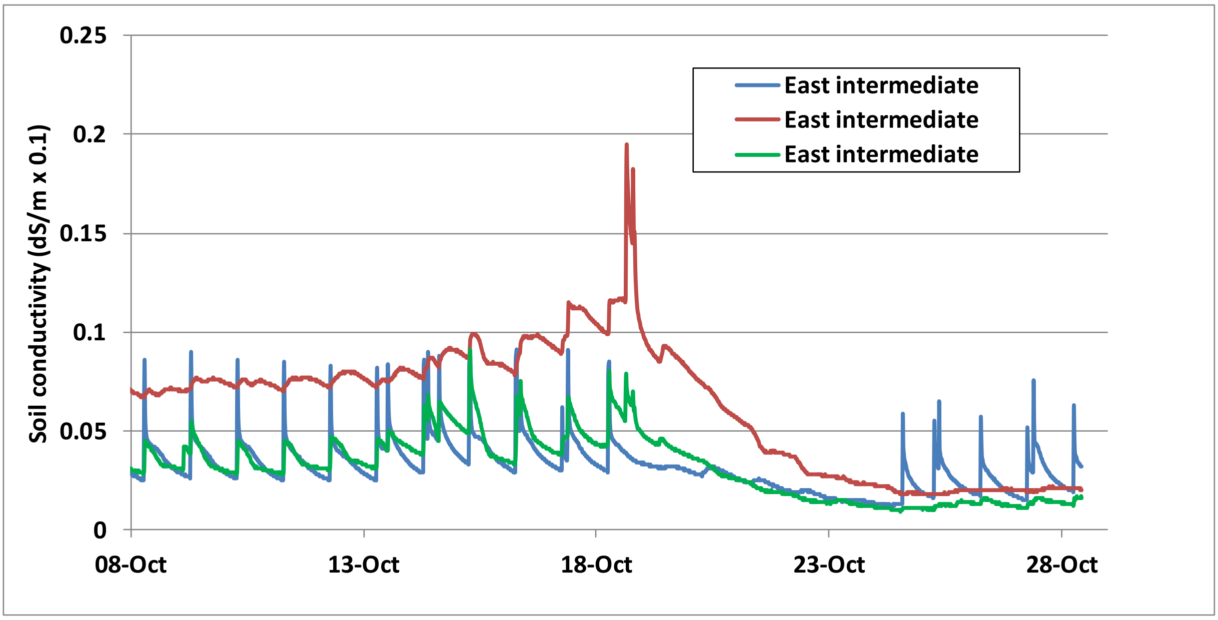



**Figure 13. Soil conductivity readings below the dripline for the 110kPa line**

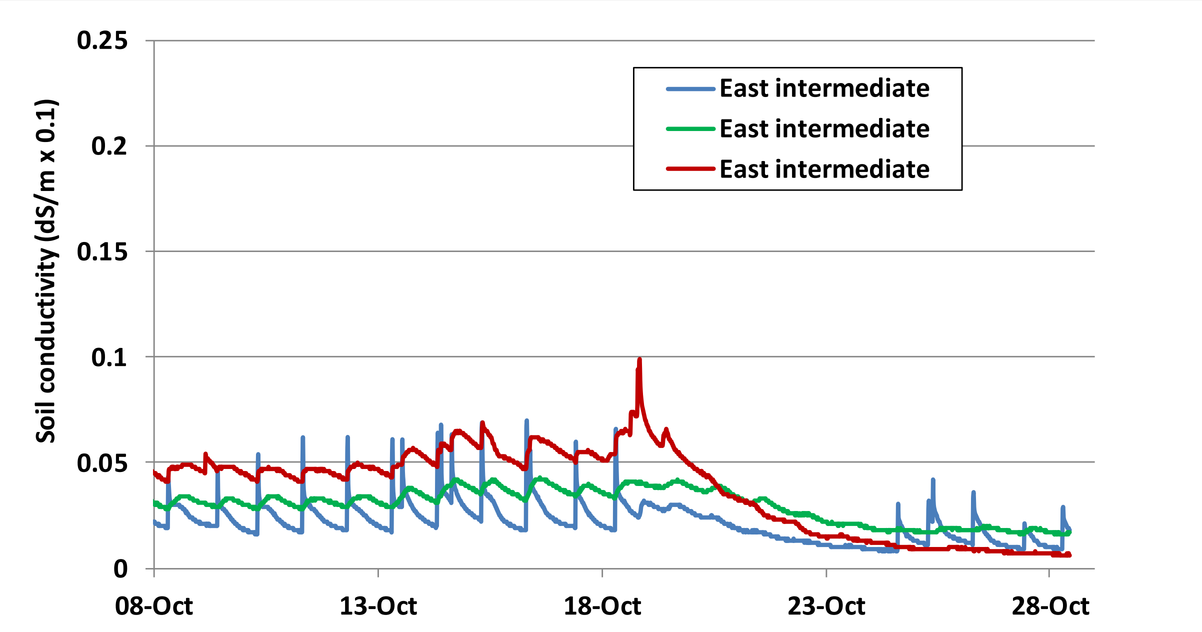



**Figure 14. Soil conductivity readings below the driplinefor the 55kPa line**

Figures 15 and 16 show the temperature profiles for the two beds. We did not see the differences expected between the east and western sides of the beds – in all cases it was less than 1ºC but it has to be remembered that the probes were at 15cm depth.

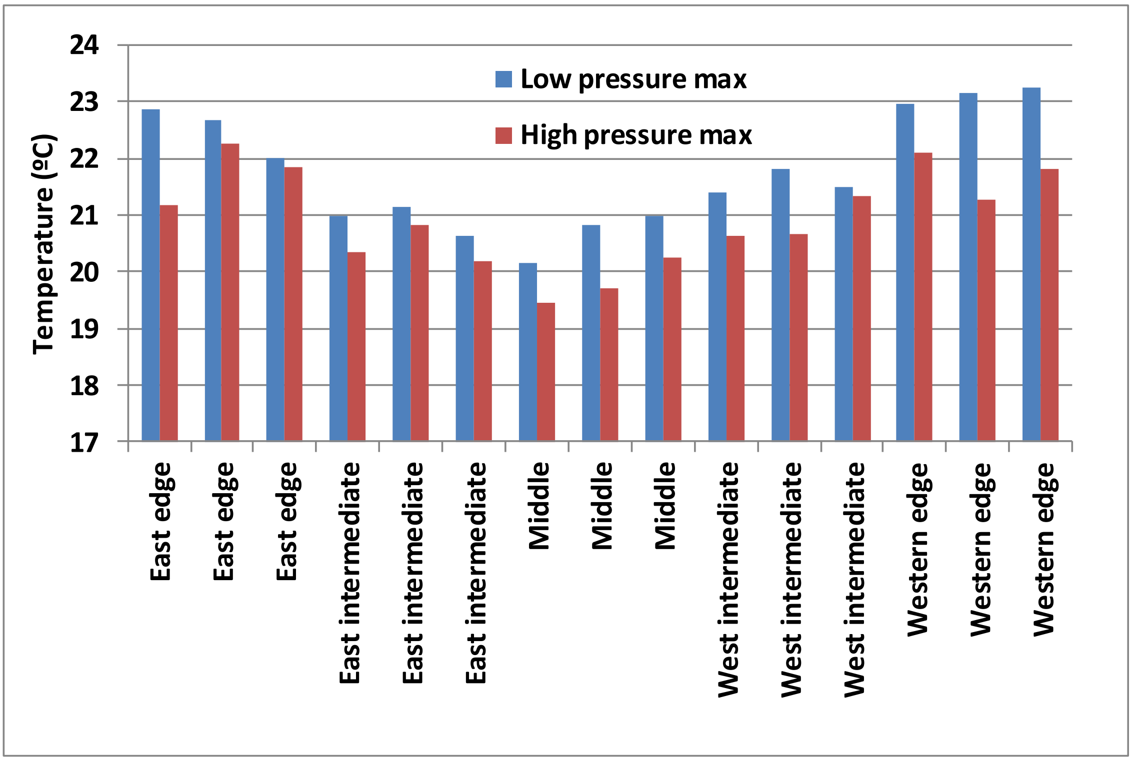



**Figure 15. Maximum temperature profile across a strawberry bed**

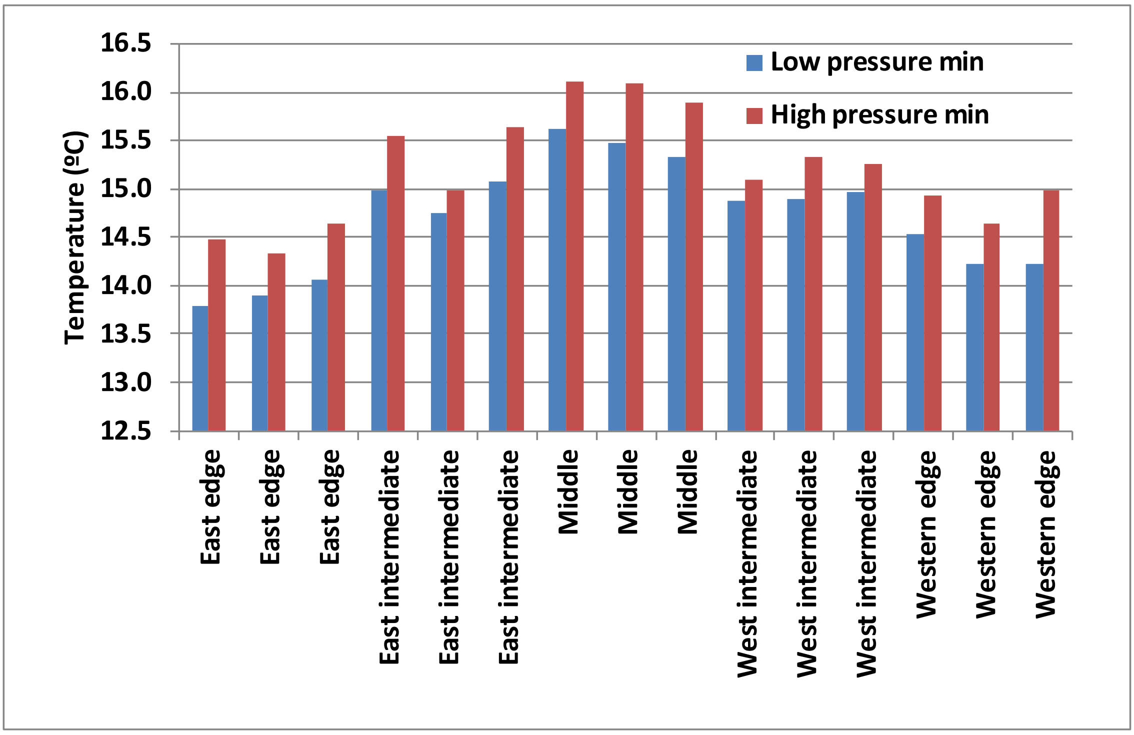



**Figure 16. Minimum temperature profile across a strawberry bed**

## Dye demonstration 1

The day before the field day, a system to inject water containing blue dye was set up at the grower consultant's property. A series of beds was set up with Netafim® drip tape with 10, 20 and 25cm emitter spacings. Three beds were compacted as normal and one bed was left uncompacted. Images of the demonstration and details of watering patterns are provided in Appendices 19 and 20.

One outstanding feature was that for the most commonly used emitter spacing, the watering patterns did not meet, regardless of whether 0.25L or 2L of water was applied. The 10cm emitters were the only ones where the wetting patterns met. This may have considerable implications for the growers. It is a common belief that strawberry plant roots migrate towards wetted areas – and that may be true. However, there is risk that if the root area is confined there will be a zone of fluctuating soil moisture and EC that may damage roots. A previous HAL project that had a few treatments (unreplicated) comparing 10cm with 25cm emitters found increases in yield from 7 to 21% with the 10cm emitter spacing depending on variety (Albion greater than Camino Real which was greater than Camarosa).

The discontinuous wetting pattern may also compromise the efficacy of fumigation. Rural Inline is injected as a liquid through the drip irrigation and the depth to which it penetrates and the pattern of dispersal as it vaporises, need to be addressed for WA sands. These wetting patterns raised more doubts and questions than previously thought.

## Dye demonstration 2

The second dye test was set up at our intensive monitoring site (Grower 4). Unfortunately, the grower had problems with the irrigation in the week prior to this exercise and we suspected the wetting pattern seen was not typical of that throughout the season. The results were enlightening and showed what happens if the soil dries out and is allowed to become non-wetting.

After two 15-minute irrigations with 1L per dripper tape, 0.5L of water had been applied. In previous work on similar soil 0.5L had travelled around 30cm deep and spread 15 to 18cm wide. On this occasion, digging through the bed showed very narrow (8–10cm wide) wetted areas that were 55–65cm deep (Appendix 21).

# Irrigation and fertiliser practice

Fertiliser programs used were not easy to determine. Some growers were quite open and provided their details while others were more reticent. Some growers were buying fertiliser from a third party and did not know exactly what was in it. We also found that programs often changed and could be hard to track.

Fertiliser application practice ranged widely. Some growers fertilised with each watering, others as little as once every four days. Some used two tanks and injected both at every irrigation while others alternated their recipes. Table 10 sets out the information we had been given at 20 September 2013. Some growers' programs seemed to change regularly.

**Table 10. Irrigation and fertiliser snapshot as at 20 September 2013**

| Grower | Irrigation duration (mins) | Daily irrigation frequency | Fertiliser program |
|---|---|---|---|
| **Grower 1** | 40 (sandy area) | 2 | Every four days with alternating recipes |
| **Grower 1** | 15 (peaty area) | 2 | Every four days with alternating recipes |
| **Grower 2** | 12 | 3 | With each irrigation* |
| **Grower 3** | 20 | 2 | With each irrigation, alternating recipes |
| **Grower 4** | 10 | 2 | With each irrigation |
| **Grower 5** | 60 | 1 | Daily |
| **Grower 6** | 50 (30 + 20) | 2 | Daily in the morning |
| **Grower 7** | 30 | 2 | With each irrigation |

* at our first meeting we were told twice a week with alternating feeds

A common practice seemed to be that when prices fell, growers stopped fertilising, and when prices picked up they started fertilising again.

Soil nitrate testing is a useful tool. Grower 1 was shown how much his soil nitrate levels dropped between fertiliser applications compared with those of other growers who fertilised with each irrigation, or at least daily. Grower consultant Gerry Verheyen showed him and several other growers the set-up on his own property and Grower 1 indicated he was going to install A and B tanks and dose pumps to fertigate with each irrigation.

# Field days

## 27 February 2014

The first major field day was held to coincide with the dye demonstration (Figure 17).

**Figure 17. Growers at the field day inspecting the dye demonstration (left) and Vietnamese interpreter Tam in action (right)**

The dye demonstration (Appendix 20) had some impact with a few growers indicating they might move away from 20cm emitters to those with closer spacings.

Interstate visitors included George Weda and Diane Davies from Toolangi Growers Co-operative with Dr Scott Mattner (ex-Victorian DPI and now employed by VSICA). Some useful discussions, facilitated in Vietnamese, were about quarantine with runner importation and treatment early in the season. In particular, Scott, having worked on fumigation trials, was able to pass on his experiences and comments.

We agreed that the current practice of using Rural Inline® may not be the best option for growers in WA sands, and given the prevalence of *Fusarium*, a product with a higher proportion of chloropicrin might be in order. Scott seemed surprised that growers were allowed to apply Rural Inline® themselves, as overseas it is regarded as a skilled task requiring proper training (quite apart from the fact that most of our growers' irrigation systems are incapable of applying it evenly).

## 5 November 2014

The field day was again held at the grower consultant's property in combination with the SGAWA AGM. We had intended to visit the demonstration site but decided there was not enough to see that would be of interest – the demonstration site being, realistically, just another strawberry field. We gave presentations on the results to date from the demonstration and intensive monitoring sites including the second batch of dye tests.

## 6 March 2015

The final field day was combined with an SGAWA meeting at the grower consultant's property (Figure 18). An outline of the fumigation survey work was given by Dr Scott Mattner (Figure 19) and Aileen Reid. Rohan Prince (Irrigation Research Officer) and Aileen Reid summarised the issues around irrigation and runner establishment.  Lam Ti Muir (Figure 20) acted as our interpreter for the day.

**Figure 18. Growers at the field day on 6 March 2015**

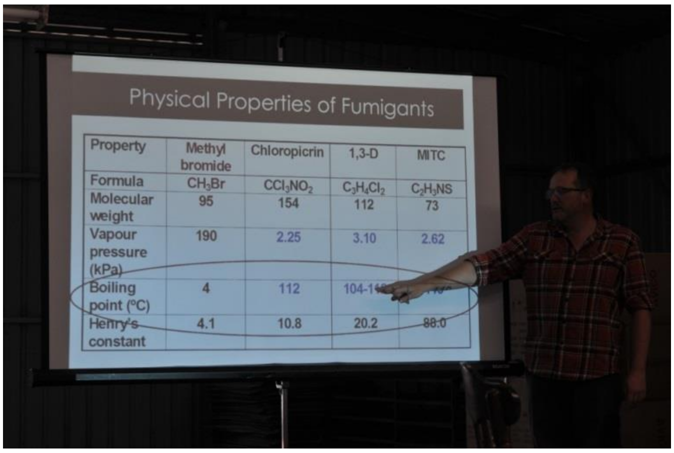



**Figure 19. Dr Scott Mattner explains the properties of various fumigants at the field day**

**Figure 20. Lam Ti Muir, our translator for the field day**

## Fumigation

The efficacy of fumigation relies on understanding the principles of irrigation and water movement in coarse sands. While talking to growers about their irrigation designs and fumigation practices it became apparent that there were major issues with the way in which fumigants were being used. For example, we discovered one grower using the fumigant metham sodium through the dripline (off-label use). The same grower also experienced high plant losses in the middle row of his beds.

The reason was that he had three rows of plants per bed with two rows of drip and the middle row received a double dose of fumigant (Figure 21).

**Figure 21. High rate of plant death in middle row due to overdose of fumigant**

It seemed many growers might not have been applying fumigants as per the label and the necessary training requirements may not have been fulfilled. The vegetablesWA Vietnamese industry development officer (IDO) Truyen Vo, seemed to have similar concerns, although they were about crops other than strawberries (such as drip-irrigated capsicums and cucumbers).

Several discussions were held with SA Rural, our local distributor and reseller. It culminated in a meeting at DAFWA South Perth between several officers from the Department of Health, the SA Rural General Manager and previous manager, Dow Agrichemicals, the Australian Pesticides and Veterinary Medicines Authority (APVMA), Truyen Vo, and several officers from DAFWA.

The training records we were able to find showed some training from 2009 at the latest. At that time the main fumigant now in use, Rural Inline®, was not common. Several growers had been trained in methyl bromide which is also no longer used. At the time of the training, Telone-C35® was being used, applied in the same manner as metham sodium, by shank injection. We understand growers were being told to apply Rural Inline® using the same method, contrary to the label. Discussions indicated that was true. We were told it was more effective and since the field day we can understand why that may be, however it is contrary to the label and therefore illegal.

The outcome of the meeting was an agreement that Dow Chemicals and SA Rural would conduct a training course in WA in the second half of November 2014. They were also to produce a video with a voiceover in Vietnamese. Dr Phat, one of the suppliers, was to assist.

That training was completed but no-one from DAFWA was informed or invited. It was held on a Saturday and we heard from a Department of Health (DOH) officer that the first day was very disorganised. To fulfil DOH requirements further days had to be scheduled to fully train all participants. The additional days meant training went into December and some growers who had holidays booked could not attend. There was no component for anything other than fumigation with the inline product and no practical component for at least the first training group.

Our ongoing suggestions that Telone C-60® might be the better product for WA continued to be ignored.

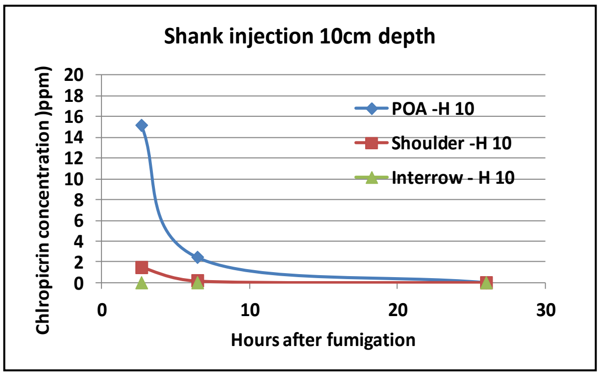
## Fumigation survey

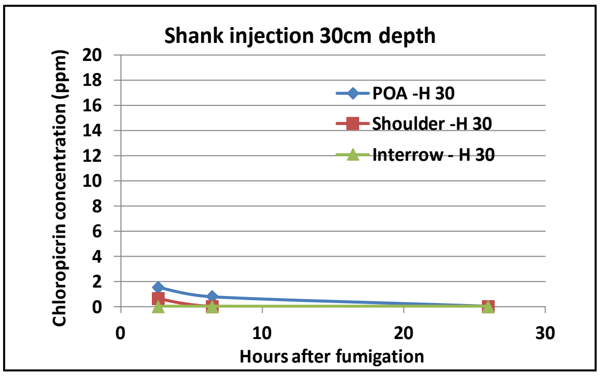
Photos from the fumigation survey can be found in Appendix 22. The first shank injection survey measured very low levels of gas in the soil (Figures 22-25). The grower assured us he had just finished fumigating his own block and was using Telone-C35® at a rate that would give the correct amount of product per hectare of bed. However, the gas levels were very low at the first two readings several hours after fumigation and even lower, not higher as expected, the next day.

The inline fumigation gave much better gas levels as shown in. We checked how many bottles the grower had used for the area and the rate was 670kg/ha, around the middle of the label recommendation (470–900kg/ha). We used two sites at this property to compare areas with higher (Figures 26-29) and lower operating pressure (Figures 30-33).

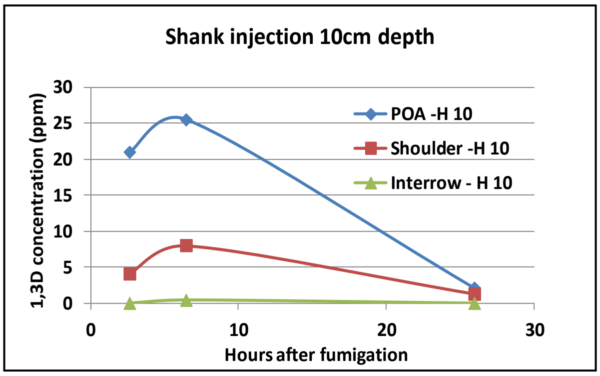
The second survey of shank injection gave much better gas levels which seemed to verify there had been a problem with the first fumigation (Figures 34-37). When we clarified the rate used for this survey it was 476kg/ha which is at the very low end of the recommended range. To allow for this discrepancy, one set of graphs has been constructed with adjusted data (Figures 38-41).

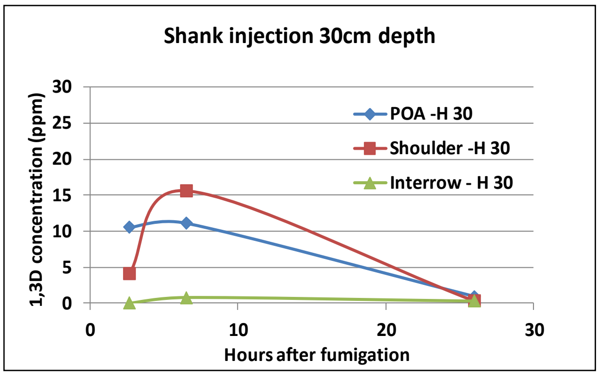
Some consistent trends were found. Chloropicrin and 1,3D were moving laterally to the shoulders of the beds at 10cm, much better and earlier in the shank treatment than the inline treatment (i.e. concentrations of the gases between the point of application and shoulder were most similar with the shank method). This is important because pathogens such as *Fusarium* are mostly concentrated in the upper part of the bed. The trends show more even coverage of the upper bed with shank than inline.



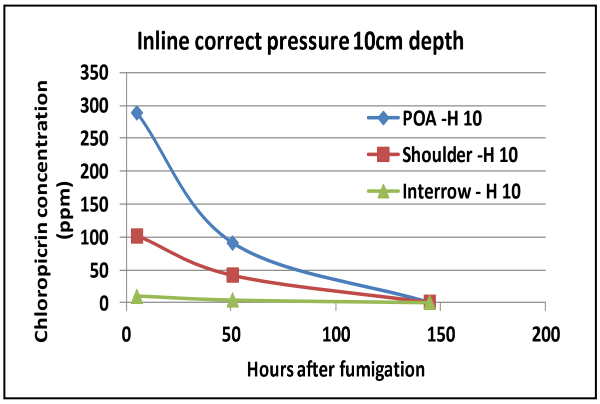



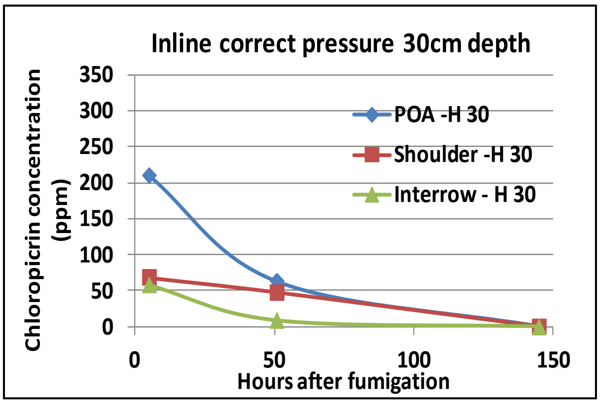

**Figures 22 and 23. Trend in chloropicrin levels at 10cm and 30cm depth after fumigation by shank injection (unknown rate of Telone-C35®) with very low gas concentrations**



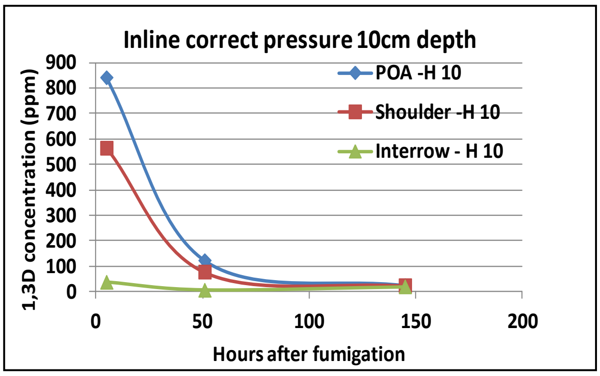



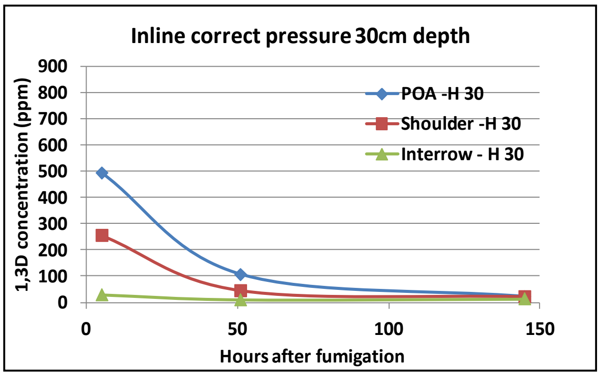

**Figures 24 and 25. Trend in 1,3D levels at 10cm and 30cm depths after fumigation by shank injection (unknown rate of Telone-C35®) showing very low concentrations**



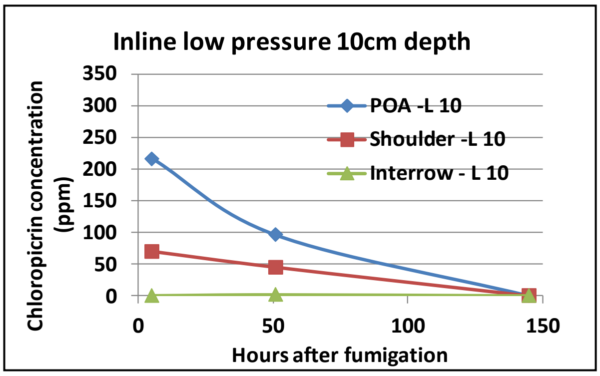



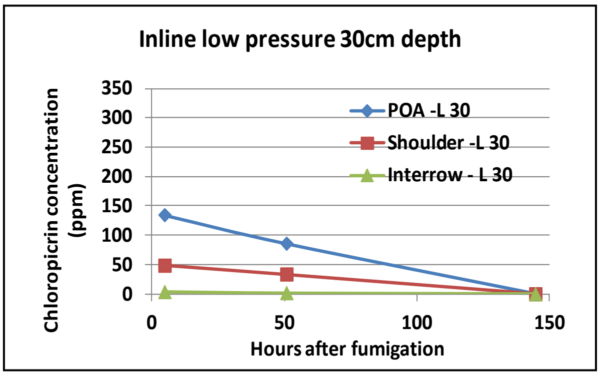

**Figures 26 and 27. Trend in chloropicrin levels at 10cm and 30cm depth after inline fumigation at the correct operating pressure using 670kg/ha of Telone-C35®**



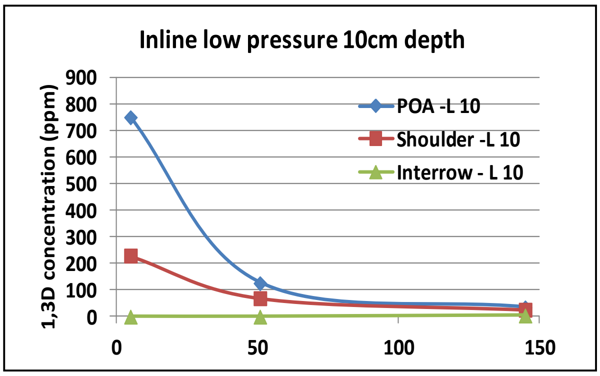



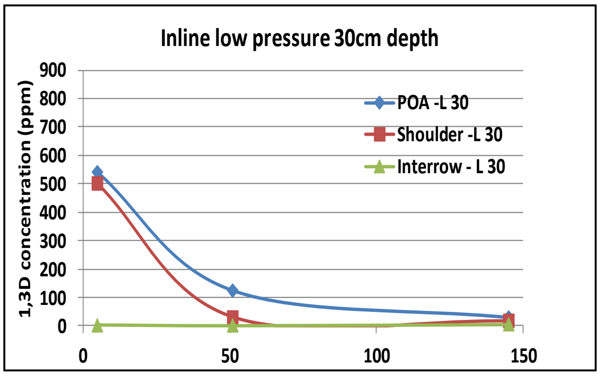

**Figures 28 and 29. Trend in 1,3D levels at 10cm and 30cm depth after inline fumigation at correct operating pressure, 670kg/ha of Telone-C35®**



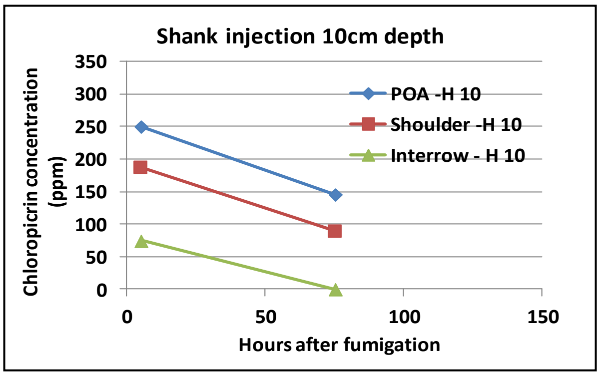



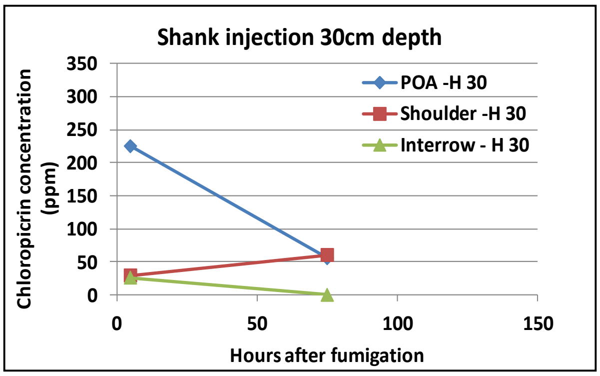

**Figures 30 and 31. Trend in chloropicrin levels at 10cm and 30cm depth after inline fumigation at suboptimal operating pressure using 670kg/ha of Telone-C35®**



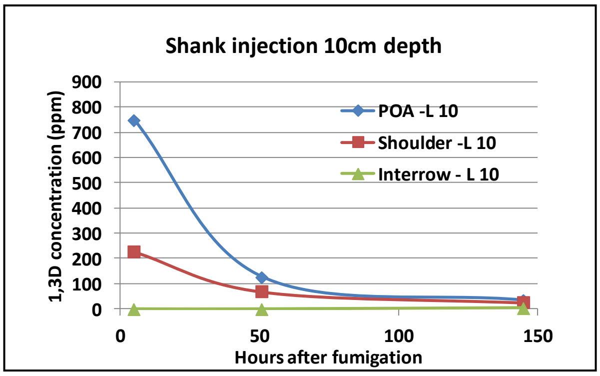



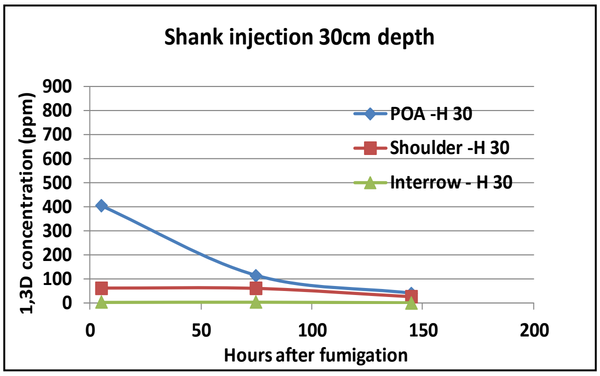

**Figures 32 and 33. Trend in 1,3D levels at 10cm and 30cm depth after inline fumigation at suboptimal operating pressure using 670kg/ha of Telone-C35®**



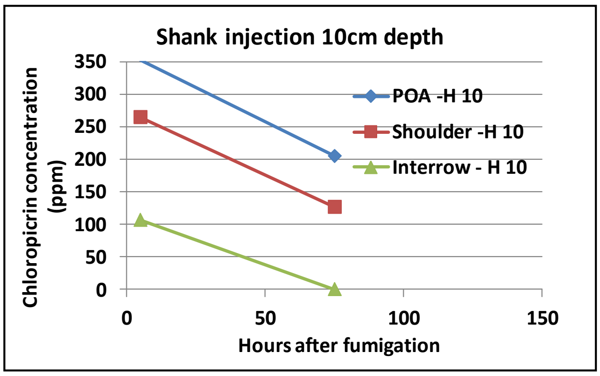



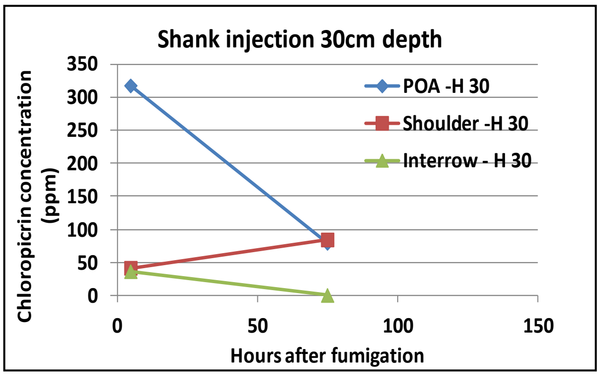

**Figures 34 and 35. Trend in chloropicrin levels at 10cm and 30cm depths after fumigation by shank injection using 476kg/ha of Telone-C35®**



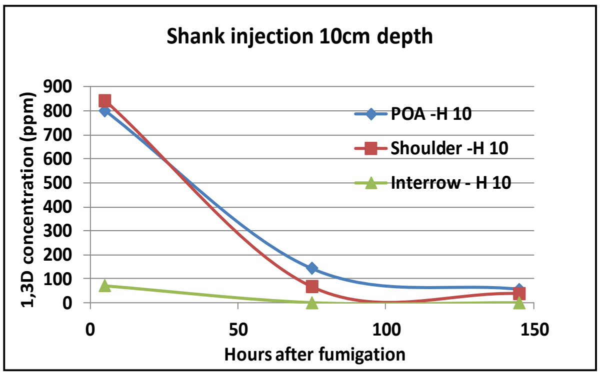



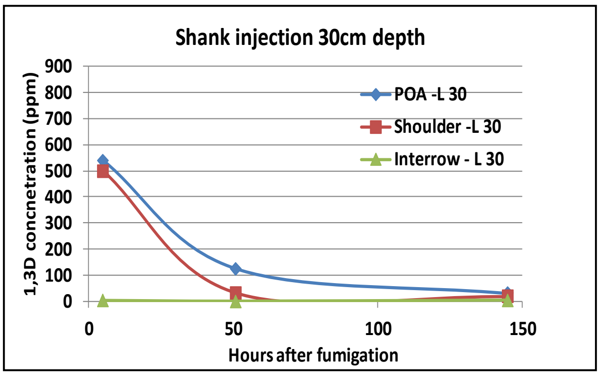

**Figures 36 and 37. Trend in 1,3D levels at 10cm and 30cm depth after shank injection using 476kg/ha of Telone-C35®**




**Figures 38 and 39. Trend in chloropicrin levels at 10cm and 30cm depth after shank injection with rates adjusted to equal 670kg/ha of Telone-C35®**




**Figures 40 and 41. Trend in 1,3D levels at 10cm and 30cm depth after shank injection into dripline with rates adjusted to equal 670kg/ha of Telone-C35®**

# Evaluation and Discussion

It became apparent at an early stage in the project that many growers' levels of English, while overtly reasonable in conversation, failed when dealing with technical terms or written English. Grower 9 showed us pictures in a 'Ute Guide' as examples of a problem he was having with his plants, however the photos were of potassium **deficiency** and he had been treating it as a **toxicity** and avoiding high potassium-based fertilisers.

Many growers did not communicate in English by email or even text messaging even though most had mobile phones. There is still a distrust of government and a reluctance to participate for fear of not performing well. Often growers did things not knowing why, only knowing that it worked, or believing the reason it did was due to something totally irrelevant. Our grower consultant has been visiting many of these growers for about 20 years, dealing with the early season runner issues, but it was difficult even for him to gain support on some issues such as the fumigation survey. As project leader, my participation in the industry has only been a fraction of that time and it will take many more years of hard work to build respect and trust. Most will have retired in that timeframe.

Strawberries present several challenges to a researcher, the most significant in terms of outputs was how to accurately measure yield. Although an annual, they crop continuously through the season, so collecting yield data was onerous. Growers could not be relied upon to leave plots untouched even if clearly marked.

The disease management part of this project has been the most difficult. Plant pathologist time was an integral part but our appointed pathologist left to complete a PhD prior to the start, and I had to find a replacement at short notice. In the first year two DAFWA pathologists worked together to supply some of the requirements, but neither had any experience with strawberries. In the second year the timing of project requirements and prior commitments of the pathologists used in 2013 conflicted heavily, so the project milestones were revised to delete that part of the project.

*Gnomoniopsis* highlights many of the issues faced. Conflicting opinions were encountered about its control. Most literature and trials centred on its control as a leaf pathogen and not a calyx issue. There was evidence of systemic infection of planting material.

Many growers remove the leaves from leaf-on runners about three weeks after planting, saying they find it helps with control. Cloche management was variable and undoubtedly the high humidity under the closed cloches combined with water dripping from the covers when they are raised and lowered, promotes not only *Gnomoniopsis* but also *Botrytis*. However, raising and lowering cloches is highly labour intensive, so getting growers to change their practices may be difficult. High tunnels may be a good option but their cost effectiveness has not been proven. Powdery mildew is more of a problem with high tunnels than cloches.

## Carryover of disease and fungicide resistance from runners to fruit

When runners arrive in Western Australia they often carry some level of a range of diseases such as *Gnomoniopsis*. Currently, the fungicides used in runner production are the same as those used in fruit production. This increases the opportunity, if it doesn't exist already, of fungicide resistance.

Project BS13004: *Integrated approach for controlling foliar diseases in strawberry runner nurseries and managing chemical resistance* is researching this issue and it is hoped that in the near future there will be some fungicides registered specifically for runner production of different chemistry than those already used in fruit production. When those fungicides are registered it will be a matter to ensure growers in WA do not use them.

## Plant establishment

Several other issues at establishment may result in or be wrongly attributed to disease when management aspects are the more likely cause. These include:

1. Uneven soil wetting, resulting in uneven fumigation and hence pockets of viable pathogenic fungi

2. Uneven soil wetting, followed by suboptimal overhead sprinkler irrigation – both in terms of system design resulting in inadequate coverage and/or poor scheduling. Growers' irrigation systems are often not designed to cope with using both sprinklers and drip at the same time. The way holes are punched in the plastic for planting varies and so varying amounts of overhead irrigation may or may not penetrate the plastic mulch. Some growers leave the filters out early in the season to get better pressure, which may lead to emitter blocking.

3. Leaving bags of runners sitting on the black plastic while planting is not good practice.

4. The variety of base dressings used, the time from planting to fertilising and actual irrigation practices during establishment vary widely and many are well below optimal. Soil testing has shown huge variation in soil nitrate (13–174mg/L) and EC at the time of planting. Some higher values could damage young plant roots.

5. Some growers make large holes in their plastic for the runners which means the overhead irrigation penetrates well, whereas other growers have tiny slits and clearly need to operate both systems together (though some growers cannot physically do so).

These practices mean variable establishment rates and struggling plants succumb to disease more easily.

## Poor environmental control

Because raising and lowering cloche covers is labour intensive, the covers are often left unopened or partially open unless fruit is being picked. It is common to see cloches ranging from 25 to 75% open at any one time, as in Figure 44 rather than being fully and evenly open as in Figure 45. This lack of ventilation subjects plants to high humidity and predisposes them to *Gnomoniopsis* and *Botrytis* infection.

**Figure 44. Variable cloche positions on a sunny day in June at 1pm**

**Figure 45. Cloches uniformly opened, on a sunny day in June at 12:30pm**

## Lack of understanding of relationship between plant stress and disease

The prime example of this is the problems that exist as a result of growers pushing runner growers to supply Fortuna early. Fortuna runners can be fragile when they have not received the required amount of chilling and growers frequently complain about significant losses, which they attribute to disease, but which is really more about the frailty of the runner when it lacks adequate chilling.

## Fumigation

Our small survey showed that fumigation in coarse sands was problematic by either method. The lateral spread of gas is highly variable and probably affected by the level of soil compaction and degree and uniformity of soil wetting. Nearly all growers who use shank injection do not monitor the flow rate accurately and certainly not on each tine.

The number of tines used per bed varied. The results showed that two (30cm spacing) or even three (approximately 25cm spacing) were inadequate – not surprising given the lateral spread of water in sands is only about 10cm.

At the field day it became apparent that growers were being advised by one of the fumigation contractors/resellers to use the rate of fumigant as stated for vegetables on the label which is well below that stated for strawberries. It seemed that his word carried more weight than the label.

# Recommendations

The project raised a number of issues that industry needs to address to optimise production.

1. **Soil/bed preparation and growing system**. Problems achieving evenly and thoroughly wet soil prior to bed formation and fumigation need to be addressed. We commonly encountered dry patches in beds early in the season. These were likely to have affected both fumigation efficacy and plant establishment. Then, as evidenced by our experience with one grower, even a few days without irrigation saw the development of preferred pathways. There could be several ways of addressing this from amending the soil, using soilless media and/or a different growing system.

2. **Irrigation systems.** This overlaps with land preparation. Poor irrigation design is widespread and few growers were interested in improving it. The impact on fumigation did not seem to be realised. It was compounded by the fact that growers were being persuaded to use inline fumigation rather than shank injection, which is more efficient.

3. **Soil water movement from the pathways into beds**. Our monitoring has shown this occurs at 15cm, shallow enough to be in the crop root zone. Therefore, fumigation of beds alone, is risky, as disease will survive in the pathways and be carried in by rain. This is exacerbated when rainfall volumes can be magnified by up to four times by sheeting off the cloches.

4. **Low cloches**. Variable and generally poor management of cloches is increasing the incidence of foliar diseases.

5. **Carryover of disease and fungicide resistance from runner growers to fruit growers requires attention**. It is pleasing to see it is being addressed by at least two current HIA projects.

6. **Fumigation**. Our survey has shown that fumigant levels vary enormously within strawberry beds and the current practices using two or even three points of injection are inadequate. Better monitoring of amounts of fumigant applied is needed as is better adherence to label recommendations.

# Scientific refereed publications

None to report.

# Intellectual Property/Commercialisation

No commercial IP generated.

# Reference

Phillips D, Reid A and Verheyen G 2008, Facilitating the development of the strawberry industry in Western Australia, Horticulture Australia Limited Project BS05001 (Finish date: 31/05/08), Department of Agriculture and Food, Western Australia (DAFWA), Strawberry Growers Association of Western Australia (Inc.).

# Acknowledgements

The project would not have been possible without the capable assistance of team members, Rohan Prince (Irrigation Research Officer), Rob Deyl (Project Technical Officer) and Gerry Verheyen (Grower Consultant).

Input on experimental design and assistance with disease assessments from Dominie Wright, Carla Wilkinson and Sarah Collins (Plant Pathologists) is also gratefully acknowledged. Truyen Vo from vegetablesWA also helped with grower introductions.

We appreciate the co-operation of those growers who allowed us onto their properties to mark out plots, harvest fruit, assess irrigation or install monitoring gear: Chi Do, Le Van Dien, Nhan Quach Trung, Selwyn Altmuner, Jamie Michael, Lam Ti Muir, Peter Doan, Dang Thanh Ngoc, Truong Tho Hoa, Truc Hoa, Hoang Van Tiep, Van Chuc Nguyen, Duong Can Oanh, Lam V An and Tran Huynh.

Specialised assistance with irrigation equipment from David MacCall and Lloyd Tucker at SDS Connect, and irrigation design from Paul Officer at Netafim was also appreciated.

Georgina Wilson (Wilson for Words) provided editing assistance.

# Appendices

## Appendix 1: Introductory project letter to growers in English and Vietnamese

**STRAWBERRY GROWERS ASSOCIATION OF WESTERN AUSTRALIA INC.**

PO BOX 382 WANNEROO 6946

1 July 2013

Dear strawberry grower,

Would you like to produce more fruit using less water and fertiliser?

Would you like to be able to pick more marketable fruit and throw less diseased fruit away?

Would you like to have less dead and dying plants on your land?

You may already know that a very small part of the money you get from selling fruit goes into a fund where it can be used to help solve industry problems (the APC fee for service). With help from the Department of Agriculture and Food, some of that money has been matched by a funding body (Horticulture Australia Limited –HAL) and will be used to help you with these problems.

The Department of Agriculture and Food WA (DAFWA) together with your association, has been successful in getting funding to work on these issues with you, the Vietnamese strawberry growers, over the next three years. The project is called '*A focus on irrigation and fertiliser practices to improve production efficiency for LOTE (Language other than English) strawberry growers.'*

We believe we can help you to fumigate your soil better so less disease gets in. Strong healthy plants can also resist disease better and how you water and feed your plants has a big impact on that. We are looking for growers to be a part of this project. It won't cost you anything and we believe we can help you make more money. All we need is your cooperation and about an hour of your time, say once a week. The degree of involvement you have in the project is up to you.

**What sort of things can we do?**

We can come in and look at your irrigation system to see if it is putting water on evenly and if not, help you to change it so it does. Even watering is needed for the fumigation you do at the beginning of each season, to work well, so the soil is clean and disease free.

We can also help you to use the fertiliser you put on, more efficiently. In our sandy soils in Perth it gets washed away very easily and that means the plant misses out on the food it needs. And you are paying for something you aren't getting any benefit from.

We can also have a look at where your disease is coming from and why and help with that too.

All this means that you can grow better plants with more fruit and make more money!

If you are interesting in finding out more, ring any of the phone numbers below, send us an email or just fill in the form over the page and return it. We can come out and see you to explain things in more detail.

Hope to hear from you soon!

Yours sincerely

Gerry Verheyen (APC Strawberry growers Committee)

Aileen Reid (DAFWA)

**People to contact to get involved:**

Gerry Verheyen on Mob: 0417 171 327 or email: gaverheyen@iinet.net.au

Aileen Reid on Mob: 0467 783 981 or Ph: 9368 3393 or email: aileen.reid@agric.wa.gov.au

Rohan Prince on Mob: 0429 680 069, Ph: 9368 3210 or email: rohan.prince@agric.wa.gov.au

I am interested in knowing more about the strawberry project

| | |
|---|---|
| Name: | ......................................................................... |
| Address: | ......................................................................... |
| | ......................................................................... |
| | ......................................................................... |
| Phone number: | ......................................................................... |
| Mobile: | ......................................................................... |
| Email: | ......................................................................... |

**HIỆP HỘI TRỒNG DÂU TÂY ÚC**
Hộp thư: P.O. Box 382, Wanneroo WA 6065

1 July 2013

Kính chào quí vị trồng dâu,

Quí vị có muốn nâng cao năng xuất cây dâu mà sữ dung ít nước tưới và phân bón không?

Quí vị có muốn gia tăng tỉ lệ trái có giá trị thương phẩm và giảm bớt lượng trái kém chất lượng do nhiểm sâu bệnh không?

Quí vị có muốn hạn chế số cây bệnh, cây chết trên đồng không?

Chắc quí vị cũng biết rằng có một tỉ lệ rất nhỏ doanh thu bán dâu của quí vị được đưa vào quĩ sữ dụng vào mục đích nghiên cứu phát triển để giải quyết những vấn đề trở ngại trong ngành (gọi là phí dịch vụ nông nghiệp – APC fee of service). Cùng với sự hổ trợ của Bộ Nông Nghiệp và Lương Thực một phần của quĩ được tổ chức quản lý quĩ (còn được gọi là Tổ chức quản lý nông nghiệp – HAL) bổ xung theo nguyên tắc đối ứng và được sữ dụng để hổ trợ nghiên cứu giúp người trồng giải quyết những vấn đề nêu trên.

Bộ Nông Nghiệp và Lương Thực Tây Úc (DAFWA) cùng với Hiệp Hội Trồng Dâu đã đệ trình và được duyệt kinh phí thực hiện dự án thực hiện cùng với quí vị - những nông dân trồng dâu Việt Nam – nhằm giải quyết các vấn đề nêu trên trong thời gian 3 năm tới đây. Dự án có tên là: *Nghiên cứu các biện pháp tưới nước và bón phân để gia tăng hiệu quả canh tác cho đối tượng nông dân không quen sữ dụng tiếng Anh LOTE.*

Chúng tôi tin tưởng rằng chúng tôi có thể giúp đở quí vị trong kỹ thuật xử lý đất bằng thuốc xông hơi tốt hơn vì thế giảm thiểu ít bệnh hại hơn. Chúng tôi cũng sẽ giúp đở quí vị các biện pháp tưới nước và bón phân – những biện pháp có liên quan mật thiết đến sức khỏe cây trồng - và khi cây trồng khỏe mạnh thì khả năng kháng bệnh của chúng cũng tốt hơn.

Chúng tôi kêu gọi quí vị tham gia vào dự án để cùng làm việc với chúng tôi. Quí vị sẽ chẳng phải tốn kém Grower 1 phí mà ngược lại còn có cơ hội gia tăng thu nhập. Chúng tôi chỉ mong quí vị dành ít thời gian cộng tác với chúng tôi, khoảng 01 giờ mỗi tuần. Việc tham gia cộng tác hoàn toàn trên nguyên tắt tự nguyện.

**Công viẹv chúng ta cùng hợp tác trong dự án?**

Chúng tôi sẽ đến thăm và giúp đánh giá hệ thống tưới của quí vị xem chúng có hoat động hữu hiệu chưa, có phân bổ nước đồng đều không, và tham vấn cho quí vị cách sửa đổi cho tốt hơn. Hơn nữa việc áp dụng nước đề làm ướt đất còn được kết hợp với biện pháp xông hơi ở đầu vụ, nếu thực hiện hợp lý thì còn giúp làm sạch mầm bệnh hại trong đât.

Chúng tôi cũng sẽ giúp quí vị xem lại cách thức bón phân cho hiệu quả hơn. Trong môi trường đất cát ở Perth thì phân bón dễ bị rửa trôi và thấm sâu theo nước mất đi gây ra tình trạng cây thiếu dinh dưỡng. Như thế thì Grower 1 phí đầu tư của quí vị cho phần phân bón thất thoát mất hiệu quả.

Chúng tôi cũng sẽ giúp quí vị tìm hiểu nguồn gốc xâm nhập và phương pháp phòng trừ sbệnh hại dâu.

Thực hiện tất cả những điều này cũng có nghĩa rằng quí vị sẽ canh tác tốt hơn với năng suất và lợi nhuận cao hơn!

Nếu quí vị có quan tâm và muốn tham gia hoặc tìm hiểu thêm thông tin về dự án, xin vui lòng liên hệ bằng điện thoại hoặc thư điện tử (email) theo các số bên dưới hoặc điền thông tin của quí vị vào mẩu in sẳn dưới đây. Chúng tôi sẳn lòng đến thăm tận nhà và trình bày Grower 1 tiết thêm cho quí vị.

Rất mong nhận được phản hồi của quí vị!

Thành thật kính chào.

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Tôi quan tâm và muốn tìm hiểu thêm về dự án:

Họ tên: ..........................................................................

Địa chỉ: ..........................................................................

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Số điện thoại nhà: ..........................................................................

Số di động: ..........................................................................

Địa chỉ email: ..........................................................................

# Appendix 2: Grower bore water test results

Bore water samples from a group of five growers were tested for the presence of various nutrients, electrical conductivity and pH as a check to ensure these were at acceptable levels, early in the project. The EC is taken into account when formulating the fertiliser program.

| Grower | Date sampled | $NO_3$-N | B | Ca | $Cl^-$ | Cu | Fe | Mg | Mn |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | mg/L | | | | |
| **Grower 1** | 5/07/13 | 1.63 | <0.05 | 5.25 | 76.64 | <0.05 | 0.27 | 6.81 | <0.05 |
| **Grower 1** | 5/07/13 | 19.44 | <0.05 | 18.57 | 85.22 | <0.05 | 0.14 | 10.55 | <0.05 |
| **Grower 2** | 22/07/13 | 0.13 | <0.05 | 2.51 | | <0.05 | 0.27 | 5.18 | <0.05 |
| **Grower 3** | 22/07/13 | 0.71 | <0.05 | 28.26 | | <0.05 | 0.08 | 11.52 | <0.05 |
| **Grower 5** | 26/09/13 | 6.60 | <0.05 | 32.75 | | <0.05 | 0.44 | 23.70 | <0.05 |
| **Grower 9** | 5/11/13 | | | | | | | | |

| Grower | Date sampled | P | K | Na | S | Zn | $H_2CO_3$ | $CO_3$ | EC | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/L | | | dS/m | | | | |
| **Grower 1** | 5/07/13 | <0.05 | 3.65 | 42.45 | 5.17 | <0.05 | 18.56 | 0 | 0.318 | 6.1 |
| **Grower 1** | 5/07/13 | <0.05 | 21.76 | 47.47 | 14.78 | <0.05 | 16.82 | 0 | 0.509 | 6.8 |
| **Grower 2** | 22/07/13 | <0.05 | 2.04 | 42.39 | 6.31 | <0.05 | | | 0.315 | 4.1 |
| **Grower 3** | 22/07/13 | <0.05 | 3.68 | 68.41 | 28.41 | <0.05 | | | 0.621 | 7.5 |
| **Grower 5** | 26/09/13 | <0.05 | 15.67 | 92.16 | 43.11 | 0.14 | 21.02 | 0 | 0.844 | 6.2 |
| **Grower 9** | 5/11/13 | | | | | | | | 1.500 | 6.4 |

## Appendix 3: Soil test results – physical characteristics

| Laboratory | Sampling date | Grower | Depth (cm) | Colour | Texture | % Clay* | % Coarse sand | % Fine sand | % Sand | % Silt* | % Organic carbon | Bulk density |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CSBP** | 19/07/13 | Grower 1 | 0–15 | GRBK | 2.0 | 7.86 | 87.91 | 4.23 | 92.14 | <0.01 | 2.55 | |
| **CSBP** | 19/07/13 | Grower 1 | 15–30 | GRBK | 2.0 | 7.7 | 88.65 | 5.6 | 94.25 | <0.01 | 2.64 | |
| **CSBP** | 19/07/13 | Grower 1 | 0–15 | DKGR | 1.5 | 5.65 | 91.14 | 3.21 | 94.35 | <0.01 | 1.19 | |
| **CSBP** | 19/07/13 | Grower 1 | 15–30 | DKGR | 1.5 | 5.67 | 91.49 | 0.91 | 92.4 | 1.92 | 1.21 | |
| **CSBP** | 19/07/13 | Grower 1 | 0–15 | DKGR | 1.5 | 7.55 | 88.58 | 5.78 | 94.36 | <0.01 | 1.29 | |
| **CSBP** | 19/07/13 | Grower 1 | 15–30 | DKGR | 1.5 | 3.78 | 90.78 | 3.49 | 94.27 | 1.94 | 1.38 | |
| **CSBP** | 17/07/13 | Grower 2 | 0–15 | BRGR | 1.5 | 2.92 | 94.98 | 2.1 | 97.08 | < 0.01 | 0.82 | |
| **CSBP** | 17/07/13 | Grower 2 | 15–30 | GRBR | 1.5 | 3.91 | 94.95 | 1.14 | 96.08 | < 0.01 | 0.86 | |
| **CSBP** | 17/07/13 | Grower 3 | 0–15 | DKGR | 1.5 | 1.91 | 94.33 | 0.81 | 95.14 | 2.95 | 0.92 | |
| **CSBP** | 17/07/13 | Grower 3 | 15–30 | DKGR | 1.5 | 3.92 | 95.18 | 1.89 | 97.07 | < 0.01 | 0.65 | |
| **CSBP** | 19/07/13 | Grower 4 | 0–15 | GRBK | 1.0 | 3.83 | 91.15 | 3.05 | 94.2 | 1.97 | 1.55 | |
| **CSBP** | 19/07/13 | Grower 4 | 15–30 | GRBK | 1.0 | 3.8 | 90.75 | 3.5 | 94.26 | 1.95 | 1.29 | |
| **CSBP** | 19/07/13 | Grower 5 | 0–15 | GRBR | 1.0 | 5.67 | 91.88 | 2.45 | 94.33 | < 0.01 | 1.21 | |
| **CSBP** | 19/07/13 | Grower 5 | 15–30 | GRBK | 1.0 | 3.83 | 93.77 | 2.41 | 96.17 | < 0.01 | 1.15 | |
| **ChemCentre** | 14/11/13 | Grower 5 | 0–15 | | 1.0 | 1.50 | | | 96.50 | 2.00 | 1.21 | |
| **ChemCentre** | 14/11/13 | Grower 5 | 15–30 | | 1.0 | 1.50 | | | 96.50 | 2.00 | 0.82 | |
| **ChemCentre** | 14/11/13 | Grower 5 | 30–45 | | 1.0 | 1.50 | | | 97.00 | 1.50 | 0.79 | |
| **ChemCentre** | 11/11/14 | Grower 11 | 0–15 | | 1.0 | 2.00 | 91.50 | 5.00 | 96.50 | 1.50 | 0.37 | 1.64 |
| **ChemCentre** | 11/11/14 | Grower 11 | 15–30 | | 1.0 | 2.00 | 92.00 | 4.50 | 96.50 | 1.50 | 0.35 | 1.60 |
| **ChemCentre** | 11/11/14 | Grower 11 | 30–45 | | 1.0 | 2.00 | 92.00 | 4.50 | 96.50 | 1.50 | 0.18 | 1.60 |

***** There is a disparity between the two laboratories as to their clay and silt analysis methodologies. The clay fractions returned by ChemCentre are more in line with our expectations of that soil type. The results for Grower 5 are an example.

## Appendix 4: Soil test results – chemical characteristics

| Laboratory | Sampling date | Customer | Depth | Conductivity | pH Level ($H_2O$) | Ammonium nitrogen | Nitrate nitrogen | Total nitrogen | Phosphorus (Colwell) | Potassium (Colwell) | Sulphur |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **(cm)** | **($dSm^{-1}$)** | | **(mg/kg)** | **(mg/kg)** | **(mg/kg)** | **(mg/kg)** | **(mg/kg)** | **(mg/kg)** |
| **CSBP** | 19/07/13 | Grower 1 | 0–15 | 0.102 | 6.6 | 3 | 8 | 0.17 | 83 | 120 | 20.2 |
| **CSBP** | 19/07/13 | Grower 1 | 15–30 | 0.068 | 6.6 | 1 | 6 | 0.11 | 78 | 99 | 9.1 |
| **CSBP** | 19/07/13 | Grower 1 | 0–15 | 0.058 | 7.3 | 1 | 4 | 0.09 | 54 | 60 | 10.0 |
| **CSBP** | 19/07/13 | Grower 1 | 15–30 | 0.063 | 7.2 | 1 | 3 | 0.08 | 48 | 58 | 7.6 |
| **CSBP** | 19/07/13 | Grower 1 | 0–15 | 0.104 | 7.0 | 4 | 11 | 0.11 | 72 | 88 | 17.3 |
| **CSBP** | 19/07/13 | Grower 1 | 15–30 | 0.079 | 6.9 | 1 | 6 | 0.1 | 82 | 84 | 10.6 |
| **CSBP** | 17/07/13 | Grower 2 | 0–15 | 0.110 | 7.2 | 2 | 26 | 0.07 | 64 | 22 | 17.7 |
| **CSBP** | 17/07/13 | Grower 2 | 15–30 | 0.090 | 7.2 | 1 | 19 | 0.06 | 67 | 32 | 13.7 |
| **CSBP** | 19/07/13 | Grower 3 | 0–15 | 0.169 | 7.2 | 6 | 38 | 0.08 | 39 | 52 | 27.2 |
| **CSBP** | 19/07/13 | Grower 3 | 15–30 | 0.130 | 6.8 | 3 | 25 | 0.11 | 33 | 40 | 19.7 |
| **CSBP** | 19/07/13 | Grower 4 | 0–15 | 0.117 | 7.3 | 3 | 16 | 0.15 | 105 | 149 | 17.3 |
| **CSBP** | 19/07/13 | Grower 4 | 15–30 | 0.120 | 6.9 | 3 | 20 | 0.1 | 87 | 111 | 20.3 |
| **CSBP** | 19/07/13 | Grower 5 | 0–15 | 0.181 | 5.9 | 29 | 6 | 0.12 | 90 | 127 | 44.3 |
| **CSBP** | 19/07/13 | Grower 5 | 15–30 | 0.121 | 5.4 | 9 | 6 | 0.11 | 68 | 73 | 33.3 |
| **ChemCentre** | 14/11/2013 | Grower 5 | 0–15 | | 5.4 | | | | | | |
| **ChemCentre** | 14/11/2013 | Grower 5 | 15–30 | | 5.6 | | | | | | |
| **ChemCentre** | 14/11/2013 | Grower 5 | 30–45 | | 5.7 | | | | | | |

### *Appendix 4: Soil test results - chemical characteristics (continued)*

| Laboratory | Sampling date | Grower | Depth (cm) | Cu (DTPA) | Fe | Mn | Zn | Exch Al | Exch Ca | Exch Mg | Exch K | Exch Na | B (Hot $CaCl_2$) | Cl | PRI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **mg/kg** | | | | **meq/100g** | | | | **mg/kg** | | |
| **CSBP** | 17/07/13 | Grower 2 | 0–15 | 0.58 | 7.73 | 1.70 | 7.16 | 0.034 | 5.22 | 0.46 | 0.06 | 0.14 | 0.23 | 38.9 | <0.0 |
| **CSBP** | 17/07/13 | Grower 2 | 15–30 | 0.51 | 7.96 | 1.50 | 7.03 | 0.035 | 4.93 | 0.40 | 0.08 | 0.10 | 0.20 | 22.9 | <0.0 |
| **CSBP** | 19/07/13 | Grower 1 | 0–15 | 0.93 | 13.57 | 2.14 | 9.77 | 0.004 | 10.88 | 1.18 | 0.31 | 0.26 | 0.42 | 19.4 | <0.0 |
| **CSBP** | 19/07/13 | Grower 1 | 15–30 | 0.56 | 15.08 | 1.55 | 8.74 | 0.007 | 11.30 | 1.20 | 0.25 | 0.15 | 0.30 | 14.5 | <0.0 |
| **CSBP** | 19/07/13 | Grower 1 | 0–15 | 0.93 | 6.79 | 1.88 | 8.36 | 0.004 | 6.23 | 0.58 | 0.15 | 0.12 | 0.24 | 15.1 | <0.0 |
| **CSBP** | 19/07/13 | Grower 1 | 15–30 | 0.99 | 7.55 | 1.78 | 8.66 | 0.002 | 6.30 | 0.54 | 0.15 | 0.10 | 0.22 | 13.3 | <0.0 |
| **CSBP** | 19/07/13 | Grower 1 | 0–15 | 0.84 | 9.00 | 1.85 | 15.14 | 0.005 | 5.42 | 0.59 | 0.22 | 0.14 | 0.31 | 32.1 | <0.0 |
| **CSBP** | 19/07/13 | Grower 1 | 15–30 | 0.85 | 7.62 | 1.55 | 14.21 | 0.011 | 6.76 | 0.70 | 0.21 | 0.35 | 0.32 | 26.1 | <0.0 |
| **CSBP** | 19/07/13 | Grower 3 | 0–15 | 2.00 | 13.30 | 1.89 | 10.57 | 0.022 | 4.09 | 0.55 | 0.13 | 0.28 | 0.24 | 66.4 | 0.3 |
| **CSBP** | 19/07/13 | Grower 3 | 15–30 | 2.19 | 12.86 | 2.21 | 10.47 | 0.015 | 2.84 | 0.39 | 0.1 | 0.19 | 0.25 | 47.0 | <0.0 |
| **CSBP** | 19/07/13 | Grower 4 | 0–15 | 2.61 | 32.36 | 1.90 | 11.37 | 0.023 | 5.48 | 0.78 | 0.35 | 0.19 | 0.43 | 25.1 | 0.7 |
| **CSBP** | 19/07/13 | Grower 4 | 15–30 | 2.26 | 33.31 | 2.44 | 9.66 | 0.016 | 4.26 | 0.62 | 0.28 | 0.17 | 0.45 | 27.7 | 1.1 |
| **CSBP** | 19/07/13 | Grower 5 | 0–15 | 3.33 | 39.35 | 5.52 | 8.46 | 0.041 | 2.26 | 0.44 | 0.33 | 0.28 | 0.28 | 53.5 | <0.0 |
| **CSBP** | 19/07/13 | Grower 5 | 15–30 | 3.39 | 47.88 | 5.67 | 8.27 | 0.065 | 2.02 | 0.36 | 0.19 | 0.24 | 0.35 | 48.8 | <0.0 |

## *Appendix 4: Soil test results – chemical characteristics (continued)*

| Laboratory | Grower | Depth | EC (1:5) | pH ($H_2O$) | Cl (titrn) | N (total) | **$NH_4$-N** | **$NO_3$-N** | P | PRI | ESP (exch) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **(cm)** | **(mS/m)** | | **(%)** | | **(mg/kg)** | | | **(mL/g)** | **%** |
| **ChemCentre** | Grower 11 | 0–15 | 17 | 6.6 | <0.01 | 0.035 | 1 | 16 | 270 | -1.2 | 6.0 |
| **ChemCentre** | Grower 11 | 15–30 | 12 | 6.1 | <0.01 | 0.033 | 1 | 15 | 230 | -1.2 | 8.2 |
| **ChemCentre** | Grower 11 | 30–45 | 6 | 6.0 | <0.01 | 0.014 | | | 100 | -0.6 | 6.1 |

| Laboratory | Grower | Depth | CEC ($NH_4Cl$) | Ca | K | Mg | Na | Al | B | Ca | Cd | Co | Cu | Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **(cm)** | | **(exch) cmol(+)/kg** | | | | | | **mg/kg (Mehlich)** | | | | |
| **ChemCentre** | Grower 11 | 0–15 | 2 | 2.7 | 0.02 | 0.17 | 0.18 | 120 | 0.1 | 570 | 0.04 | 0.13 | 6.1 | 110 |
| **ChemCentre** | Grower 11 | 15–30 | 2 | 2.2 | <0.02 | 0.14 | 0.21 | 120 | <0.1 | 490 | 0.03 | 0.08 | 5.4 | 94 |
| **ChemCentre** | Grower 11 | 30–45 | 3 | 1.3 | <0.02 | 0.09 | 0.09 | 100 | <0.1 | 160 | <0.01 | 0.02 | 2.3 | 48 |

| Laboratory | Grower | Depth | K | Mg | Mn | Mo | Na | Ni | P | S | Zn | As | Pb | Se |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **(cm)** | **mg/kg (Mehlich)** | | | | | | | | | | | |
| **ChemCentre** | Grower 11 | 0–15 | 8 | 21 | 24 | 0.03 | 29 | 0.2 | 180 | 46 | 18 | <0.1 | 0.5 | <0.1 |
| **ChemCentre** | Grower 11 | 15–30 | 4 | 19 | 19 | 0.03 | 35 | 0.1 | 150 | 37 | 16 | <0.1 | 0.5 | <0.1 |
| **ChemCentre** | Grower 11 | 30–45 | 5 | <10 | 3.7 | 0.01 | 12 | 0.1 | 54 | 11 | 3.8 | <0.1 | 0.4 | <0.1 |

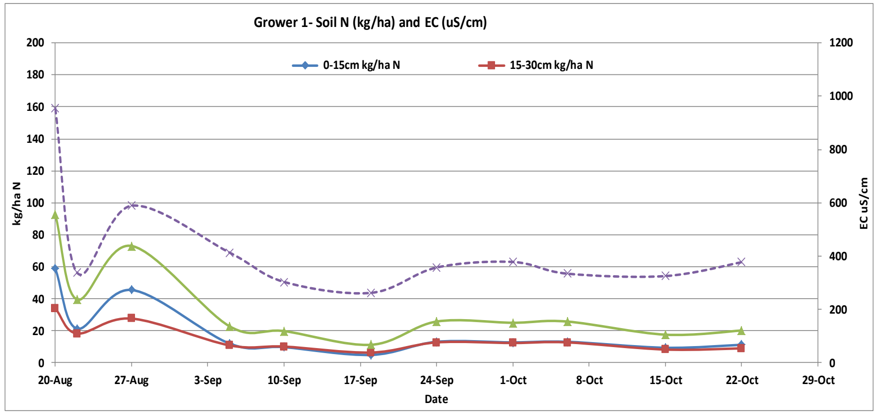
## Appendix 5: Grower irrigation configurations

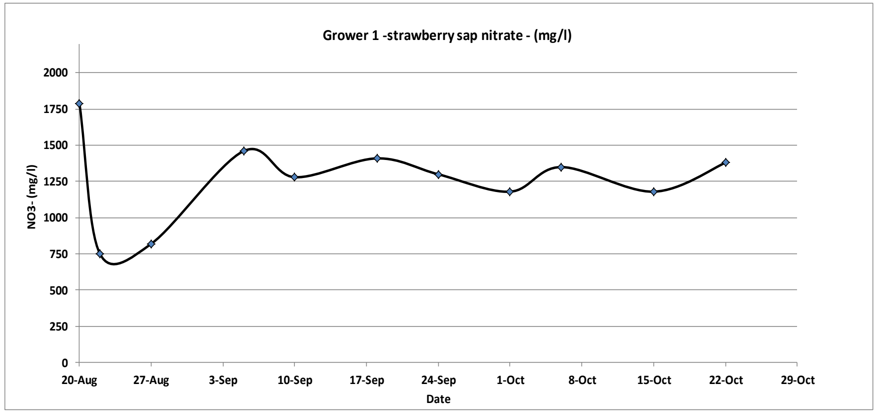
| Grower | Tape manufacturer and type | Application rate (L/hr) | Emitter spacing (cm) | Bed width (m) | Plant rows/bed | Tape rows/bed | Precipitation rate over bed area (mm/hr) | Bed tape placement (m apart) | Plant configuration L x W (cm) |
|---|---|---|---|---|---|---|---|---|---|
| **Grower 1** | Netafim Streamline® | 1.6 | 20 | 1.200 | 4 | 3 | 20.0 | 0.275 | 30 x 25 |
| **Grower 2** | John Deere T-Tape® | 1.5 | 25 | 1.100 | 4 | 2 | 10.9 | 0.500 | 30 x 25 |
| **Grower 3** | John Deere T-Tape® | 1.5 | 20 | 1.000 | 4 | 2 | 15.0 | 0.500 | 35 x 20 |
| **Grower 4** | John Deere T-Tape® | 1.0 | 20 | 1.000 | 3 | 2 | 10.0 | 0.250 | 40 x 30 |
| **Grower 5** | Netafim Streamline® | 1.6 | 25 | 1.000 | 4 | 2 | 12.8 | 0.500 | 40 x 30 |
| **Grower 6** | Netafim Streamline® | 1.6 | 20 | 1.200 | 4 | 2 | 13.3 | 0.500 | 30 x 25 |
| **Grower 7** | Netafim Streamline® | 1.6 | 20 | 0.675 | 2 | 1 | 11.9 | NA | 26 x 27.5 |

# Appendix 6: Soil and sap monitoring records from five growers

## Soil and sap monitoring – Grower 1

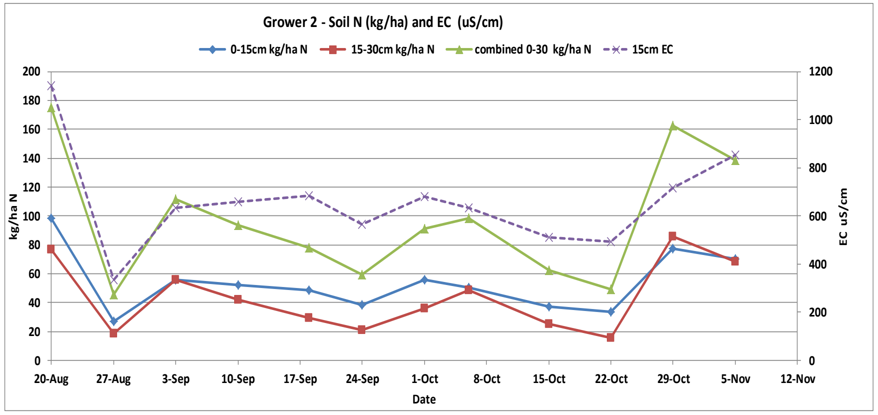
| Date | Nitrate (soil solution) mg/L | | kg/ha N | | | EC | | pH | Petiole sap | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–15cm | 15–30cm | 0–15cm kg/ha N | 15–30cm kg/ha N | Combined 0–30cm kg/ha N | 15cm | 30cm | 15cm | $NO_3^-$ | N |
| **20/8/13** | 158 | 91 | 59 | 34 | 93 | 954 | 456 | 6.5 | 1790 | 404 |
| **22/8/13** | 57 | 49 | 21 | 18 | 39 | 338 | 276 | 6.1 | 750 | 169 |
| **27/8/13** | 122 | 74 | 45 | 28 | 73 | 589 | 345 | 5.8 | 820 | 185 |
| **5/9/13** | 32 | 29 | 12 | 11 | 23 | 413 | 356 | 6.7 | 1460 | 330 |
| **10/9/13** | 26 | 27 | 10 | 10 | 20 | 303 | 356 | 6.2 | 1280 | 289 |
| **18/9/13** | 13 | 17 | 5 | 6 | 11 | 262 | 232 | 7.2 | 1410 | 318 |
| **24/9/13** | 35 | 34 | 13 | 13 | 26 | 357 | 349 | 5.9 | 1300 | 294 |
| **1/10/13** | 34 | 33 | 13 | 12 | 25 | 378 | 232 | 6.0 | 1180 | 266 |
| **6/10/13** | 35 | 34 | 13 | 13 | 26 | 334 | 251 | 6.7 | 1350 | 305 |
| **15/10/13** | 25 | 22 | 9 | 8 | 18 | 325 | 248 | 6.3 | 1180 | 266 |
| **22/10/13** | 30 | 24 | 11 | 9 | 20 | 377 | 315 | 6.7 | 1380 | 312 |

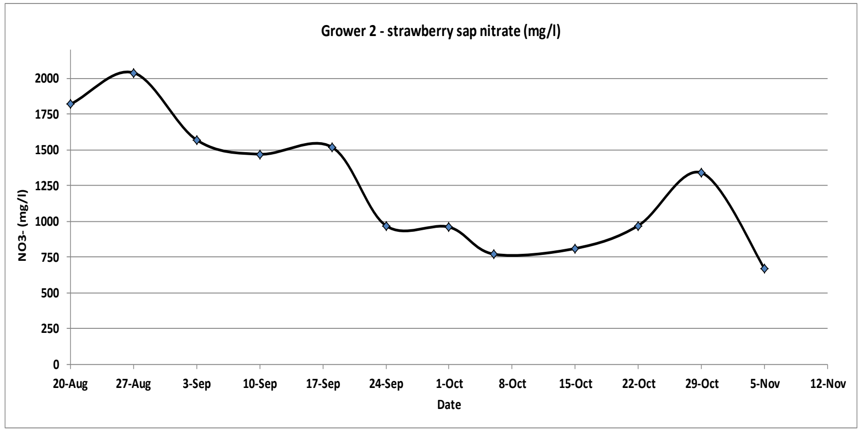


## Soil and sap monitoring – Grower 2

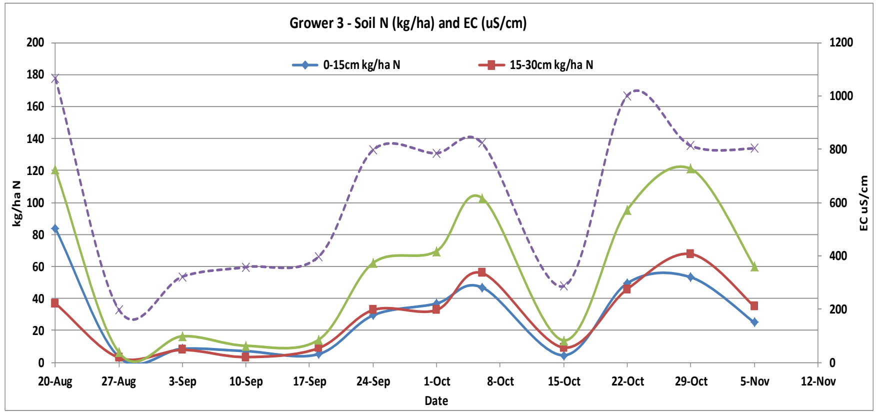
| Date | Nitrate (soil solution) mg/L | | kg/ha N | | | EC | | pH | Petiole sap | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–15cm | 15–30cm | 0–15cm kg/ha N | 15–30cm kg/ha N | Combined 0–30cm kg/ha N | 15cm | 30cm | 15cm | $NO_3^-$ | N |
| **20-Aug** | 264 | 206 | 98 | 77 | 175 | 1142 | 852 | 6.5 | 1820 | 411 |
| **27-Aug** | 72 | 50 | 27 | 19 | 45 | 333 | 238 | 5.8 | 2040 | 461 |
| **3-Sep** | 150 | 149 | 56 | 56 | 111 | 635 | 645 | 6.3 | 1570 | 355 |
| **10-Sep** | 140 | 112 | 52 | 42 | 94 | 658 | 548 | 7.0 | 1470 | 332 |
| **18-Sep** | 130 | 79 | 48 | 29 | 78 | 686 | 452 | 7.0 | 1520 | 343 |
| **24-Sep** | 103 | 56 | 38 | 21 | 59 | 565 | 333 | 6.8 | 970 | 219 |
| **1-Oct** | 149 | 96 | 56 | 36 | 91 | 681 | 477 | 7.0 | 960 | 217 |
| **6-Oct** | 135 | 130 | 50 | 48 | 99 | 635 | 578 | 6.9 | 770 | 174 |
| **15-Oct** | 100 | 68 | 37 | 25 | 63 | 510 | 376 | 7.0 | 810 | 183 |
| **22-Oct** | 90 | 42 | 34 | 16 | 49 | 492 | 330 | 6.8 | 970 | 219 |
| **29-Oct** | 207 | 230 | 77 | 86 | 163 | 717 | 775 | 6.8 | 1340 | 303 |
| **5-Nov** | 189 | 183 | 70 | 68 | 139 | 855 | 805 | 6.6 | 670 | 151 |

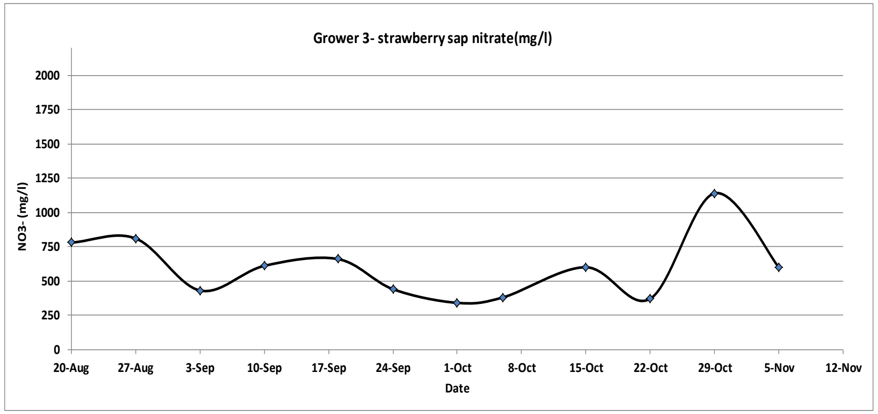


## Soil and sap monitoring – Grower 3

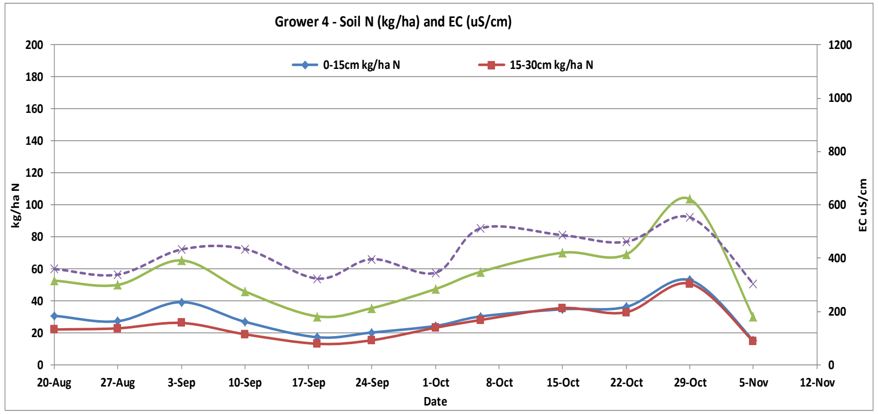
| Date | Nitrate (soil solution) mg/L | | kg/ha N | | | EC | | pH | Petiole sap | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–15cm | 15–30cm | 0–15cm kg/ha N | 15–30cm kg/ha N | Combined 0–30cm kg/ha N | 15cm | 30cm | 15cm | $NO_3^-$ | N |
| **20-Aug** | 225 | 99 | 84 | 37 | 121 | 1067 | 569 | 6.1 | 780 | 176 |
| **27-Aug** | 9 | 8 | 3 | 3 | 6 | 198 | 151 | 6.3 | 810 | 183 |
| **3-Sep** | 23 | 21 | 9 | 8 | 16 | 322 | 280 | 5.6 | 430 | 97 |
| **10-Sep** | 19 | 9 | 7 | 3 | 10 | 358 | 241 | 7.1 | 610 | 138 |
| **18-Sep** | 14 | 24 | 5 | 9 | 14 | 397 | 420 | 7.0 | 660 | 149 |
| **24-Sep** | 79 | 88 | 29 | 33 | 62 | 797 | 733 | 6.9 | 440 | 99 |
| **1-Oct** | 99 | 88 | 37 | 33 | 70 | 785 | 726 | 6.5 | 340 | 77 |
| **6-Oct** | 126 | 150 | 47 | 56 | 103 | 823 | 816 | 6.8 | 380 | 86 |
| **15-Oct** | 12 | 25 | 4 | 9 | 14 | 286 | 305 | 7.0 | 600 | 135 |
| **22-Oct** | 133 | 123 | 50 | 46 | 95 | 1001 | 881 | 6.4 | 370 | 84 |
| **29-Oct** | 143 | 182 | 53 | 68 | 121 | 813 | 802 | 6.6 | 1140 | 257 |
| **5-Nov** | 67 | 94 | 25 | 35 | 60 | 803 | 878 | 6.6 | 600 | 135 |

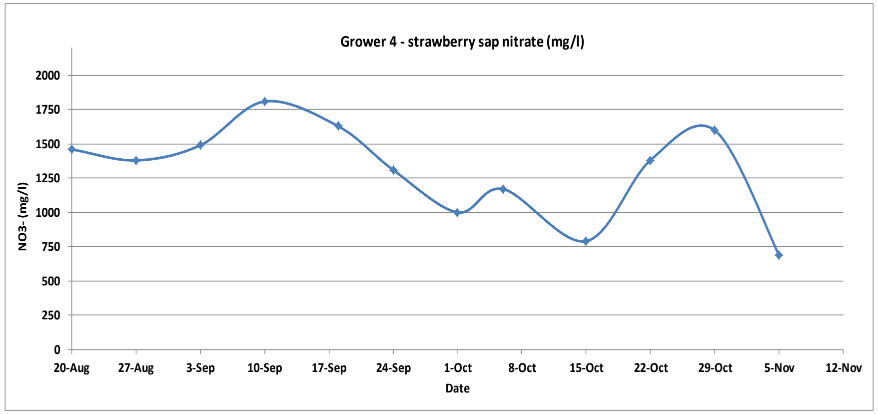


## Soil and sap monitoring – Grower 4

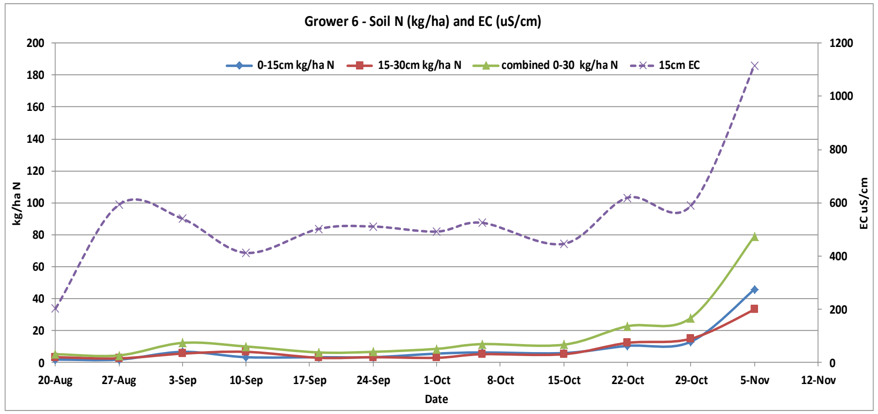
| Date | Nitrate (soil solution) mg/L | | kg/ha N | | | EC | | pH | Petiole sap | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–15cm | 15–30cm | 0–15cm kg/ha N | 15–30cm kg/ha N | Combined 0–30cm kg/ha N | 15cm | 30cm | 15cm | $NO_3^-$ | N |
| **20-Aug** | 82 | 59 | 31 | 22 | 53 | 359 | 289 | 6.6 | 1460 | 330 |
| **27-Aug** | 73 | 61 | 27 | 23 | 50 | 338 | 301 | 5.9 | 1380 | 312 |
| **3-Sep** | 105 | 70 | 39 | 26 | 65 | 432 | 341 | 5.8 | 1490 | 336 |
| **10-Sep** | 72 | 51 | 27 | 19 | 46 | 434 | 309 | 6.7 | 1810 | 409 |
| **18-Sep** | 46 | 35 | 17 | 13 | 30 | 323 | 256 | 7.4 | 1630 | 368 |
| **24-Sep** | 54 | 41 | 20 | 15 | 35 | 396 | 318 | 7.2 | 1310 | 296 |
| **1-Oct** | 65 | 62 | 24 | 23 | 47 | 345 | 322 | 6.6 | 1000 | 226 |
| **6-Oct** | 81 | 75 | 30 | 28 | 58 | 512 | 398 | 6.9 | 1170 | 264 |
| **15-Oct** | 93 | 95 | 35 | 35 | 70 | 486 | 499 | 6.6 | 790 | 178 |
| **22-Oct** | 97 | 88 | 36 | 33 | 69 | 461 | 455 | 6.6 | 1380 | 312 |
| **29-Oct** | 142 | 136 | 53 | 51 | 104 | 553 | 491 | 6.6 | 1600 | 361 |
| **5-Nov** | 41 | 39 | 15 | 15 | 30 | 304 | 276 | 6.5 | 690 | 156 |

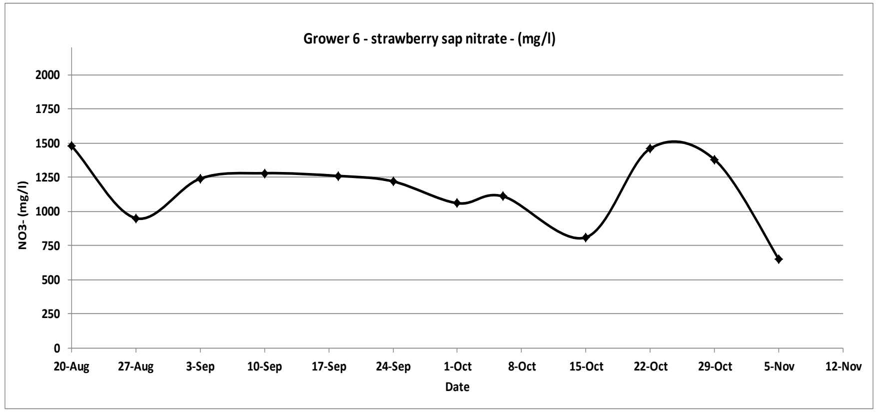


## Soil and sap monitoring – Grower 6

| DATE | Nitrate (soil solution) mg/L | | kg/ha N | | | EC | | pH | Petiole sap | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–15cm | 15–30cm | 0–15cm kg/ha N | 15–30cm kg/ha N | Combined 0–30cm kg/ha N | 15cm | 30cm | 15cm | $NO_3^-$ | N |
| **20-Aug** | 5 | 9 | 2 | 3 | 5 | 202 | 157 | 6.6 | 1480 | 334 |
| **27-Aug** | 5 | 7 | 2 | 3 | 4 | 593 | 156 | 6.5 | 950 | 215 |
| **3-Sep** | 18 | 15 | 7 | 6 | 12 | 540 | 470 | 6.4 | 1240 | 280 |
| **10-Sep** | 9 | 18 | 3 | 7 | 10 | 412 | 320 | 7.5 | 1280 | 289 |
| **18-Sep** | 9 | 8 | 3 | 3 | 6 | 502 | 341 | 7.5 | 1260 | 285 |
| **24-Sep** | 9 | 9 | 3 | 3 | 7 | 511 | 415 | 7.4 | 1220 | 275 |
| **1-Oct** | 15 | 8 | 6 | 3 | 9 | 492 | 343 | 7.4 | 1060 | 239 |
| **6-Oct** | 17 | 14 | 6 | 5 | 12 | 525 | 404 | 7.0 | 1110 | 251 |
| **15-Oct** | 16 | 14 | 6 | 5 | 11 | 446 | 391 | 7.4 | 810 | 183 |
| **22-Oct** | 28 | 33 | 10 | 12 | 23 | 619 | 610 | 7.3 | 1460 | 330 |
| **29-Oct** | 35 | 40 | 13 | 15 | 28 | 589 | 481 | 7.1 | 1380 | 312 |
| **5-Nov** | 123 | 89 | 46 | 33 | 79 | 1116 | 886 | 6.9 | 650 | 147 |



# Appendix 7: Fertiliser programs used by growers

## Fertiliser usage — Grower 1 (approx. 79,000 plants per shift or 0.7ha)

| Product | % element in product | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | Fe | B | S | Mn | Zn | Mo | Cu |
| **Calcium nitrate** | 15.5 | | | 19.3 | | | | | | | | |
| **Potassium nitrate** | 13.5 | | 38.0 | | | | | | | | | |
| **Polyfeed™** | 12.0 | 2.6 | 33.2 | | | 0.1 | 0.02 | | 0.05 | 0.015 | 0.007 | |
| **$MgSO_4.7H_2O$** | | | | | 10.0 | | | 13.0 | | | | |
| **MAP** | 12.0 | 26.6 | | | | | | | | | | |
| **Manganese sulphate** | | | | | | | | | 32.0 | | | |
| **Yara Boron** | | | | | | | 21.0 | | | | | |
| **Iron chelate** | | | | | | 13.0 | | | | | | |
| **Librel BMX** | | | | | | 3.35 | 0.875 | | 1.7 | 0.6 | 0.023 | 1.7 |

| **Amount of product (kg/16 days)** | |
|---|---|
| **Calcium nitrate** | 50 |
| **Potassium nitrate** | |
| **Polyfeed™** | 150 |
| **$Mg SO_4.7H_2O$** | 25 |
| **MAP** | 25 |
| **Manganese sulphate** | |
| **Yara Boron** | |
| **Iron chelate** | |
| **Librel BMX** | |

## Fertiliser usage— Grower 1 (continued)

**Breakdown of program by element**

| | N | P | K | Ca | Mg | Fe | B | S | Mn | Zn | Mo | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Calcium nitrate** | 7.75 | 0 | 0 | 9.65 | | | | | | | | |
| **Potassium nitrate** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Polyfeed** | 18 | 3.9 | 49.8 | 0 | | 0.15 | 0.03 | | 0.075 | 0.023 | 0.011 | |
| **Mg $SO_4.7H_2O$** | 0 | 0 | 0 | 0 | 2.5 | | | 3.25 | | | | |
| **MAP** | 3 | 6.65 | 0 | 0 | | | | | | | | |
| **Manganese sulphate** | 0 | 0 | 0 | 0 | | | | | | | | |
| **Boron Yara** | 0 | 0 | 0 | 0 | | | 0 | | | | | |
| **Iron chelate** | 0 | 0 | 0 | 0 | | 0 | | | | | | |
| **Librel BMX** | 0 | 0 | 0 | 0 | | 0 | 0 | | 0 | 0 | 0 | 0 |
| **Total** | **28.75** | **10.55** | **49.8** | **9.65** | **2.5** | **0.15** | **0.03** | **3.25** | **0.075** | **0.023** | **0.011** | **0** |
| | 41.07 | 15.07 | 71.14 | 13.79 | 3.57 | 0.21 | 0.04 | 4.64 | 0.11 | 0.03 | 0.02 | |
| **Kg/ha/day over 16 days** | **2.57** | **0.94** | **4.45** | **0.86** | **0.22** | **0.01** | **0.003** | **0.29** | **0.01** | | | |
| | | | | | | | | | | | | |
| **N:K** | 1.732 | | | | | | | | | | | |
| | | | | | | | | | | | | |
| **Goal kg/ha/day from week 4 onwards** | **2.500** | **0.461** | **4.063** | **1.935** | **0.452** | **0.714** | **0.017** | **0.008** | **0.007** | **0.002** | **0.0004** | **0.0004** |

## Fertiliser usage — Grower 3 (145,000 plants on 3ha or 1.29ha bed area)

| **Product** | **% element in product** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **N** | **P** | **K** | **Ca** | **Mg** | **S** | **B** | **Cu** | **Fe** | **Mn** | **Mo** | **Zn** |
| **Kristalon Brown** | 3.0 | 4.8 | 31.5 | | 2.4 | 11.0 | 0.025 | 0.01 | 0.07 | 0.04 | 0.004 | 0.025 |
| **$KNO_3$** | 13.8 | | 38.4 | | | | | | | | | |
| **Calcinit** | 15.5 | | | 19.0 | | | | | | | | |
| **$MgSO_4$** | | | | | 9.9 | 14.0 | | | | | | |
| **MAP** | 12.0 | 26.6 | | | | | | | | | | |

| **Amount of product per week (kg)** | |
|---|---|
| **Kristalon Brown** | 50 |
| **$KNO_3$** | 50 |
| **Calcinit** | 50 |
| **$MgSO_4$** | 25 |
| **MAP** | 25 |

| **Kg/week** | **N** | **P** | **K** | **Ca** | **Mg** | **S** | **B** | **Cu** | **Fe** | **Mn** | **Mo** | **Zn** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kristalon Brown** | 1.50 | 2.40 | 15.75 | 0.00 | 1.20 | 5.50 | 0.013 | 0.005 | 0.035 | 0.020 | 0.002 | 0.013 |
| **$KNO_3$** | 6.90 | | 19.20 | | | | | | | | | |
| **Calcinit** | 7.75 | | | 9.5 | | | | | | | | |
| **$MgSO_4$** | | | | | 2.475 | 3.5 | | | | | | |
| **MAP** | 3.00 | 6.65 | | | | | | | | | | |
| **Total** | **19.15** | **9.05** | **34.95** | **9.50** | **3.675** | **9.00** | **0.013** | **0.005** | **0.035** | **0.020** | **0.002** | **0.013** |
| **kg/ha/week** | 10.85 | 2.26 | 12.58 | 9.96 | 1.78 | 2.81 | 0.016 | 0.003 | 0.066 | 0.032 | 0.003 | 0.029 |
| **Goal (kg/ha bed area/week)** | **14.0** | **2.9** | **16.2** | **12.9** | **2.294** | **3.630** | **0.020** | **0.004** | **0.085** | **0.042** | **0.004** | **0.038** |

## Fertiliser usage — Grower 5 (200,000 plants and 1.83ha bed area on 4ha block)

| | % element in product | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | S | B | Cu | Fe | Mn | Mo | Zn |
| **Kristalon Brown™** | 3 | 4.8 | 31.5 | 0 | 2.4 | 11 | 0.025 | 0.01 | 0.07 | 0.04 | 0.004 | 0.025 |
| **Potassium nitrate** | 13.8 | | 38.4 | | | | | | | | | |
| **Calcium nitrate** | 15.5 | | | 19 | | | | | | | | |
| **Magnesium sulphate** | | | | | 9.9 | 14 | | | | | | |
| **Mono-ammonium phosphate** | 12 | 26.6 | | | | | | | | | | |
| **Sett Enhanced™** | | | | 11 | | | 1.4 | | | | | |
| **Fish emulsion** | 2.5 | 0.3 | 0.25 | 0.5 | | | | | | | | |

| **Rate per week (kg) of product** | |
|---|---|
| **Kristalon Brown™** | 75 |
| **Potassium nitrate** | |
| **Calcium nitrate** | 75 |
| **Magnesium sulphate** | |
| **Mono-ammonium phosphate** | |
| **Sett Enhanced™** | 20 |
| **Fish emulsion** | 80 |

## Fertiliser usage — Grower 5 (continued)

| | % element in product | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Actual kg/week of element** | **N** | **P** | **K** | **Ca** | **Mg** | **S** | **B** | **Cu** | **Fe** | **Mn** | **Mo** | **Zn** |
| **Kristalon Brown™** | 2.25 | 3.60 | 23.625 | 0.00 | 1.80 | 8.25 | 0.019 | 0.008 | 0.053 | 0.030 | 0.003 | 0.019 |
| **Potassium nitrate** | | | | | | | | | | | | |
| **Calcium nitrate** | 11.625 | | | 14.25 | | | | | | | | |
| **Magnesium sulphate** | | | | | | | | | | | | |
| **Mono-ammonium phosphate** | | | | | | | | | | | | |
| **Sett Enhanced™** | | | | 2.2 | | | 0.28 | | | | | |
| **Fish emulsion** | 2.00 | 0.24 | 0.20 | 0.40 | | | | | | | | |
| | | | | | | | | | | | | |
| **Total** | 15.875 | 3.840 | 23.825 | 16.850 | 1.800 | 8.250 | 0.299 | 0.008 | 0.053 | 0.030 | 0.003 | 0.019 |
| **Kg/ha/week equivalent** | 8.7 | 2.1 | 13.0 | 9.2 | 1.0 | 4.5 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Goal (kg/ha bed area/week)** | 14.0 | 2.9 | 16.2 | 12.9 | 2.294 | 3.630 | 0.020 | 0.004 | 0.085 | 0.042 | 0.004 | 0.038 |

## Appendix 8: Leaf analyses from growers and varieties

| Grower | Sampling date | Total N | P | K | S | Cl | Na | Mg | $NO_3$ | Cu | Mn | Zn | B | Mo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **(%)** | | | | | | | **(mg/kg)** | | | **(µg/kg)** |
| **Grower 4 Camarosa** | 26/09/13 | 2.97 | 0.46 | 2.45 | 0.18 | 0.23 | 0.05 | 0.35 | 358.23 | 6.47 | 141.56 | 38.25 | | 984.71 |
| **Grower 4 Festival** | 26/09/13 | 2.93 | 0.53 | 2.28 | 0.22 | 0.64 | 0.07 | 0.49 | 425.51 | 4.17 | 405.52 | 85.91 | | 939.88 |
| **Grower 5 Camarosa** | 26/09/13 | 2.95 | 0.52 | 2.66 | 0.18 | 0.56 | 0.05 | 0.37 | 367.15 | 8.05 | 310.64 | 53.73 | | 963.92 |
| **Grower 4 Camarosa** | 9/10/14 | 2.53 | 0.44 | 2.61 | 0.17 | 0.44 | 0.02 | 0.38 | 535.36 | 6.77 | 472.31 | 76.24 | 31.95 | 1428.70 |
| **Demonstration** | 16/07/14 | 3.59 | 0.58 | 2.59 | 0.22 | 0.38 | 0.01 | 0.42 | 736.61 | 4.96 | 92.81 | 36.86 | 38.30 | |
| **Grower practice** | 16/07/14 | 3.67 | 0.63 | 2.49 | 0.24 | 0.46 | 0.02 | 0.44 | 531.7 | 5.59 | 59.66 | 38.32 | 35.63 | |

| Plant tissue standards | Total N | P | K | S | Mg | $NO_3$ | Cu | Mn | Zn | B |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pre-harvest** | | | **(%)** | | | | | **(mg/kg)** | | |
| **DRIS*** | 3.1–3.8 | 0.50–0.90 | 1.8–2.2 | 0.19–0.23 | 0.33–0.45 | | 3.3–5.8 | | 13–28 | 31–46 |
| **University of Florida** | 3.0–3.5 | 0.20–0.40 | 1.5–2.5 | 0.25–0.80 | 0.25–0.50 | | 5–10 | | 20–40 | 20–40 |
| **Main harvest** | | | | | | | | | | |
| **DRIS*** | 2.4–3.0 | 0.30–0.40 | 1.3–1.8 | 0.15–0.21 | 0.28–0.42 | | 2.6–4.9 | 65–320 | 13-28 | 40–70 |
| **University of California Publication 4098** | >3.0 | 0.15–1.30 | 1.0–6.0 | >0.10 | 0.3–0.7 | | 3–30 | 30–700 | 20–50 | 35–200 |
| **University of Florida** | 2.8–3.0 | 0.20–0.40 | 1.1–2.5 | 0.25–0.80 | 0.20–0.40 | | 5–10 | 25–100 | 20–40 | 20–40 |

***** Diagnosis and Recommendation Integrated System

# Appendix 9: Irrigation assessment offer letter (English and Vietnamese)

Dear strawberry grower,

In 2013, The Department of Agriculture and Food WA (DAFWA) together with your association gained funding for a project is called ***'A focus on irrigation and fertiliser practices to improve production efficiency for LOTE (Language other than English) strawberry growers.'***

As part of the work, irrigation system assessments were done at the end of the 2013 season and field days looking at the movement of blue dye and fumigation effectiveness were run prior to the 2014 season.

Even watering helps you to use the water and fertiliser you put on, more effectively. In our sandy soils in Perth, water and fertiliser drain very easily and so the plant misses out on the water and food it needs. And you are also paying for something that is not helping you!

Strong healthy plants that are properly watered and fed are also more resilient against disease.

Even watering is very important for the fumigation you do at the beginning of each season, so the soil is clean and disease free.

**We are looking for growers who want an irrigation assessment.**

It won't cost you anything and we believe we can help you grow better plants with more even production possibly less disease. We are keen to hear from growers who are;

- Planning to be farming in the future
- Willing to make themselves available for an hour or so during the assessment.
- Willing to discuss the results following analysis of the test
- Will consider improvements to their system to improve irrigation

**If you are keen to be involved please contact**

Rohan Prince on Mob: 0429 680 069, Ph: 9368 3210 or email: rohan.prince@agric.wa.gov.au

Aileen Reid on Mob: 0467 783 981 or Ph: 9368 3393 or email: aileen.reid@agric.wa.gov.au

Robert Deyl on Mob: 0455075427 or Ph: 9368 3718 or email: robert.deyl@agric.wa.gov.au

I am interested in having my irrigation system tested.

Name: ..........................................................................

Address: ..........................................................................

..........................................................................

..........................................................................

Phone number: ..........................................................................

Mobile: ..........................................................................

Email: ..........................................................................

**Irrigation assessment offer letter (Vietnamese)**

**STRAWBERRY GROWERS ASSOCIATION OF WESTERN AUSTRALIA INC.**

PO BOX 382 WANNEROO 6946

Kính gửi những người trồng dâu tây,

Năm 2013, Sở Nông Nghiệp và Thực Phẩm WA (DAFWA) cùng với hiệp hội của quý vị đã được cấp kinh phí cho dự án mang tên ***'Tập Grower 4 vào thực hành bón phân và tưới tiêu nhằm nâng cao hiệu quả sản xuất cho những người trồng dâu tây nói LOTE (Ngôn ngữ không phải là tiếng Anh).'***

Là một phần của công việc, các đánh giá hệ thống tưới tiêu đã được thực hiện vào cuối mùa vụ 2013 và những ngày đánh giá tại hiện trường để xem xét sự thay đổi trong tính hiệu quả của thuốc nhuộm xanh và khử trùng đã được thực hiện trước mùa vụ năm 2014.

Thậm chí việc tưới nước cũng giúp quý vị sử dụng hiệu quả hơn nước và phân bón mà quý vị đưa vào. Đối với loại đất pha cát của chúng ta tại Perth, nước và phân bón rất dễ bị thoát và do đó cây bị mất lượng nước cũng như thức ăn cần thiết. Và quý vị cũng đang phải trả tiền cho một số thứ chẳng giúp ích gì cho quý vị!

Những cây khỏe mạnh cứng cáp được bón phân và tưới nước hợp lý cũng có khả năng chống chịu bệnh tốt hơn.

Ngay cả việc tưới nước cũng rất quan trọng đối với với công tác khử trùng mà quý vị thực hiện vào đầu mỗi mùa vụ để đất sạch và không bị bệnh.

**Chúng tôi đang tìm kiếm những người trồng dâu muốn đánh giá công tác tưới tiêu.**

Quý vị sẽ không mất bất kỳ Grower 1 phí nào và chúng tôi tin rằng chúng tôi có thể giúp quý vị trồng cây tốt hơn thậm chí là với năng suất cao hơn và khả năng cây bị bệnh thấp hơn. Chúng tôi rất muốn nghe ý kiến từ những người trồng dâu mà;

- Đang có kế hoạch trồng trọt trong tương lai
- Sẵn sàng có mặt khoảng một tiếng trong buổi đánh giá.
- Sẵn sàng thảo luận về kết quả sau khi phân tích kiểm tra
- Sẽ cân nhắc cải thiện hệ thống của mình để cải thiện công tác tưới tiêu

**Nếu quý vị muốn tham gia, vui lòng liên lạc với một trong các cán bộ dưới đây hoặc điền vào và gửi lại mẫu đính kèm qua fax chậm nhất vào ngày 26 tháng 9**

Rohan Prince qua Điện Thoại Di Động: 0429 680 069, Điện Thoại Cố Định: 9368 3210 hoặc email: rohan.prince@agric.wa.gov.au

Aileen Reid qua Điện Thoại Di Động: 0467 783 981 hoặc Điện Thoại Cố Định: 9368 3393 hoặc email: aileen.reid@agric.wa.gov.au

Robert Deyl qua Điện Thoại Di Động: 0455075427 hoặc Điện Thoại Cố Định: 9368 3718 hoặc email: robert.deyl@agric.wa.gov.au

***' Tập Grower 4 vào thực hành bón phân và tưới tiêu nhằm nâng cao hiệu quả sản xuất cho những người trồng dâu tây nói LOTE (Ngôn ngữ không phải là tiếng Anh).'***

Att: Rohan Prince

DAFWA South Perth

Fax 9367 7389

Tôi muốn hệ thống tưới tiêu của tôi được kiểm tra.

Tên: ..........................................................................

Địa Chỉ: ..........................................................................

..........................................................................

..........................................................................

Điện Thoại Cố Định: ..........................................................................

Điện Thoại Di Động: ..........................................................................

Email: ..........................................................................

# Appendix 10: Images from demonstration site

**Figure A10.1. Overall view of headworks**

**Figure A10.2. Close-up view of site**

**Figure A10.3. View of irrigation monitoring equipment**

**Figure A10.4. Final installation in place, one of four sets**

## Appendix 11: Intensive soil moisture, EC and temperature monitoring images

**Figure A11.1. Section of plastic cut and pulled back to expose the bed**

**Figure A11.2. Inserting a probe under a dripline**

**Figure A11.3. Probe being installed at edge of bed**

**Figure A11.4. All probes installed**

## Appendix 11: Intensive soil moisture, EC and temperature monitoring images continued

**Figure A11.5. Close-up view of monitoring gear**

**Figure A11.6. Completed installation**

# Appendix 12: Grower visits during project

## Visits in 2013 season

| Grower | Rob Deyl | Aileen Reid | Gerry Verheyen | Rohan Prince |
|---|---|---|---|---|
| **Grower 1** | 10 | 6 | 5 | 2 |
| **Grower 2** | 8 | 6 | 1 | |
| **Grower 3** | 8 | 6 | | 2 |
| **Grower 4** | 10 | 8 | 4 | 2 |
| **Grower 5** | 4 | 2 | 1 | 1 |
| **Grower 6** | | 1 | 3 | 1 |
| **Grower 7** | 1 | 1 | | 1 |
| **Grower 8** | 1 | | | 1 |
| **Grower 9** | 1 | 1 | | |
| **Grower 10** | 1 | | | 1 |
| **Grower 11** | 2 | 2 | 2 | |
| **Grower 12** | | | 1 | |
| **Grower 13** | | 1 | 1 | |

## Visits in 2014 season

| Grower | Rob Deyl | Aileen Reid | Gerry Verheyen | Rohan Prince |
|---|---|---|---|---|
| **Grower 1** | 8 | 2 | 5 | 2 |
| **Grower 2** | 3 | 2 | 1 | |
| **Grower 3** | 2 | 1 | | 2 |
| **Grower 4** | 8 | 2 | 4 | 2 |
| **Grower 5** | | 3 | 2 | |
| **Grower 6** | At least weekly | 5 | 3 | |
| **Grower 7** | 2 | 3 | | |
| **Grower 11** | 2 | 2 | 2 | |
| **Grower 13** | 1 | 5 | 3 | |
| **Grower 14** | 1 | 2 | | |
| **Grower 15** | | 1 | | |
| **Grower 16** | | 1 | | |

# Appendix 13: Using pesticides in strawberry production – your responsibilities as a grower webnote (English)

Using pesticides correctly will control pests and diseases effectively and keep you safe and healthy.

There are rules and regulations for pesticide use you must follow to make sure that you, the food you grow, your neighbours and the environment remain safe.

Using pesticides wrongly or illegally can mean you lose the right to sell your fruit into certain markets –your actions can even mean ALL growers may lose access to markets.

Once you have been found to use pesticides badly you may not be able to buy other pesticides any more and you might have to go out of business.

You can only use pesticides that are registered for use on strawberries or that have a current Minor Use Permit for use on strawberries. Over the page is a list of those that are allowed as of 12 February 2015 but these change often and must be checked regularly. The APVMA website (www.apvma.gov.au) is updated each day and can be used to find both registered chemicals and Minor Use Permits.

Using the wrong pesticide may also be a waste of money if it does not control the pest of disease.

The pesticide label is a legal document and penalties can be applied if the pesticide is not used according to the directions on the label. This includes the rate of the pesticide – ie how much you put in the tank, how often you apply it, how you apply it (what sort of spray equipment) and how soon you can harvest the crop after you have used that pesticide.

You can be fined and if many growers are not using the pesticide properly, it may be withdrawn and you will no longer be able to use it.

The withholding period listed on the label states how soon after spraying you can **pick** the crop (not sell). If you pick the crop too soon (earlier than the withholding period) it will have residues from the pesticide that are too high for people to eat that food safely. Many retailers eg Coles and Woolworths, and also government departments, test food at random for residues and if they are found to be too high, you can be prosecuted. You can also be charged for the cost of recalling your product from the shop so it can cost you a lot of money. If chemicals are found in your product that are from pesticides that are not registered for use on strawberries, this is illegal and you may also be prosecuted, with your product withdrawn from sale.

*The Food Act 2008* and it subsidiary legislation, *The Food Regulations 2009*, has three levels of offence: 'knowingly', 'ought to know' and 'Strict liability' where there is no excuse for not knowing. The penalties range from $40,000 to $100,000 and potential imprisonment for an individual grower or $200,000 to $500,000 for a company. When you buy a pesticide, you agree to the legal use of the pesticide as described on the label and therefore higher penalties may occur.

A booklet (A guide to the use of pesticides in Western Australia) covering your obligations when you use pesticide can be downloaded from this web page:
http://www.health.wa.gov.au/publications/subject_index/p/poisons.cfm

**Table 1. Insecticides and fungicides registered for use on strawberries as at 12 February 2015**

| Example of product name | Actives | Problem | Withholding period | Other conditions of use |
|---|---|---|---|---|
| **Captan** | Captan | Various fungal diseases | 1 day | No more than 5 sprays per season |
| **Cropcare Captan (only)** | Captan | Various fungal diseases | 1 day | No restriction on number of sprays per season but spraying more than every 14 days may violate residue limits |
| **Copper** | Copper | Various fungal diseases | 1 day | |
| **Teldor** | Fenhexamid | Grey mould | None | Not more than 2 sprays in a row |
| **Rovral** | Iprodione | Grey mould | 1 day | Not more than 2 sprays in a row |
| **Systhane** | Myclobutanil | Powdery mildew | None | Not more than 2 sprays in a row |
| **Fontelis** | Penthiopyrad | Powdery mildew | 1 day | No more than 3 sprays per season, no more than 2 applications in a row |
| **Scala** | Pyrimethanil | Grey mould | 1 day | May be used in the same season but no more than three applications of these chemicals in total per season |
| **Switch** | Cyprodinil /Fludioxonil | Colletotrichum, Grey mould | 3 days | |
| **Wettable sulphur** | Sulfur | Powdery mildew | None | |
| **Thiragranz** | Thiram | Various fungal diseases | 7 days | |
| **Barmac Thiram (only)** | Thiram | Various fungal diseases | 2 days | |
| **Flint** | Trifloxystrobin | Powdery mildew | 1 day | No more than 3 sprays per season Do not spray twice in a row |
| **Zineb** | Zineb | Various fungal diseases | 7 days | |
| **Abamectin** | Abamectin | Two spotted mite | 3 days | No more than 2 sprays per season |
| **Lorsban** | Chlorpyrifos | Crickets | None | For bran baiting around plants only |

**Table 1. (continued) Insecticides and fungicides registered for use on strawberries as at 12 February 2015**

| Example of product name | Active ingredients | Problem | Withholding period | Other conditions of use |
|---|---|---|---|---|
| **Torque** | Fenbutatin oxide | Two-spotted mite | 1 day | |
| **Lannate** | Methomyl | Caterpillars | 3 days for fresh fruit, 10 days if fruit to be frozen | |
| **Gemstar** | Nuclear polyhedrosis virus of helicoverpa zea | Caterpillars | None | |
| **Pirimor** | Pirimicarb | Aphis | 2 days | |
| **Success Neo** | Spinetoram | Caterpillars, western flower thrips | 1 day | |
| **Dipterex** | Trichlorfon | Caterpillars | 2 days | |
| **Kelthane/Masta-Mite** | Dicofol or dicofol/tetradifon | Two-spotted mite | 7 days | Not for use in IPM programs |
| **Calibre** | Hexythiazox | Two-spotted mite (eggs only) | 1 day | Only 1 spray per season |
| **Omite** | Propargite | Two-spotted mite | 3 days | |

**Table 2. Minor use permits for strawberries as at 12 February 2015**

| Permit no. | Active | Trade name | Problem | Withholding period | Other conditions of use | Permit expiry |
|---|---|---|---|---|---|---|
| **PER12486** | Trichlorfon | Dipterex | Fruit fly | 14 days | | 31-May-16 |
| **PER14724** | Bifenazate | Acramite | Two-spotted mite | 1 day | | 30-Jun-17 |
| **PER12927** | Spinetoram | Success Neo | Fruit fly (suppression only) | 1 day, no more than 4 applications per season | | 31-May-16 |
| **PER12940** | Maldison | Malathion | Fruit fly | 3 days | | 31-May-16 |
| **PER100147** | Phosphorous acid | Foli R Fos | Phytophthora | 6 weeks | | 31-Oct-17 |
| **PER13331** | Pyriproxyfen | Admiral | Greenhouse and silverleaf whitefly | 2 days | | 31-Oct-15 |
| **PER13542** | Maldison | Malathion | Rutherglen bug | 3 days | | 30-Jun-17 |
| **PER14646** | Pirimicarb | Pirimor | Aphids | | | 31-Mar-15 |
| **PER14453** | Chlorantraniliprole | Coragen | Caterpillars | No more than 3 applications per crop. No more than 2 sprays in a row | | 31-May-17 |
| **PER13377** | Emamectin | Proclaim | Cluster caterpillar, Heliothis, lightbrown apple moth and looper | 3 days, no more than 3 applications per crop | | 30-Sep-15 |
| **PER14192** | Indoxacarb | Avatar | Garden, white fringed weevil | 2 days | | 30 Sept 2018 |

**Table 3. There are additional chemicals registered or with minor use permits for use on RUNNER CROPS only in some Australian States. There are no RUNNER CROPS grown in Western Australia. It is ILLEGAL to use these chemicals in Western Australia. This is for information ONLY.**

| NOT FOR USE IN WESTERN AUSTRALIA | | | | | |
|---|---|---|---|---|---|
| **Permit no.** | **Active** | **Trade name** | **Problem** | **Other conditions of use** | **Expiry Date** |
| **PER14577** | Quinoxyfen | Legend | Powdery mildew | Runner crops ONLY | 30-Sept-19 |
| **PER14483** | Pyraclostrobi n | Cabrio | *Colletotrichum gloeosporioides* | For use in tissue culture (TC) and foundation nurseries ONLY | 30-Sep-18 |
| **PER13120** | Bitertanol | Baycor | Powdery mildew, blight, scorch | Runner crops ONLY | 30-Nov-16 |
| **PER13697** | Metalaxyl -M | Ridomil Gold 480EC | Crown rot (*Phytophthora cactorum)* IN RUNNER PRODUCTION ONLY | Runner crops ONLY | 30-Sep-17 |
| **PER12387** | Cyprodinil/ Fludioxonil | Switch | *Colletotrichum* crown or petiole rot | Runner crops ONLY | 31-Oct-15 |
| **PER13697** | Phosphorous acid | Phos acid | Crown rot (*Phytophthora cactorum*) IN RUNNER PRODUCTION ONLY | Foliar spray only unless dipping bundles of runners | 30-Sep-17 |
| | **Nemacur** | Fenamiphos | Nematodes | Runner crops ONLY | |
| | **Octave** | Prochloraz | *Colletotrichum* | Runner crops ONLY | |

# Appendix 14: Irrigation and fertiliser guidelines for strawberries for web (English)

## Introduction

It is difficult to provide prescriptive guidelines for strawberry irrigation given the wide range of planting configurations and hence irrigation layouts. The aim of these notes is to help growers in Western Australia understand the factors affecting their crop requirements so they can adapt their practices accordingly.

The fertiliser requirements for strawberries differ between varieties although many growers use only one recipe for all.

## Water and soil

Irrigation water for strawberries needs to be excellent quality, as strawberries are very sensitive to salts, in particular chloride (but not sodium).

Chloride will start to depress yield at very low levels. Ideally the electrical conductivity (EC) of irrigation water needs to be below 0.75dS/m (750uS/cm) or total dissolved solids (TDS) of 400mg/L.

Yield will drop by about 25% if water contains 650mg/L TDS (1.20dS/m), and even more if the water is saltier.

If your water contains more than 0.5 parts per million (ppm) iron, then some treatment to remove the iron may be needed to avoid dripper blockages.

Soil pH should be in the range 5.5 to 7.5 (slightly acid to neutral). If pH correction is required, this should be done prior to planting using lime and/or dolomite.

It is not necessary or desirable to apply any nitrogen (N), potassium (K) or phosphorus (P) fertiliser prior to planting if fertigation is used. In our coarse sands they will leach and be wasted before the plants develop enough roots to be able to access the nutrients . A base dressing of mixed trace elements may be applied pre-plant if wished since they are less easily leached, but it can also be applied through the irrigation with the rest of the fertiliser. If adding compost to the soil, apply it close to planting to avoid leaching of nutrients.

Very high levels of salts have been observed early in the season when pre-plant compost is applied. This is something to be aware of and monitor, especially with the more sensitive varieties such as Fortuna.

High levels of fertiliser salts may damage young roots and allow access of pathogens that leads to disease. High levels of nitrogen early will promote vegetative growth at the expense of flowering and fruiting.

## Poultry manure

Application of raw poultry manure is banned in several shires and city councils on the Swan Coastal Plain, from Gingin to Harvey, as it provides a breeding ground for stable flies, which are a serious pest to animals and humans. Poultry manure also contains easily leachable nutrients so as in the case of applying a base dressing of NPK fertiliser, much is wasted before plants can access it. Other products such as composted chicken manure or other types of compost do not breed stable fly but as mentioned above, are still able to leach nutrients.

When forming beds, ensure the soil is rolled well. Fluffy soil will decrease the lateral spread of water and plant establishment will be adversely affected.

## Irrigation and fertiliser practice

The following guidelines are based on research conducted in Wanneroo over many years. With good fertiliser and irrigation practices, and depending on variety, strawberries can consistently produce up to 1.5 kilograms of fruit per plant each season.

The industry average is closer to 0.50–0.75kg but 1 kilogram should easily be achievable by following recommended guidelines.

## Irrigation systems

Overhead sprinklers are used for establishment and for cooling plants in hot weather, but drip irrigation is recommended throughout the season.

Drip irrigation is more efficient, as it uses less water and applies it more evenly. Fruit is kept dry, lowering disease incidence.

## Overhead irrigation for establishment

Overhead irrigation should be applied to prevent new runners from wilting. When plants arrive they have no active roots. Reducing plant stress (wilting) will promote quicker root establishment and nutrients can then be taken up, enabling good plant growth.

The frequency and duration of overhead irrigation will depend on weather and the condition of the runners at planting. Compact runners with smaller leaves require less irrigation as they have less leaf area than long large-leafed runners that lose water more readily.

Many growers use 'leaf-off' plants. These generally arrive about two weeks later than leaf-on plants and have experienced a larger degree of chilling. They are less fragile than leaf-on plants but still require some overhead cooling.

When planting in February or early March cooling may be required between once and four times an hour during the heat of the day until roots are established and drip irrigation is effective.

Growers can use a significant proportion amount of their water allocation during this period and as the goal is cooling rather than irrigation, using a low output nozzle with a finer droplet size may reduce water use.

Good irrigation uniformity and cooling can be achieved by using smaller nozzles at the right pressure. Twin-nozzle sprinklers may use up to 1000 litres per hour whereas some newer low-flow sprinklers may only need 500L to achieve the desired result.

Drip irrigation should be used in addition to overhead irrigation during establishment to promote root establishment and prevent soils from drying out between planting holes.

Sands in Western Australia can become water repellent or non-wetting if soil moisture is not maintained, and are almost impossible to re-wet using drip irrigation. Even in uniformly wet sandy soils the lateral spread of water is no better than about 15–18cm. When sandy soils dry out, water follows preferred pathways and even that limited spread may not be achieved.

Other factors can have major effects on the penetration of overhead irrigation and rain, such as:

- the size and shape of the planting hole punched in the plastic
- the evenness of the bed surface, and
- how tightly the plastic has been laid.

## Drip irrigation

The most common configuration for commercial strawberries on sand is two lines of drip irrigation per four-row bed with each line laid between the two outer rows of plants.

However, growers use a range of planting and irrigation configurations including two, three and four-row beds using one, two or even three rows of drip tape. Some growers plant two 'pairs' of rows with plants offset rather than four rows equally spaced across the bed.

Bury the lines slightly so they stay in place and don't move around. This gives the best chance of all plants receiving the same amount of water and fertiliser.

A 25cm dripper spacing is common but a closer spacing, if scheduled effectively, will lead to more even irrigation and may give better yields and quality.

Dye tests and irrigation monitoring in the Wanneroo area have shown that increased volumes (longer duration) will not increase the spread of water beyond about 15–18cm total or 7.5–9cm on either side of the dripper. This indicates that 15 to 20cm distance between drippers would deliver irrigation more evenly to the crop than 25cm.

Experience in Wanneroo including dye testing showed that a yield advantage was achieved with a 10cm dripper spacing but that may not be practical for many growers.

Longer run times only waste water (and fertiliser) by sending it deeper into the soil profile, past the root zone.

Questions exist as to what degree plant roots will grow towards soil water and what detriment, if any, this may have on yields. In Florida, soils are also sandy but have a higher proportion of finer silt particles, and so lateral water movement is better. Beds there are constructed 30cm higher than the pathways and growers aim to promote extensive root growth to fill the bed as a matter of priority after planting, to maximise nutrient uptake and efficiency.

## Cultivar differences

Strawberry cultivars vary in their vigour, leaf area and fruit production which suggests that different amounts of irrigation and fertiliser are required. For example, Fortuna is recognised as being a smaller, less vigorous plant. Its root system may not explore the soil to the same degree as Camarosa and Festival.

Most growers in WA treat all varieties the same but this may not be the best option, especially for water and fertiliser.

Work in Wanneroo has shown that stand-alone evaporation-based irrigation scheduling does not work well with strawberry crops grown under black plastic mulch, high tunnels, or plastic cloches.

## Irrigation requirements

Evapotranspiration and the impact of rainfall are altered by plastic mulch and cloches or tunnels.

When rain falls throughout the cooler months, growers often reduce or stop watering in the belief that water falling in the pathways can be accessed by the plants. However, on coarse sandy soils this is not so. Some water does enter the beds during heavy falls (25mm or more) but it is largely below the root zone and serves mostly to leach fertiliser.

Soil moisture monitoring is essential to determine the effectiveness of water applied and the water potential of the soil. Information on using soil moisture sensors to fine-tune irrigation can be found here.

Previous research in Western Australia suggested that replacing 70% of evaporation was adequate to supply plant needs over most of the season. More recent experience indicates that water requirements could be as high as 100% of evaporation for maximum production.

Using soil moisture monitoring equipment to fine-tune irrigation for each particular variety/plant spacing/irrigation configuration and soil type is the best practice.

In WA's sandy soils irrigation should be split into two or three times a day, even four times when daily evaporation gets to around 10mm per day. The aim is to apply small amounts more often (<3mm at a time) to keep fertiliser in the root zone rather than flushing it below the roots.

Many modern soil moisture probes also monitor EC (the concentration of salts in the root zone). That can be useful when levels start to climb, given strawberries are a salt-sensitive crop. If levels rise, apply water only for a day to leach out the build-up of salts.

## Fertiliser

Fertiliser should be applied daily at least. If the system is able to maintain pressure between irrigations then fertiliser can be applied with each watering.

An efficient system requires a fertiliser injector and two or even three different tanks.

With the two tank system, calcium nitrate and half of the potassium nitrate are dissolved in Tank A and the other fertilisers are dissolved in Tank B. Tank B may be divided further so that sulphates and phosphates are kept separate, making three tanks.

The most basic system uses a venturi, where a given amount of fertiliser is simply sucked into the line. In that case the grower may only have one tank, and since some nutrients cannot be mixed together then two different feeds may be used on different days.

Growers who feed manually often fertilise less often because the process is labour intensive. Every three to four days is common. But soil nutrient monitoring shows fertiliser levels decline rapidly between feeds. This will reduce plant growth.

One example of a fertiliser program is shown in Table 1. Other fertilisers may be used to make up the suggested quantities of each element required. Note that the amounts are given per hectare of bed area, that is, pathways are excluded.

**Table 1. Example of nutrient solution applied through irrigation**

| **Product** | **Rate (kg/ha/day)** | **Applied nutrients (kg/ha of bed area)** | | | | |
|---|---|---|---|---|---|---|
| | | **N** | **P** | **K** | **Ca** | **Mg** |
| Calcium nitrate (15.5% N, 19% Ca) | 6.5 | 1.0 | | | 1.2 | |
| Potassium nitrate (13% N, 38% K) | 6.4 | 0.8 | | 2.4 | | |
| Magnesium sulphate (9.9% Mg) | 3.0 | | | | | 0.3 |
| Mono-ammonium phosphate (11% N, 22.8% P) | 1.9 | 0.2 | 0.4 | | | |
| **Total nutrients applied per day** | | **2.0** | **0.4** | **2.4** | **1.2** | **0.3** |

This fertiliser program applies approximately 450kg of nitrogen, 100kg of phosphorus, 580kg of potassium, 288kg of calcium and 76kg of magnesium per hectare per season (April to November). Rates of nitrogen in excess of 450kg/ha risk compromising fruit quality and taste.

Despite a common belief that strawberries cannot be given nitrogen (N) in the ammonium form, trials around the world have shown better N uptake when some ammonium is present. One quarter of the N requirement can be given as ammonium when growing in soil as opposed to hydroponics. More than that will affect fruit quality making it soft (more prone to bruising and fungal rots) and flavourless.

## Trace elements

You can add all trace elements at the start of the season as a broadcast application which is then rotary hoed in (shown in Table 2). Or you can add them to your nutrient solution mixture above.

If they are added as sulphates, rather than chelates, then you need to keep them in the 'B' tank.

**Table 2. Trace element fertiliser options**

| **Fertiliser** | **Formula** | **Quantity (g/1000L)** |
|---|---|---|
| Iron chelate | Fe-EDTA (13% iron) | 860 |
| Manganese sulphate | $MnSO_4.H_20$ | 169 |
| Borax | $Na_2B_4O_7.10H_2O$ | 953 |
| Zinc sulphate | $ZnSO_4.7H_2O$ | 201 |
| Copper sulphate | $CuSO_4.5H_2O$ | 19 |
| Sodium molybdate | $Na_2MoO_4.2H_2O$ | 12 |

Alternatively, use a proprietary trace element mix and add to the appropriate tank at recommended rates.

Note:

- The electrical conductivity (EC) of the nutrient solution emitted from your drippers should not exceed 2µS/cm. High salt concentrations can damage the crop.
- Calcium nitrate should not be mixed in the same tank as fertilisers containing phosphates or sulphates.

- When fertigating, keep the soil at or near field capacity to avoid concentrating salts in the root zone. As the soil dries, the concentration of salts increases.

## Calibrating nutrient solution injection pumps

1. Start irrigation and injection pumps.
2. Adjust each injection pump to the same output.
3. Measure the EC at the dripper and adjust each injection pump up or down to get an EC of about 2.2µS/m in total, for example 1.7µS/m for the fertiliser and 0.5µS/m for the bore water.
4. Measure the output of the injection pump for one minute to work out the flow rate.

## Calculation of injection time (worked example)

Assume you are using two 1000L tanks for your fertiliser stock solution. The following amounts of fertiliser are contained in your two tanks.

75kg calcium nitrate
75kg potassium nitrate
36kg MAP
18kg magnesium sulphate

There is 23.4 kg of nitrogen containing fertiliser in the above recipe. If you have two pumps, each with a flow rate of 120L/hour it will take 2000/120 = 16.6 hours before the tanks empty.

Injection rate – 23.4kg N/16.6 hours = 1.40kg N/hour = 23.5g N per minute

If the area for one station is:

Nine 4-row beds each 125m long x 1.2m wide = 1350m$^2$

**AND** the amount of nitrogen needed is 2kg/ha per day

= 0.2g/m$^2$/day

= 0.2 x 1350m$^2$

= 270g

**Required injection time = 270/23.5 = 11.5 minutes**

To increase or decrease the amount of N, you can either change the injection time or increase the concentration of the recipe provided the final EC of the solution does not exceed 2.2Sµ/m.

## Further reading

The websites below provide useful information from other growing areas:

http://www.haifa-group.com/knowledge_center/crop_guides/strawberry/mineral_nutrition_of_strawberries/

https://edis.ifas.ufl.edu/cv003

http://apps.cdfa.ca.gov/frep/docs/Strawberry.html

http://www.berrykonsult.eu/gb/growth/fertigation

# Appendix 15: Strawberry plant establishment for web (English)

A survey of strawberry plant establishment across a number of growers properties has shown huge variation with some growers losing almost half their plants. Many stories circulate and there is no doubt there can be differences between varieties and between runner growers. However growers who pay attention to detail do not suffer the extent of losses commonly seen and in fact their losses are usually within acceptable limits, that is less than 10 per cent.

Good plant establishment is important because it costs virtually the same to manage a hectare of land whether it is full or half full. It costs the same to prepare, fertilise and irrigate vacant plant spaces as it does plants. Sprays are still applied over the whole area and pickers still have to cover the same amount of ground.

## Reasons for poor establishment

### Uneven soil moisture at planting

Perth’s sandy soils can be difficult to wet up thoroughly. When wetting up the soil prior to fumigation it may take 4-5 cultivations to ensure the soil is completely and evenly moist.  Do not assume that because the surface looks moist, that is the case for the whole 15-30 cm.

If the soil is not evenly moist (and compact) all the way through then when you apply fumigant, it will not move evenly through the soil and you may be left with areas that are not fumigated. Those areas may have disease left over from the previous crop and can infect new plants.

At planting time this uneven wetting persists. Plants will be stressed and set back until their roots are able to access soil moisture. In the long run, stressed plants often never fully recover and yield much less, if at all. Often they die.

### Poor irrigation practices at planting time

Growers are continually seeking to plant earlier to achieve the higher prices associated with early cropping and the high process and as the weather is often quite warm in March and April, irrigation in the first 2-3 weeks after planting is critical. The sooner the plant can establish a root system, the better it will be able to withstand changes in temperature and access nutrients for early growth.

When runners first arrive they are virtually non-functioning. They have no active roots and need to draw on their carbohydrate reserves to produce them. The shorter the timeframe this happens in the better. This means they need to be treated like a cutting and prevented from wilting as much as possible until they can grow new roots.

Runners need to be kept as cool as possible when they arrive. Do not leave bags of runners on the tops of beds in full sun! For best establishment, runners should be kept fully hydrated and not allowed to wilt. As soon as they are planted they should be overhead watered a little and often – say 5-10 minutes every daylight hour – especially when it is warm.

The purpose of overhead watering is to keep plants cool and prevent wilting. Trickle irrigation is still required to keep the root environment moist and allow new roots to form. Until a good root system develops the plants will be fragile and prone to drying out.

Do not rely on overhead irrigation to keep the soil moist. While some growers make quite large holes in the plastic for the plants the bed surface is seldom perfectly even and there is no way to guarantee water will penetrate every planting hole. Other growers make only small slits and much of the overhead irrigation runs off.

Our irrigation monitoring shows that water falling on pathways between beds does not usually benefit the plants in the coarse WA sands. Occasionally with large falls of rain we may see that water entering the soil under the beds at 45 cm but that is below the vast majority of plant roots.

There is a big correlation between sprinkler irrigation and plant survival and early growth.

There are several things to look at with sprinkler irrigation.

**Sprinkler system design**. Many growers have sprinklers at spacings that are inappropriate ie too wide to get good even coverage. We can see the effects of this in early plant growth and establishment – it often matches the watering pattern of the sprinklers – where precipitation rates are good plants survive and are green, where less water falls plants either die or are slow to take off. It is important to have your sprinklers at the spacing that is recommended for them at the pressure you run.

Most growers have had their system designed for drip irrigation. If the sprinklers are to operate effectively, the number of sprinklers run in each shift will need to be much less, a and the number of valves, greater. Many growers have Naan 5022 sprinklers. They are designed to operate at between 280-300kPa.

**Frequency of overhead irrigation**. As previously mentioned the purpose of the overhead irrigation is more to cool the plants than to irrigate so the sprinklers should be run for 5-10 minutes every hour when it is warm.

# Appendix 16: Gnomoniopsis fruit rot and leaf blotch webnote (English)

**Caused by:** *Gnomoniopsis comari* (previously known as *Gnomoniopsis*) is a fungus, also called *G. fragariae*, *G. fructicola*.

**Symptoms:** Figure 1 shows how the fruiting bodies of the fungus develop on crop residue. Spores are produced there, that infect the next crop**.**

**Figure 2 shows very early symptoms of the disease on leaves. It is important to start controlling the disease at this stage.** The fungus first infects the calyx (see Figure 3), and the disease spreads into the fruit as a rot. Both green and ripe fruit may be infected. Infected fruit ripens early and turns pale red to brown. They remain firm, but are often invaded by other fruit rots such as grey mould. The brown calyces are the most common symptom and fruit with these may be unmarketable or down-graded.

### Occurrence

Festival is much more susceptible than Camarosa. The disease usually affects the first flush of fruit then disappears as the weather warms up.

Figure 1 **The black 'dots' are the fruiting bodies of the fungus on strawberry crop residue. The spores produced, infect the next crop.**

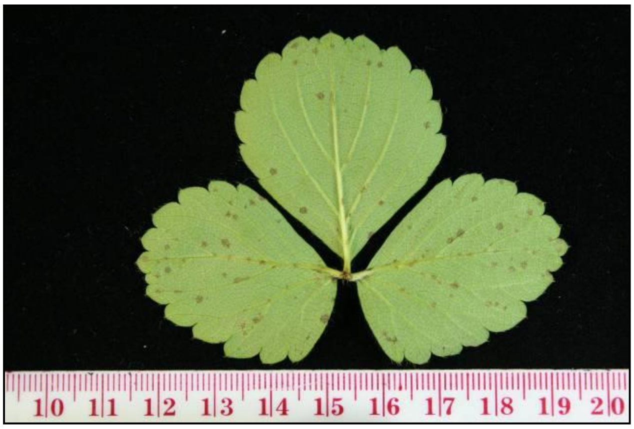



Figure 2 **Early symptoms of infection on a leaf (small lesions on the underside).**

Figure 3 **The start of stem end rot in fruit caused by *Gnomoniopsis* (note the brown calyces).**

Figure 4 **Leaf symptoms of *Gnomoniopsis* on Festival.**

**Sources of infection**

Crop residue left in the soil from previous and current strawberry crops is the main source of infection. Planting material also carries the spores but levels are usually quite low and it is unlikely that runners are a significant source of infection.

**Spread**

The fungus spreads by splashing water from rain or overhead irrigation in humid weather. *Gnomoniopsis* is a weak pathogen and infects plants through stomata or wounds. It is favoured by cool, wet weather, reproducing at temperatures over 5ºC and grows best around 20ºC.

**Control (in descending order of importance)**

1. Keep foliage dry. Avoid overhead irrigation. This disease is not a problem under high tunnels. It tends to affect the outer rows of plants more because water drips from the plastic and wets the leaves, especially when lifting the covers and putting them back down. Bend cloche frames out so they are 50-100 mm from the black plastic at the sides of the beds. This keeps the plastic from touGrower 1ng the plants.
2. *Gnomoniopsis* doesn't like warmth so try to keep the plants as warm as possible in winter. When venting, only raise one side of the covers.
3. Remove all residues of previous crops from the soil. Thoroughly compost all old plant material after removal or bury deeply on- or off-site.
4. Remove and dispose of any leaves showing signs of early infection (see Figure 3).
5. Keep potash (potassium) levels higher than nitrogen. A ratio of at least 1:1.5 N:K over winter. Too much nitrogen makes too many leaves and plants are soft and get disease more easily. Talk to your advisor about your fertiliser program to make sure it is OK.

6. Control using fungicides can be highly variable. Some of this could be due to resistance. Fungi can become resistant to pesticides if you use the same ones all the time. If that happens the pesticide stops working. It is not a bad idea to use a different chemical each time you spray. *Botrytis* (grey mould) may also be a problem at the same time of year and you will also need to alternate chemicals for that disease. See Table 1 for the registered chemicals for each disease. Different chemicals are used to control each disease.
7. Switch® has a minor use permit for this disease but you can only use 3 sprays over the whole season. Alternate with Fontelis® or Flint®. Thiram can also be used early in the season. Captan can also be used but only a total of **5 times** over the whole season.

**Table 1. Pesticides registered for *Gnomoniopsis* and *Botrytis* (as at 11 March 2014)**

| ***Gnomoniopsis*** | ***Botrytis*** |
|---|---|
| Switch® (cyprodinil/fludioxonil) | Teldor® (fenhexamid) |
| Fontelis® (penthiopyrad) | Rovral® (iprodione) |
| Flint® (trifloxystrobin) | Scala® (pyrimethanil) |
| Systhane® (myclobutanil) | Captan |
| Thiram | Carbendazim (not recommended, harmful to predatory mites and bees) |
| Captan | |

**Acknowledgements:** Thanks to Scott Mattner (DPI Victoria) for use of photos and editorial assistance.

For further information contact Aileen Reid on telephone (08) 9368 3393 or by email aileen.reid@agric.wa.gov.au

**Vietnamese translation**

# Thối quả và đốm lá do *nấm Gnomoniopsis*

***Aileen Reid, Cán Bộ Phát Triển Nghề Làm Vườn***

**Gây ra bởi:** *Gnomoniopsis comari* (trước đây được biết đến là *Gnomoniopsis*) là một loại nấm, còn được gọi là *G. fragariae*, *G. fructicola*.

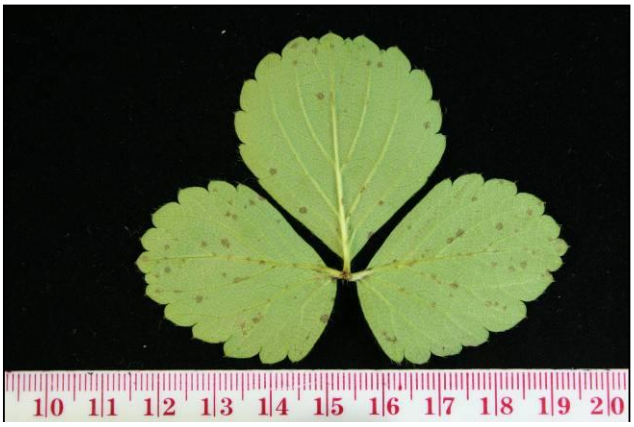
**Các triệu chứng:** Hình 1 cho thấy các thể quả của nấm phát triển trên tàn dư thực vật như thế nào. Bào tử được tạo ra ở đó, và lây nhiễm sang vụ sau.

**Hình 2 cho thấy các triệu chứng rất sớm của bệnh trên lá. Điều quan trọng là phải bắt đầu kiểm soát bệnh ở giai đoạn này.** Loại nấm này lây nhiễm lên đài hoa trước tiên (xem Hình 3), và bệnh lây lan làm thối quả. Cả quả xanh và chín đều có thể bị nhiễm nấm. Quả bị nhiễm nấm chín sớm và chuyển sang màu đỏ nhạt đến nâu. Chúng vẫn còn rắn, nhưng thường bị xâm lấn bởi những dạng thối quả khác như mốc xám. Đài hoa màu nâu là triệu chứng phổ biến nhất và trái cây với những triệu chứng này có thể không bán được hoặc bị xuống cấp.

**Biểu Hiện**

Dâu tây Festival dễ bị mắc bệnh hơn nhiều so với dâu tây Camarosa. Bệnh thường ảnh hưởng đến lần ra quả đầu tiên sau đó biến mất khi thời tiết ấm lên.

Hình 1 **Các "chấm" đen là thể quả của nấm trên tàn dư thực vật của cây dâu tây. Các bào tử được tạo ra, lây nhiễm sang vụ sau.**





Hình 2 **Các triệu chứng ban đầu của nhiễm trùng trên lá (tổn thương nhỏ ở mặt dưới)**

Hình 3 **Bắt đầu thối đầu cuống ở quả dâu tây do nấm *Gnomoniopsis* gây ra (lưu ý đài hoa màu nâu).**

Hình 4 **Các triệu chứng trên lá của nấm *Gnomoniopsis* ở dâu tây Festival.**

**Nguồn lây nhiễm**
Tàn dư thực vật còn lại trên đất từ vụ dâu hiện tại và trước đó là nguồn lây nhiễm chính. Nguyên liệu làm giống cũng mang theo các bào tử nhưng mức độ thường rất thấp và thực vật thân bò khó có khả năng là nguồn lây nhiễm chính.

**Lây lan**
Loại nấm này lây lan qua nước bắn ra từ mưa hoặc tưới từ trên cao trong điều kiện thời tiết ẩm. Nấm *Gnomoniopsis* là một tác nhân gây bệnh yếu và lây nhiễm sang cây trồng qua các lỗ khí hoặc vết thương. Việc lây bệnh này được tạo thuận lợi nhờ thời tiết mát và ẩm, phát triển tốt nhất ở nhiệt độ trên 5ºC.

**Kiểm soát (theo thứ tự quan trọng giảm dần)**

1. Giữ khô lá. Tránh tưới từ trên cao. Bệnh này không phải là vấn đề nếu mái che cao. Nó có xu hướng ảnh hưởng tới hàng cây bên ngoài nhiều hơn do nước rơi từ bạt nhựa và làm ướt lá, đặc biệt khi nâng tấm phủ lên và đậy nó trở lại. Uốn cong khung lồng kính ra ngoài sao cho cách tấm bạt nhựa màu đen 50-100mm về Grower 5 bên luống cây. Điều này giúp cho bạt nhựa không chạm vào cây.
2. *Gnomoniopsis* không ưa thời tiết ấm vì vậy cố gắng giữ ấm cho cây càng nhiều càng tốt trong mùa đông. Khi thông khí, chỉ nâng một bên của tấm phủ.
3. Loại bỏ tất cả tàn dư của cây trồng vụ trước khỏi đất. Ủ kỹ tất cả những nguyên liệu làm giống cũ sau khi nhổ lên hoặc chôn sâu tại chỗ hoặc cách xa nơi trồng.
4. Loại bỏ và xử lý bất kì lá nào có dấu hiệu nhiễm bệnh sớm (xem Hình 3).
5. Duy trì lượng kali cacbonat (kali) cao hơn ni-tơ. Vào mùa đông tỉ lệ tối thiểu là 1:1,5 N:K. Quá nhiều ni-tơ khiến cây ra rất nhiều lá và cây sẽ mềm cũng như dễ mắc bệnh hơn. Trao đổi với tư vấn viên về chương trình phân bón của quý vị để đảm bảo tỷ lệ phù hợp.
6. Kiểm soát sử dụng thuốc diệt nấm có thể cho ra kết quả rất khác nhau. Một số trong những khác biệt này có thể là do sức đề kháng. Nấm có thể trở nên kháng thuốc trừ sâu nếu quý vị chỉ luôn sử dụng cùng một loại. Nếu hiện tượng này xảy ra, thuốc trừ sâu sẽ không còn tác dụng. Sử dụng hóa chất khác nhau mỗi lần phun cũng là một ý tưởng không tồi. *Botrytis* (mốc xám) cũng có thể là một vấn đề ở cùng thời điểm trong năm và quý vị cũng sẽ cần phải thay đổi hóa chất phù hợp với loại bệnh đó. Xem Bảng 1 để biết hóa chất đã được đăng ký cho mỗi bệnh. Các hóa chất khác nhau được sử dụng để kiểm soát mỗi loại bệnh.
7. Switch® được phép sử dụng một lượng rất nhỏ đối với loại bệnh này, quý vị chỉ có thể sử dụng 3 liều phun trong cả vụ. Thay thế bằng Fontelis® hoặc Flint®. Cũng có thể sử dụng Thiram vào đầu vụ. Captan cũng có thể sử dụng nhưng chỉ được tổng cộng **5 lần** phun trong cả vụ.

**Bảng 1. Các thuốc trừ sâu đã được đăng ký để trị nấm *Gnomoniopsis* và *Botrytis* (kể từ ngày 11 tháng 3 năm 2014)**

| ***Gnomoniopsis*** | ***Botrytis*** |
|---|---|
| Switch® (cyprodinil/fludioxonil) | Teldor® (fenhexamid) |
| Fontelis® (penthiopyrad) | Rovral® (iprodione) |
| Flint® (trifloxystrobin) | Scala® (pyrimethanil) |
| Systhane® (myclobutanil) | Captan |
| Thiram | Carbendazim (không được khuyến nghị, có hại đến côn trùng săn mồi và ong) |
| Captan | |

**Lời Cảm Ơn:** Xin cảm ơn Scott Mattner (DPI Victoria) đã cho phép sử dụng ảnh và trợ giúp biên tập.

Để biết thêm thông tin, vui lòng liên lạc Aileen Reid theo số điện thoại (08) 9368 3393 hoặc qua email aileen.reid@agric.wa.gov.au

# Appendix 17: Media release usage

## Countryman newspaper article

iSENTIA
INFLUENCE · INFORM · INSIGHT



Countryman(WA), Perth
04 Jul 2013

General News, page 40 - 480.82 cm²
Rural - circulation 8,099 (—T—)

ID 201857814 BRIEF AG (P) INDEX 1 PAGE 1 of 1

# Project set to sweeten fruit profits

Boosting the profits of WA strawberry growers by using irrigation and fertilisers more efficiently is the aim of a new project led by the Department of Agriculture and Food.

Vietnamese strawberry growers, who now comprise at least 80 per cent of the industry, will receive specialised technical advice from a combined department and industry team.

Project leader Aileen Reid said traditional ways of communicating technical information had struggled with some Vietnamese growers, due to language barriers, and a new approach was being tried.

"We will be translating information into Vietnamese, using computer tablets in the field and providing short video clips on DVD to demonstrate good practices," she said.

"Experienced grower Gerry Verbeyen is part of the team and will be working closely with growers on their farms to provide practical input."

Ms Reid said more efficient irrigation was the key to improved returns for growers through better use of available water and control of soil-borne diseases.

"Our understanding is that many growers are applying too much water, but much of this is leached to the groundwater and wasted," she said.

"This has been demonstrated by the department in similar work with the tomato industry.

"Overwatering also leads to very high humidity around the plants and can cause more foliar diseases."

Strawberry specialist Gerry Verbeyen, of Wanneroo, and DAFWA project leader Aileen Reid are part of a new project aimed at boosting the profits of WA strawberry growers by using irrigation and fertilisers more efficiently.

## Joondalup Weekender article

iSENTIA
INFLUENCE - INFORM - INSIGHT

Joondalup Weekender, Perth
15 Aug 2013

General News, page 3 - 254.70 cm²
Suburban - circulation 42,672 (—T—)

ID 206516478 BRIEF AG (P) INDEX 1 PAGE 1 of 1



Strawberry specialist Gerry Verheyen, of Wanneroo, and DAFWA project leader Aileen Reid

# Project a sweet translation

VIETNAMESE strawberry growers are being targeted in a new project to boost the profits of the WA strawberry industry.

Under the Department of Agriculture and Food program, Vietnamese strawberry growers – who make up at least 80 per cent of the industry – will get specialised advice on correct irrigation and fertiliser use.

Project leader Aileen Reid said language barriers had made technical information hard to communicate with some of the growers.

"We will be translating information into Vietnamese, using computer tablets in the field and providing short video clips on DVD to demonstrate good practices," she said.

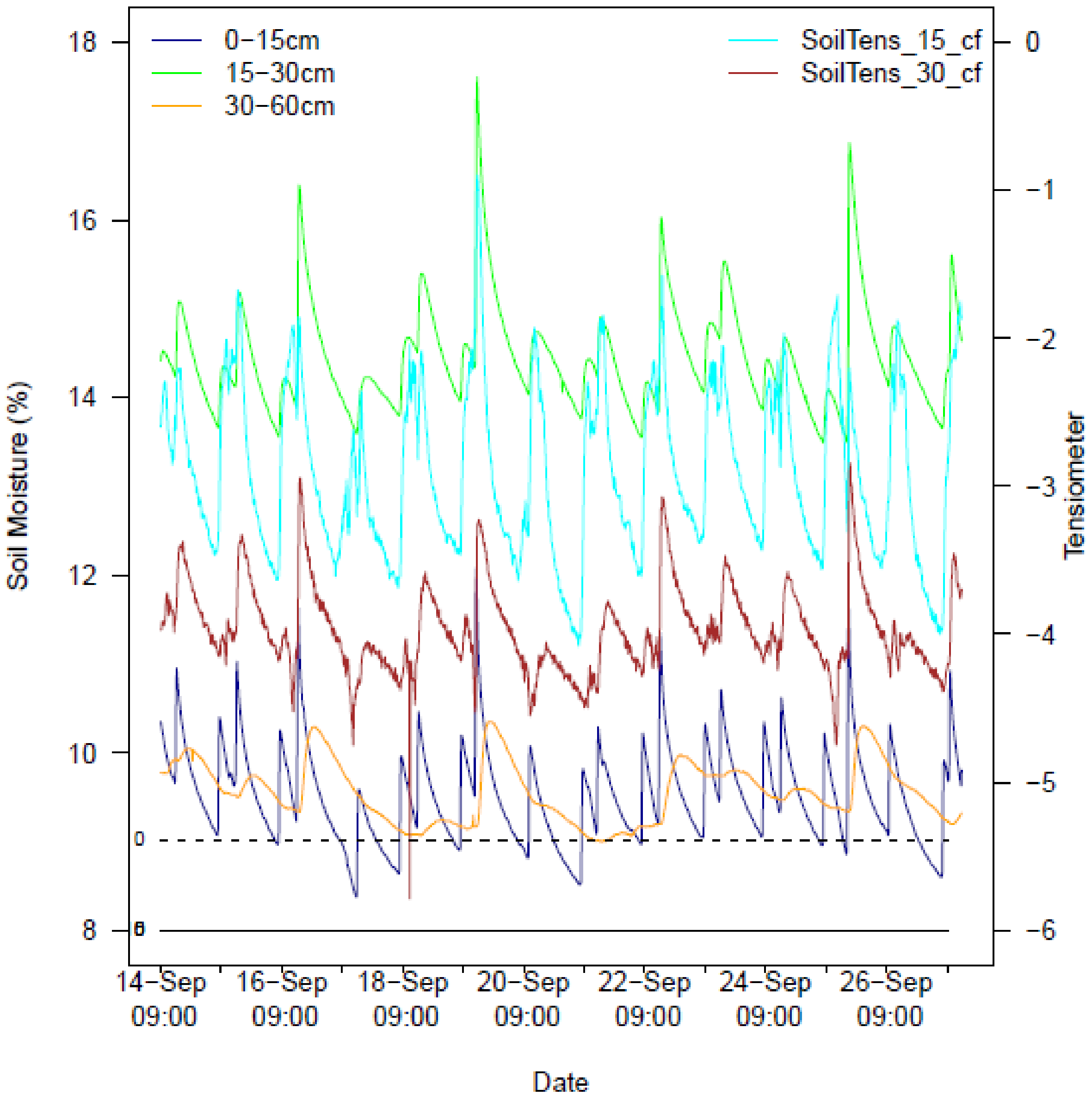
Ms Reid said more efficient irrigation was the key to improved returns for growers through better use of water and control of soil-borne diseases.

The WA strawberry industry is located mainly in the Wanneroo, Carabooda and Bullsbrook areas.

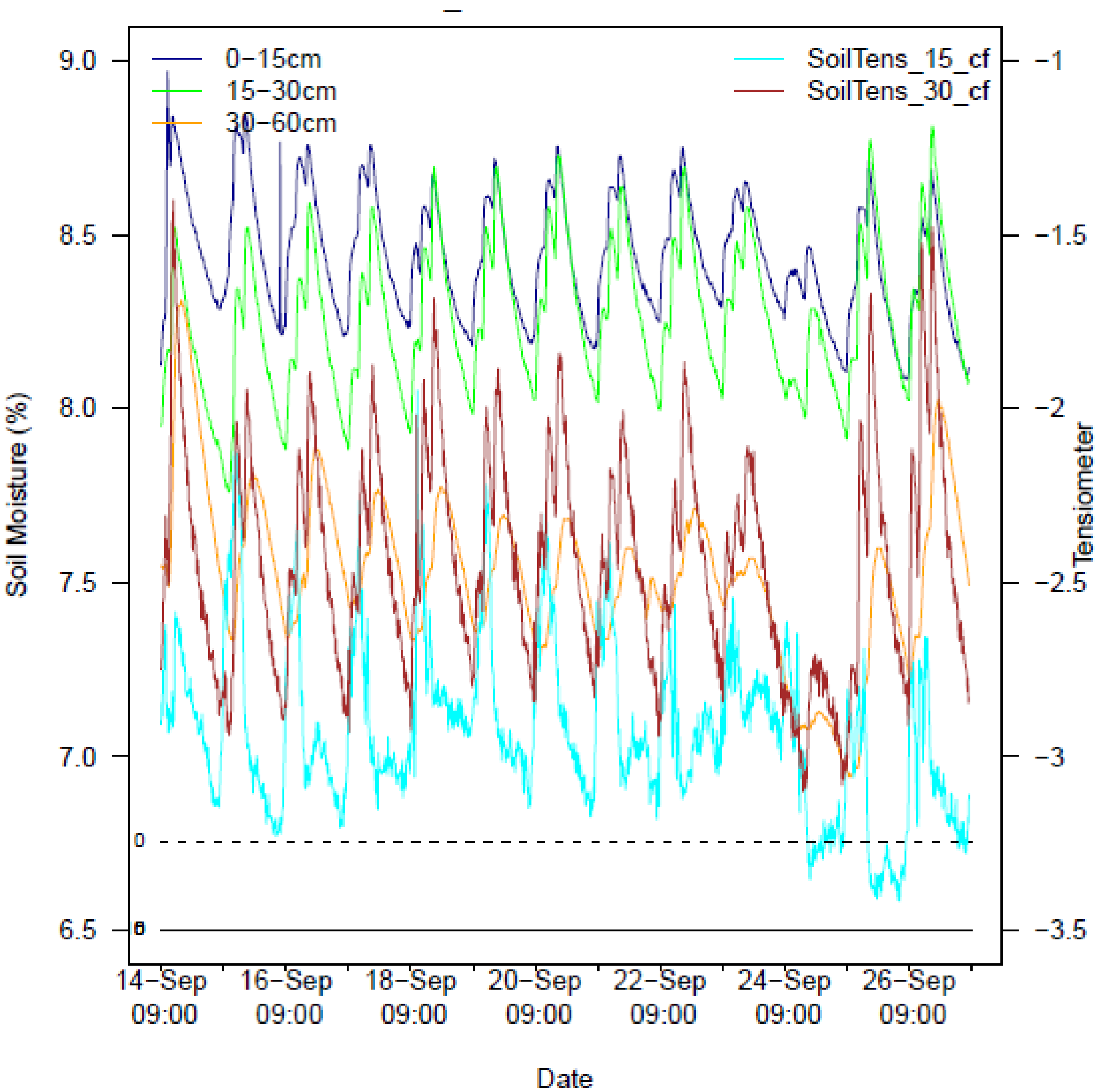
Claire Ottaviano

# Appendix 18: Examples of moisture monitoring graphs from five growers

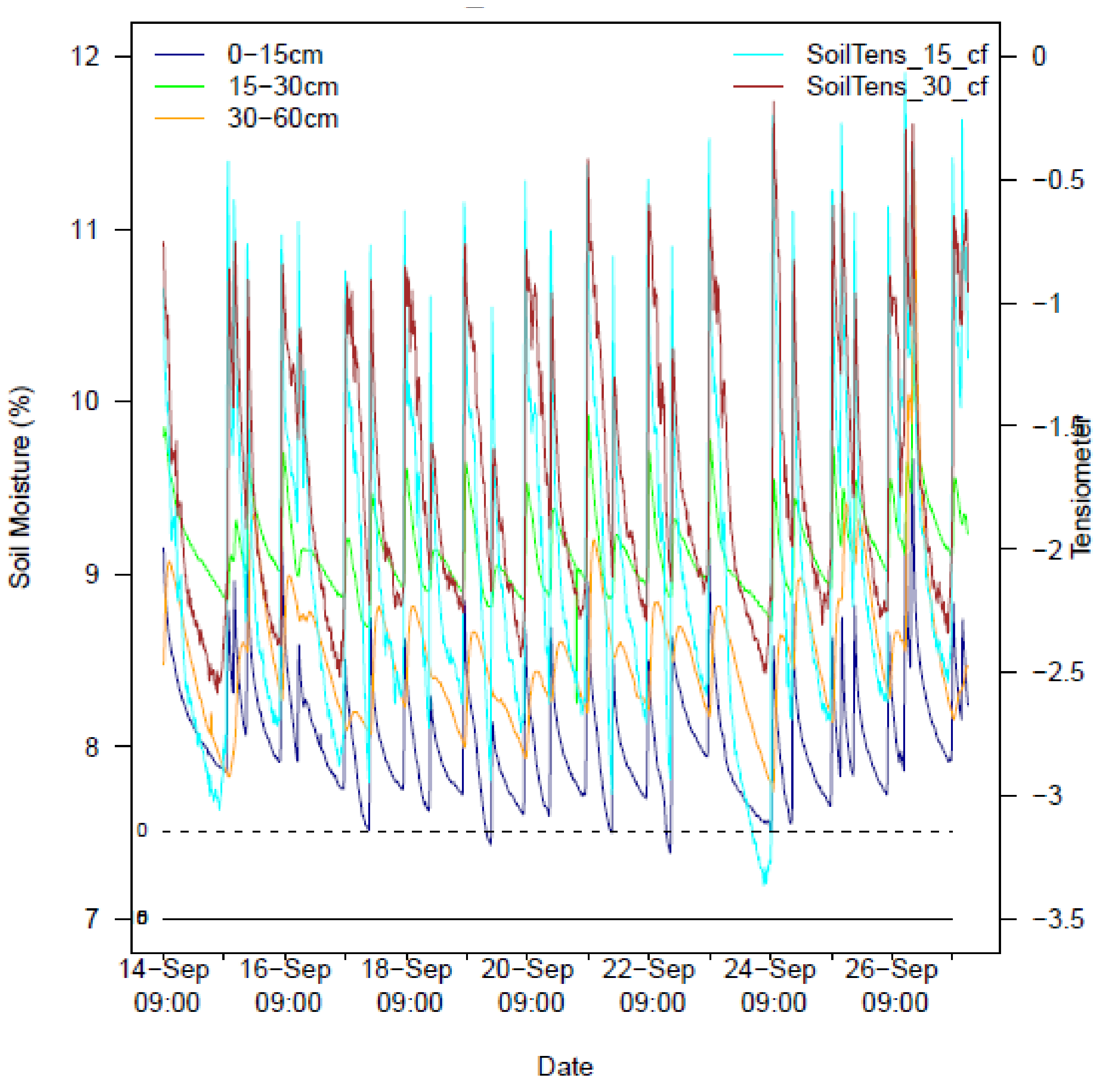
## Moisture monitoring — Grower 1



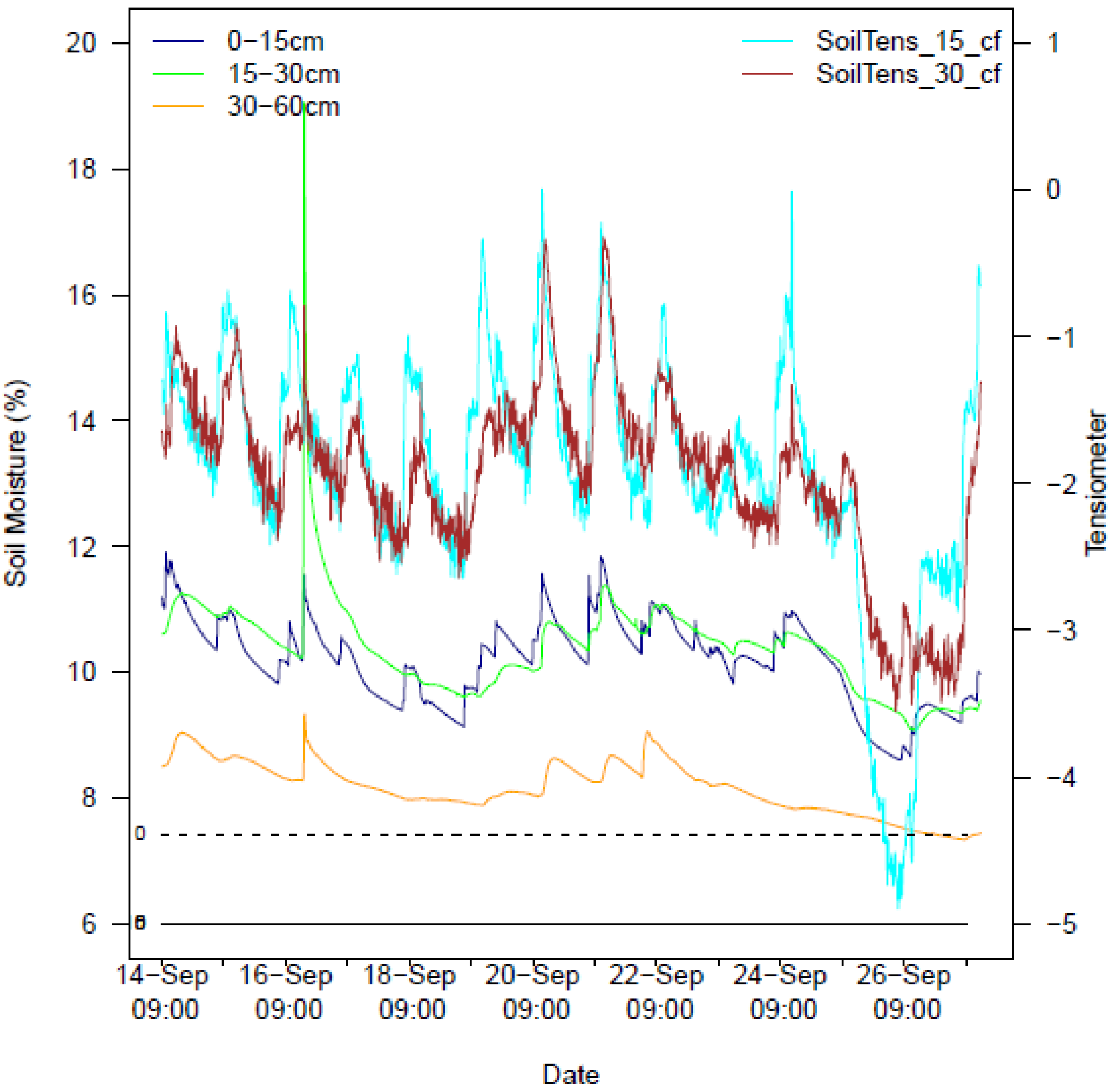
## Moisture monitoring — Grower 2



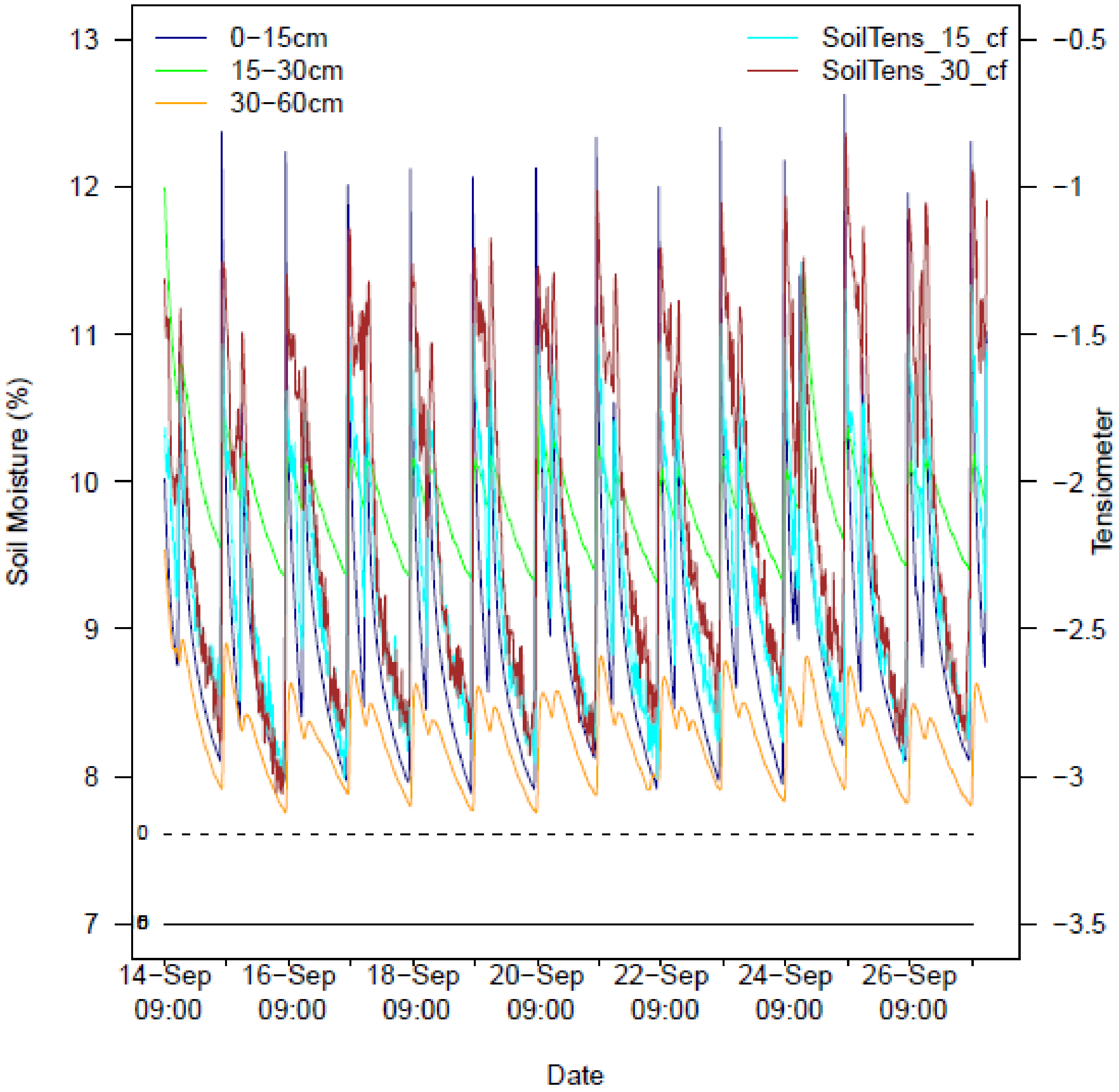
**Moisture monitoring — Grower 3**



## Moisture monitoring — Grower 4



## Moisture monitoring — Grower 6



# Appendix 19: Dye demonstration details

**Table A19.1. Netafim dripline and flow details**

| Emitter spacing (cm) | Flow rate (L/hr) |
|---|---|
| **10** | 1.075 |
| **20** | 1.175 |
| **25** | 0.97 |
| **25** | 0.97 |

**Table A19.2. Run times used to deliver set volumes of water**

| **Emitter spacing** | **Water volume (L)** | | | |
|---|---|---|---|---|
| | 0.25 | 0.5 | 1.0 | 2.0 |
| **(cm)** | Run time (mins) | | | |
| **25** | 15.5 | 30.9 | 61.9 | 123.7 |
| **20** | 12.8 | 25.5 | 51.1 | 102.1 |
| **10** | 14.0 | 27.9 | 55.8 | 111.6 |
| **25** | | 30.9 | | 123.7 |

**Table A19.3. Depth and spread of irrigation applied**

| | Volume applied (L) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Emitter spacing** | **0.25** | | **0.5** | | **1.0** | | **2.0** | |
| | **Depth** | **Spread** | **Depth** | **Spread** | **Depth** | **Spread** | **Depth** | **Spread** |
| | (cm) | | | | | | | |
| 25 | 15.0 | 14.0 | 24.0 | 16.0 | 32.0 | 18.0 | 63.0 | top 22<br>base 14 |
| 20 | 15.0 | 14.0 | 22.0 | 15.0 | 33.0 | 16.0 | 30.0 | 18 |
| 10 | 18.0 | 9.0 | 28.0 | Overlap | 70.0 | overlap | 90.0 | Overlap |
| 25 (nc)* | | | 26.0 | 10.0 | | | 70.0 | 22 |

* Not compacted

# Appendix 20: Photos of first dye demonstration

**Figure A20.1. Overview of dye demonstration site**

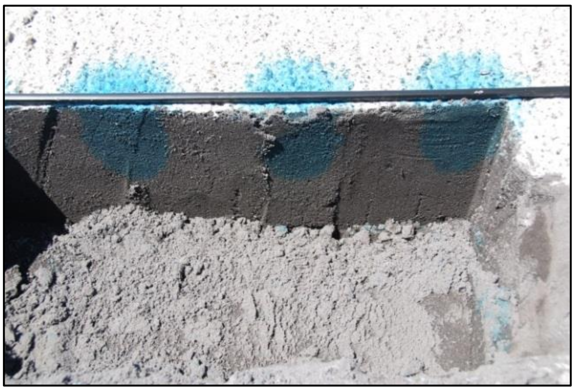


**Figure A20.2. 25cm spacing, 0.25L applied**

**Figure A20.3. 25cm spacing, 0.5L applied**

**Figure A20.4. 25cm spacing, 1.0L applied**

**Figure A20.5. 25cm spacing, 2.0Lapplied**

**Figure A20.6. 20cm spacing, 0.25L applied**

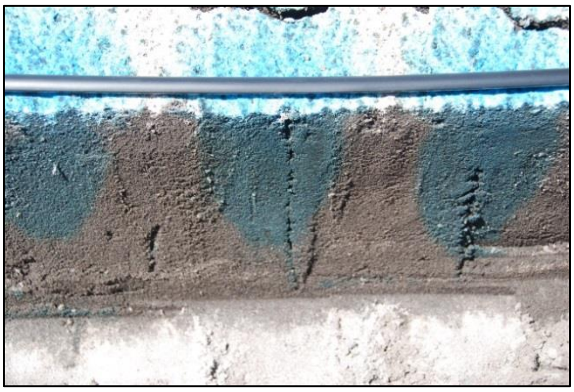


**Figure A20.7. 20cm spacing, 0.5L applied**

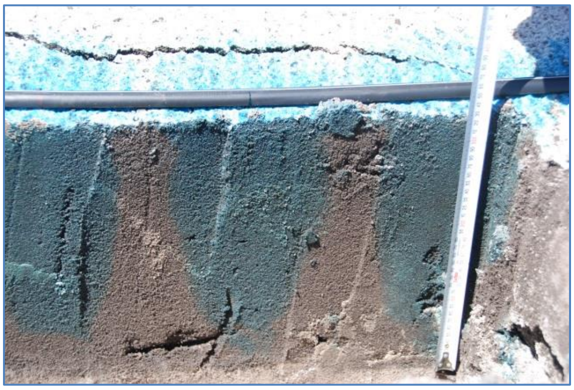


**Figure A20.8. 20cm spacing, 1.0L applied**

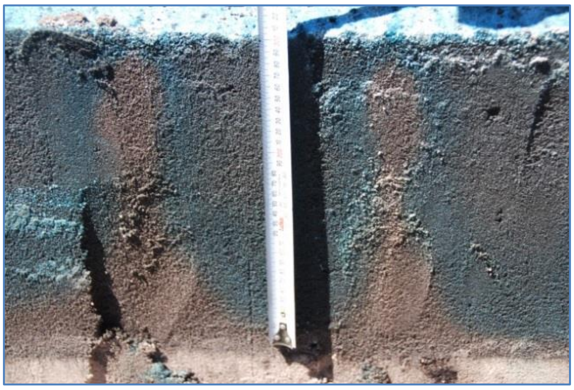


**Figure A20.9. 20cm spacing, 2.0L applied**

**Figure A20.10. 10cm spacing, 0.25L applied**

**Figure A20.11. 10cm spacing, 0.5L applied**

**Figure A20.12. 10cm spacing, 1L applied**

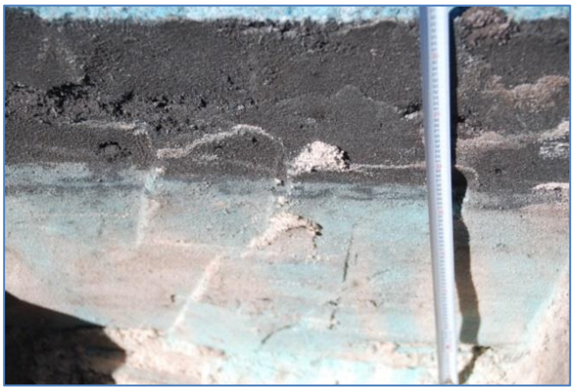


**Figure A20.13. 10cm spacing, 2L applied**

**Figure A20.14. 25cm spacing, 2L applied, uncompacted**

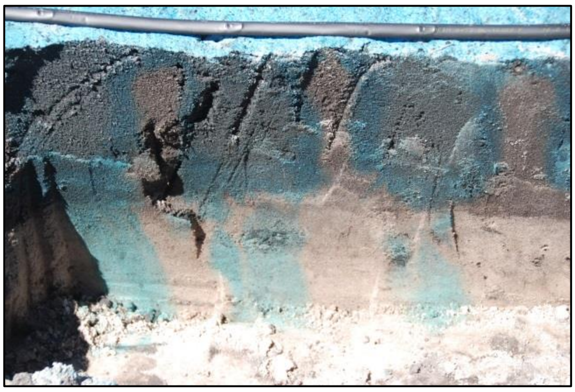


**Figure A20.15. 25cm spacing, 0.5L applied, uncompacted**

# Appendix 21: Dye test and plant root distribution

**Figure A21.1 Plastic pulled back to expose bed surface**

**Figure A21.2. Root development appears even but irrigation is barely overlapping the root zone**

**Figure A21.3. Juxtaposition of irrigation and plant roots**

**Figure A21.4. Depth and spread of 15 minute irrigation**

## Appendix 22: Fumigation survey

**Figure A22.1. Grower preparing to shank inject Telone C-35®**

**Figure A22.2. Scott Mattner sampling gases after fumigation**

**Figure A22.3. Dr Mattner (left) with team members Stuart Vincent (technical officer), Gerry Verheyen (grower consultant) and Aileen Reid (project leader)**

**Figure A22.4. Peter Maloney (videographer) preparing to film the fumigation**