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FACILITATING THE DEVELOPMENT OF THE STRAWBERRY INDUSTRY IN WESTERN AUSTRALIA

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The purpose of this report is to communicate the findings of Project BS05001 which demonstrated new techniques for sustainable and efficient strawberry production using new technologies to the Western Australian and Australian Strawberry Industry on a dedicated commercial scale 'model farm'.

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Media summary

Western Australian growers want better information on management practices and performance of new varieties to accompany their commercial release to minimise losses from trial and error. At the same time they are concerned about declining rainfall and the need to irrigate more efficiently to preserve their water resource, reduce costs and minimise fertiliser pollution of groundwater. This project was conceived to meet these needs.

A ‘model farm’ was established on a leading grower’s property at Wanneroo on the northern outskirts of Perth to demonstrate new varieties and production methods to local growers on a commercial scale that they could relate to. Some of the new electronic technology used for monitoring and managing irrigation used on the ‘model farm’ was also introduced to growers and tested on strawberry farms in W.A.’s second largest production district on the south coast near Albany.

New varieties were tested under a range of irrigation and nutrition regimes at the model farm in three consecutive seasons. Times of planting and crop covering methods - including greenhouses and low plastic cloches were compared in combination with the other treatments. The minimum size for each treatment plot at the site was 1250 plants, and each year approximately 60,000 plants were planted at the site comparing up to 48 different management practices. This enabled all fruit from the site to be marketed and a true commercial comparison of the new practices made.

Varieties and other treatments tested changed each year on the basis of the previous year’s results. Field days were held on a monthly basis during the harvest season from August to November each year, to show growers how the various new methods and varieties performed over time.

The work showed the potential of the new variety Camino Real for WA conditions as well as the yield advantages of early April planting with ‘green leaf’ plants and covering with high plastic tunnels. Irrigation and fertigation applied multiple times daily throughout the crop’s life according to a pre determined formula was shown to reduce water and fertiliser wastage while achieving very high yields. A fertiliser schedule that applied 2 kg/ha of nitrogen per day in a fixed ratio with other nutrients throughout the crop’s life maximised marketable yields for all varieties tested. Rates as low as 1.5 kg/ha per day (N) were sufficient for some varieties and situations.

Technical summary

A ‘model farm’ was established on a leading grower’s property at Wanneroo to demonstrate new varieties and production methods to local growers and the wider Australian industry on a commercial scale that growers could relate to. New innovations and techniques compared at the model farm included combinations of variety, planting date, row covers, irrigation and fertiliser regimes.

Three crops were grown at the model farm in three consecutive seasons. Each year, 45-48 different treatments were compared in plots of 1250 plants each, in a full crop of around 60,000 plants. The treatments compared changed from year to year based on the results from the previous year’s work. Most of the work was done with four new varieties and a control, three planting dates, two runner types, three row covering methods (high ‘walk in tunnels’, conventional cloches and uncovered) and two fertigation schedules compared each year, while a small number of plots were set aside for other work such as Australian breeding line evaluation, small plots of new varieties from non traditional origins and plug plant trials. All possible combinations of these variables could not be compared with only 45-48 beds available each year, so some low priority treatments were excluded.

All fruit from these beds was harvested separately, graded and weighed to produce a marketable yield and the produce was sold. Data on each bed was recorded separately and the results presented to growers at a series of monthly field days from August to November.

As well as the yield data, measurements of key irrigation and nutrition parameters were made using a range of monitoring aids. These included six drainage lysimeters which were dug in to a depth of 1.2 meters below the crop soon after it was planted. These lysimeters captured ‘through drainage’ water continuously through the life of the crop and compared two irrigation rates with and without row covers.

Other monitoring aids tested included sixteen ‘state of the art’ soil moisture monitoring devices (TDR scans) which were placed to compare soil moisture levels resulting from the two irrigation rates under selected treatments. These TDR scans were set up as four monitoring stations in the field, coupled to a data logger at each station with remote computer access via a connected modem. The units allowed real time access to soil moisture data. They were used to monitor and fine tune the planned irrigation schedules.

Each year, yields approaching six punnets per plant (1500 grams per plant) were achieved with the best variety, time of planting and irrigation/nutrition management. Yields under the high tunnels were equally good as low cloches, while both of these covering methods were vastly superior to the uncovered treatment for marketable yields and earliness.

The key findings of the work were that the new variety from California, Camino Real showed great promise when planted in early April using ‘green leaf’ runners and grown under high plastic tunnels. The industry standard variety, Camarosa continues to perform well and justified it’s popularity with commercial growers in W.A. Ventana yielded very well and it’s fruit were very appealing, but it proved to be too soft for shipping interstate or beyond. The day neutral variety Albion looked good and tasted good, but it did not show the same yield potential as Camarosa or Camino Real, in the Wanneroo environment.

The work consistently showed that high yields could be achieved by fertigating daily or multiple times daily with a nutrient solution that supplied 2 kg/ha of nitrogen per day in a fixed ratio with other nutrients. In some situations a rate as low as 1.5 kg/ha per day (N) may be sufficient to maximise yields. Irrigating with drip tape under plastic soil mulch with drippers spaced 10 cm apart proved to be slightly better than using drippers spaced at 25 cm. Scheduling daily irrigation using the ‘crop factor’ principle proved to be effective, but it’s effectiveness was enhanced by monitoring soil moisture using TDR technology and using this data to adjust daily application rates. These techniques were proven in more than one season and offer the potential for significant and sustainable water savings in the future.

Irrigation monitoring equipment was also installed at two grower sites in Albany in the first year of the project and by the third year, all strawberry growers on the south coast of WA had this equipment installed, and were using it to guide their irrigation practices.

1. Year 1 Annual Report (2005/06)

1.1 Introduction

This is the first of three annual reports for the Horticulture Australia project BS05001 – 'Facilitating the development of the strawberry industry in Western Australia'. This project is managed by the Strawberry Growers Association of WA Inc. and the work is being done in collaboration with the Department of Agriculture and Food WA (DAFWA). The project has been funded by voluntary contributions from the W.A. Strawberry Producers Committee (APC), Toolangi Strawberry Runner Growers Co-operative and DAFWA with matching funding from Horticulture Australia Ltd (HAL). The project has been funded for three years, 2005, 2006 and 2007, and this report is for work done in the first year of the project.

Two previous projects funded by grower levies matched by HAL have been completed since 1997 in W.A. Both these projects researched irrigation and nutrition practices for strawberries in W.A as well as other aspects of production. The last project to be completed (BS01006) examined mechanisms to bring Australian bred strawberry varieties into widespread commercial cultivation, with emphasis on the variety Kiewa, including development of a nutrition and irrigation 'package' to ensure high yield and good flavour.

A key finding from this project was that individual grower production practices were more important than the variety grown in determining crop yield.

New varieties of overseas and Australian origin were adopted throughout the period of this work, but improved irrigation and nutrition practices have largely been ignored. One of the perceived reasons for this is that the technology transfer of these methods has not been done on an individual basis, and the methods have not been demonstrated to growers on a commercial scale.

Our work (HAL project BS01006) showed that a spring crop of strawberries can produce good yields with as little as 4 ML of water for the season. Current industry practice is expected to use much more water and the project was predicated on the belief that there is significant scope for water savings in the industry. Similarly, strawberries have been shown to be highly responsive to nitrogen fertiliser on sandy soils but rates in excess of 450 kg/ha (N) for the full season, have been shown to adversely affect flavour and consumer acceptance (Phillips *et al*. 2004). Adoption of these results is essential to ensure growers attain high yields while not adversely affecting consumer acceptance of their product.

In project BS01006, runners of the Australian bred variety Kiewa were tested from different runner producers at different times of digging. These results showed that strawberries can be very sensitive to field and post digging chilling in their growth habit and flowering response. It also showed that greater differences in yield resulted from grower management and location than from runner origin. Since it affects the amount of chilling plants receive, there is a case for examining the effect of runner digging and planting dates on plant growth and fruiting for all new varieties likely to be commercialised.

This project has two principle aims. Firstly, to accelerate the rate of adoption of new varieties by the Western Australian strawberry industry by providing specific agronomic and post harvest information to accompany commercial releases. Growers will profit through a reduction in the initial period of trial and error that usually accompanies new varieties. Independent testing will ensure that varieties with poor handing characteristics or lacking in taste, are culled before large quantities are planted. Together these will help to maximise grower profit and market (wholesaler and consumer) satisfaction.

The second aim is to demonstrate and facilitate more widespread adoption of efficient irrigation and nutrition practices. This is critical since current strawberry production districts in W.A. face continuing water supply reduction due to long term decline in rainfall and increasing demands for water from competing users, coupled with groundwater pollution from excessive fertiliser use.

We intend to demonstrate higher strawberry yields per kilolitre of water applied through the use of irrigation scheduling and efficient nutrition practices, while reducing pollution of groundwater resulting from excessive fertiliser use. Our previous work showed the potential to double average commercial yields in Perth spring crops by employing these methods.

A ‘model farm’ was established on Gerry Verheyen’s property in Wanneroo, to test and showcase the results of past research on a commercial scale and to introduce new varieties and production methods to local growers. The site is on a small commercial scale (approximately one hectare) but all fruit grown here is packed and marketed to ensure it meets commercial standards. This facility has enabled evaluation of new varieties together with a range of irrigation and nutrition regimes. Times of planting and runner type are also included.

Field days were being held on a monthly basis during the harvest season from August to November at the “model Farm’ to show growers how the various new methods and varieties performed over time.

1.2 Materials and Methods

Layout

The demonstration block consisted of 45 beds, each 125 m long. Each bed was 1.2 m wide with 30 cm pathways between each bed. The beds were covered with black plastic. There were four rows of plants per bed spaced 30 cm apart. Two lines of Netafim inline drip (25 cm spacing, dripper output 0.90 L/hour) irrigation were buried below the plastic, between the two outer rows of plants. In line plant spacing was 37 cm for all varieties except Gaviota and Camino Real which, due to their lower vigour were spaced at 33 cm.

The area was divided into five irrigation blocks, each comprising nine beds. A water meter was installed at the bottom of one line of drip tape in each of the five blocks. Each irrigation block allowed a different combination of irrigation and fertiliser rate (fertigation treatment) to be applied to the whole block of nine beds.

Soil preparation

Prior to planting, the area was soil sampled down the profile at 30 cm intervals to a depth of 1.2 m (see Lysimeters). Two soil types were present on the site. Bassendean sand (white sub-soil) at the bottom of the slope and Karrakatta sand (yellow sub-soil) at the top of the slope. Strawberry beds ran up the slope and both soil types were represented in every bed.

The Karrakatta sand showed high levels of residual soil phosphorus at depth whilst the Bassendean sand had virtually no phosphorus below 30 cm (Figure 1.1). Full test results are detailed in Table 1.1.

The soil was fumigated with Telone C-35 prior to planting. No lime, trace elements or other base dressing were applied.

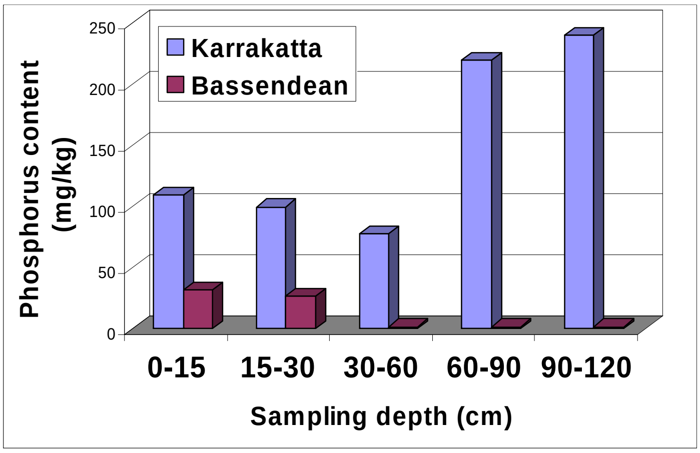


Figure 1.1 Soil phosphorus concentrations in the two soil types over the range of sampling depths.

Pest and disease control

Predators were introduced into the crop for two spotted mite control. Applications of fungicide for powdery mildew and botrytis, and pesticides for mites and caterpillars were also applied as required throughout the season.

Tables 1.1a, b. Soil analyses prior to trial

Sample no.	Depth	EC (1:5) mS/m	pH ($CaCl_2$)	OrgC (W/B) %	N (total) %	B (M3) mg/kg	Ca (M3) mg/kg	Cd (M3) mg/kg	Co (M3) mg/kg	Cu (M3) mg/kg
1K	0-15	11	5.1	0.57	0.042	0.3	450	0.03	0.06	1.4
2K	15-30	10	4.9	0.6	0.042	0.2	430	0.03	0.05	1.5
3K	30-60	4	4.6	0.12	0.007	0.1	49	< 0.01	0.02	0.1
4K	60-90	3	4.4	0.13	0.008	0.2	46	< 0.01	0.02	0.1
5K	90-120	3	4.4	0.14	0.009	0.2	44	< 0.01	0.02	0.1
6B	0-15	5	4.5	1.1	0.07	0.2	580	0.04	0.06	1.1
7B	15-30	7	4.4	1.05	0.059	0.2	520	0.04	0.06	1
8B	30-60	3	4.2	0.09	0.005	0.1	53	< 0.01	0.02	< 0.1
9B	60-90	2	4.5	0.06	0.005	0.1	27	< 0.01	0.02	0.3
10B	90-120	2	4.7	0.03	0.005	< 0.1	19	< 0.01	0.02	0.1

Sample no.	Depth	Fe (M3) mg/kg	K (M3) mg/kg	Mg (M3) mg/kg	Mn (M3) mg/kg	Mo (M3) mg/kg	Na (M3) mg/kg	Ni (M3) mg/kg	P (M3) mg/kg	S (M3) mg/kg	Zn (M3) mg/kg
1K	0-15	43	16	44	12	< 0.01	48	0.2	110	43	7.8
2K	15-30	41	10	37	10	0.01	49	0.7	100	31	7.8
3K	30-60	45	8	8	< 1	0.02	13	0.1	78	4	0.4
4K	60-90	67	17	7	< 1	0.02	12	0.1	220	4	0.5
5K	90-120	71	11	6	< 1	0.01	10	0.2	240	5	0.5
6B	0-15	43	15	62	9	0.01	29	0.4	32	7	9.1
7B	15-30	38	10	52	8	0.01	37	0.4	27	7	8.6
8B	30-60	6	2	5	< 1	< 0.01	11	< 0.1	2	1	0.4
9B	60-90	3	2	4	< 1	< 0.01	9	0.5	2	1	0.3
10B	90-120	2	4	3	< 1	0.01	8	< 0.1	2	1	0.3

Note: Samples 1-5 were from a high point on the block and were Karrakatta sand (yellow sub-soil), samples 6-10 were taken from a low point and were Bassendean sand (white sub-soil).

Lysimeters

Six round PVC lysimeters (29 cm internal diameter) were buried below the crop (Figure 1.2). Two were placed in row 20, one each in rows 25 and 29 and two in row 34 (Figure 1.3). Each was positioned such that the centre of the lysimeter was directly located under one dripper outlet. The top of each lysimeter was approximately 40 cm below the soil surface. Soil removed in order to bury the lysimeters was replaced in the reverse order to maintain the soil profile as much as possible. The soil was watered in for compaction.

Figure 1.2. Installing a lysimeter under a strawberry bed. Note the careful placement of soil removed so it can be returned to the cavity in the order necessary to retain the natural soil profile.

Each lysimeter was pumped out weekly from 3 May and leachate volumes recorded. Samples were retained for nitrate analysis. These were analysed using an RQflex® reflectometer and Merckoquant indicator strips.

Trial plan

The demonstration block compared 45 combinations of variety, planting date, row covers, irrigation and fertiliser regimes. Principally there were four varieties, three planting dates, two row covering methods and four irrigation/fertigation schedules compared in the majority of the beds while a small number of beds were set aside for other work such as Australian breeding line evaluation and plug plant trials. All possible combinations of these variables could not be compared with only 45 beds available, so some low priority treatments were excluded. The range of fertigation options that could be compared for example was limited by the minimum size of a fertigation block being 9 beds.

Results are thus presented for the combinations of treatments tested, but some possibilities remain untested. An example of this is that the first planting date was all covered with low plastic tunnels and all beds (9) were grown with a high irrigation and fertiliser regime. Scenarios that included lower fertigation regimes or no row covers were not tested, nor were runners planted without leaves at this planting date.

For the first (early) planting date (10 April), plants were supplied and planted from field grown runners with leaves still attached (green leaf runners - gl). These plants occupied beds 1-9 and all beds were covered with low tunnels at planting. The rest of the beds were planted with conventionally supplied plants with no leaves attached (conventional runners – c). This block was grown throughout with a high irrigation and fertiliser regime.

Different irrigation and fertiliser regimes were superimposed on the remaining four blocks. These were:

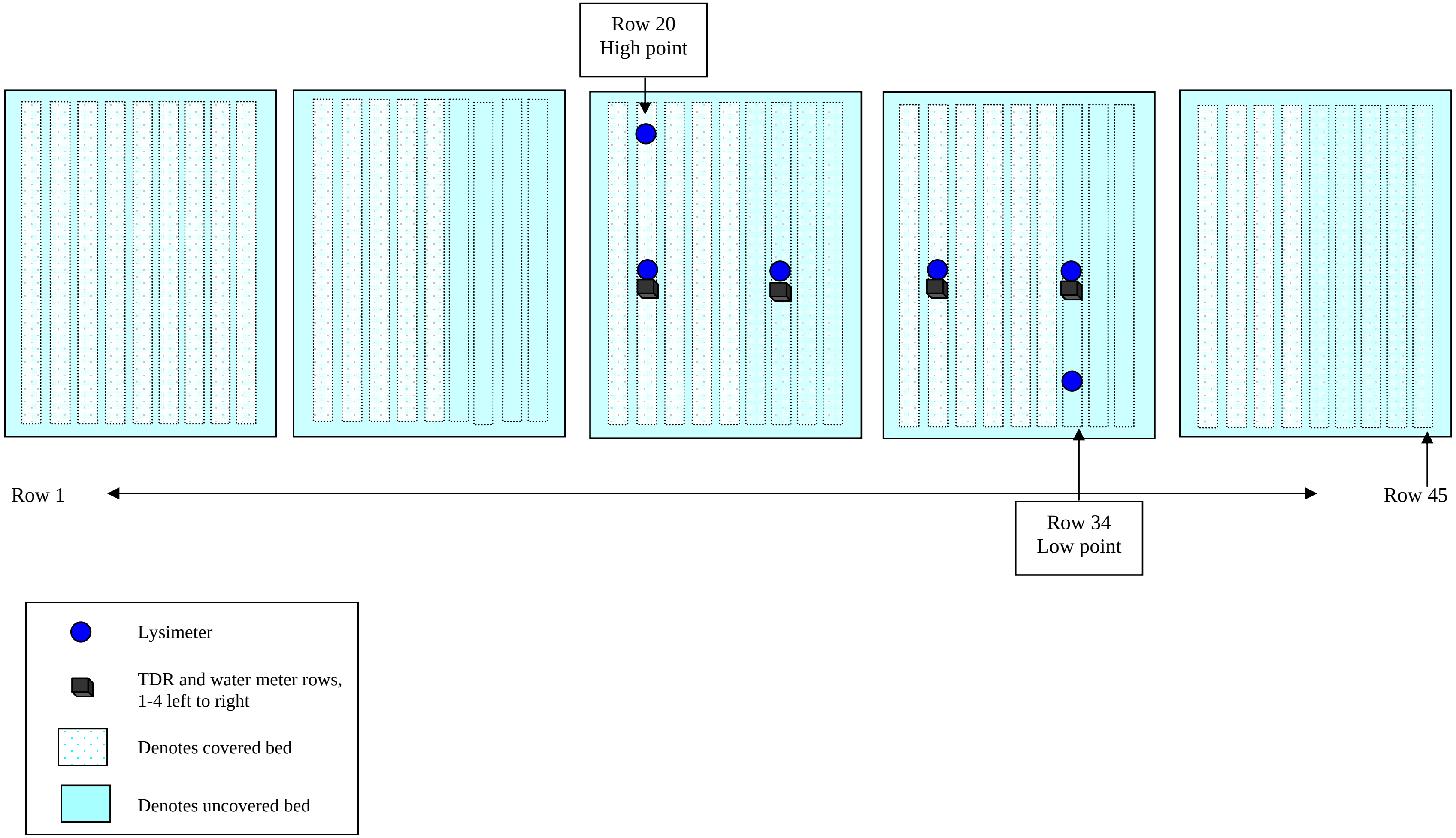
1. Beds 10-18 - high irrigation and high fertiliser.
2. Beds 19-27 - medium irrigation and medium fertiliser.
3. Beds 28-36 - high irrigation and medium fertiliser.
4. Beds 37-45 - medium irrigation and high fertiliser.

Each of these blocks, comprised a range of varieties and beds that were covered with low tunnels, or left uncovered.

Table 1.2. Treatments in the 45 beds in 2005/06. gl = green leaf runners; c = conventional runners

Bed no.	Planting date	Variety	Irrigation regime	Fertiliser regime	Covers	Plant number	Runner types, extra treatments and equipment locations
1	10 Apr	Camarosa	High	High	Yes	1250	(gl)
2	10 Apr	Ventana	High	High	Yes	1250	(gl)
3	10 Apr	Camarosa	High	High	Yes	1250	(gl)
4	10 Apr	Ventana	High	High	Yes	1250	(gl)
5	10 Apr	Camino Real	High	High	Yes	1500	(gl)
6	10 Apr	Gaviota	High	High	Yes	1500	(gl)
7	10 Apr	Camino Real	High	High	Yes	1500	(gl)
8	10 Apr	Gaviota	High	High	Yes	1500	(gl)
9	12 Apr	Festival+plug	High	High	Yes	500	(gl)
10	28 Apr	Camarosa	High	High	Yes	1250	(c)
11	28 Apr	Ventana	High	High	Yes	1250	(c)
12	20 May	Gaviota	High	High	Yes	1500	(c)
13	20 May	Camino Real	High	High	Yes	1500	(c)
14	28 Apr	Camino Real	High	High	Yes	1500	(c)
15	28 Apr	Camarosa	High	High	No	1250	(c)
16	28 Apr	Ventana	High	High	No	1250	(c)
17	28 Apr	Camino Real	High	High	No	1500	(c)
18	20 May	Kiewa	High	High	No	1250	(c)
19	28 Apr	Ventana	Medium	Medium	Yes	1250	(c)
20	28 Apr	Camarosa	Medium	Medium	Yes	1250	Lysimeter and TDR (c)
21	20 May	Gaviota	Medium	Medium	Yes	1500	(c)
22	20 May	Camino Real	Medium	Medium	Yes	1500	(c)
23	28 Apr	Camino Real	Medium	Medium	Yes	1500	(c)
24	20 May	Ventana	Medium	Medium	No	1250	(c)
25	28 Apr	Camarosa	Medium	Medium	No	1250	Lysimeter and TDR (c)
26	28 Apr	Ventana	Medium	Medium	No	1250	(c)
27	28 Apr	Gaviota	Medium	Medium	No	1500	(c)
28	28 Apr	Ventana	High	Medium	Yes	1250	(c)
29	28 Apr	Camarosa	High	Medium	Yes	1250	Lysimeter and TDR (c)
30	20 May	Gaviota	High	Medium	Yes	1500	(c)
31	20 May	Camino Real	High	Medium	Yes	1500	(c)
32	28 Apr	Camino Real	High	Medium	Yes	1500	(c)
33	20 May	Camarosa	High	Medium	Yes	1250	(c)
34	28 Apr	Camarosa	High	Medium	No	1250	Lysimeter and TDR (c)
35	28 Apr	Gaviota	High	Medium	No	1500	(c)
36	28 Apr	Ventana	High	Medium	No	1250	(c)
37	10 May	New breeding lines	Medium	High	Yes	1500	(c)
38	20 May	Camino Real	Medium	High	Yes	1500	(c)
39	20 May	Gaviota	Medium	High	Yes	1500	(c)
40	14 May	Advanced breeding lines	Medium	High	Yes	1500	(c)
41	20 May	Kiewa	Medium	High	No	1250	(c)
42	20 May	00-039-24	Medium	High	No	1500	(c)
43	20 May	98-030-3	Medium	High	No	1500	(c)
44	20 May	Camino Real	Medium	High	No	1500	(c)
45	20 May	Gaviota	Medium	High	No	1500	(c)

Figure 1.3 Field layout of the demonstration block showing bed covering, lysimeters, TDR's and water meter placements



Irrigation

The irrigation regime was based on evaporation replacement adjusted with a crop factor according to growth stage.

High regime: 75 per cent increasing to 175 per cent, commencing in June and July at 75 per cent and rising at approximately 15 per cent each month until November (175 per cent).

Medium regime: 50 per cent increasing to 117 per cent commencing in June and July at 50 per cent and rising at approximately 10 per cent each month until November (117 per cent).

The evaporation figures used in conjunction with these crop factors were 'long term averages' from the Medina Research Station weather station located approximately 50 km south of the 'model farm'. In June and July, the monthly average was applied throughout the month, but in August and subsequent months, the averages used were for the first two weeks and second two weeks of the month. Irrigation rates were thus adjusted every two weeks from August onwards. These figures were an average over 30 years of recordings. Table 1.3 shows the evaporation data that schedules were based on and the actual crop factors and irrigation times used in each fortnight of the crop's life.

Table 1.3 Irrigation schedule for 2005

Date	Irrigation rate	Long term average daily evaporation data (Medina 30 years)	Crop factor %	Daily irrigation (mm)	Irrigation time (min)	Fertigation time (min)
01 Apr	High	4.1	100	4.1	41	16
	Medium	4.1	100	4.1	41	11
01 May	High	2.7	100	2.7	27	16
	Medium	2.7	100	2.7	27	11
15 May	High	2.6	90	2.4	24	16
	Medium	2.6	60	1.6	16	11
01 Jun	High	1.7	75	1.4	14	13
	Medium	1.7	50	0.9	9	9
01 Jul	High	1.7	75	1.4	14	13
	Medium	1.7	50	0.9	9	9
01 Aug	High	2.2	90	2.1	21	17
	Medium	2.2	60	1.4	14	11
15 Aug	High	2.6	90	2.4	24	17
	Medium	2.6	60	1.6	16	11
01 Sep	High	3.0	105	3.2	32	17
	Medium	3.0	70	2.2	22	11
15 Sep	High	4.0	105	4.2	42	17
	Medium	4.0	70	2.9	29	11
01 Oct	High	4.4	125	5.5	55	16
	Medium	4.4	85	3.7	37	11
15 Oct	High	5.0	140	6.9	69	16
	Medium	5.0	95	4.8	48	11
01 Nov	High	6.1	157	9.6	96	17
	Medium	6.1	105	6.4	64	11
15 Nov	High	7.0	175	12.2	122	17
	Medium	7.0	117	8.2	82	11

Irrigation was applied once per day until 20 September when it was increased to twice a day and then three times a day from 15 November.

Fertigation

Plants were fertigated during each irrigation with a stock nutrient solution supplied from two 1000 litre tanks. The total quantities of nutrients supplied from these two tanks were as follows:

Nutrient solution composition (g/L) of the stock solutions:

- Calcium nitrate 75.0
- Magnesium sulphate 12.5
- Mono-ammonium phosphate 12.5
- Potassium nitrate 75.0
- Magnesium nitrate 25.0

All of the calcium nitrate and half of the potassium nitrate was dissolved in Tank A and the other fertilisers were dissolved in Tank B. Each tank had its own injection pump, and the injection rate of stock solution from each tank during the fertigation cycle was 1 litre per minute of nutrient solution for every 135 litres per minute of water moving down the main line.

Where twice daily irrigations were applied during the warmer months, the fertigation was split over both irrigations. In each irrigation cycle, water and fertiliser were applied in three phases. A typical cycle would start with water only for a number of minutes to fill the lines, followed by the required time to inject the nutrient solution through the drip lines and then followed by three minutes of water only to ensure that no nutrients were able to drain back into the main line (flushing valves were fitted at the lowest end of the sub-main).

The fertigation plan was based on the results of past research at Medina Research Station with the variety Kiewa. This program showed that strawberries were very responsive to nitrogen, and a high yielding crop, with good flavour could be produced with around 450 kg/ha (N) for the season. This result could be achieved by injecting approximately 2 kg/ha per day of N into the drip lines. This program was the standard treatment tested here and is described in the text that follows as the ‘medium’ program. This program was compared with a ‘high’ schedule which supplied 150 per cent of the ‘medium’ N rate, i.e. approximately 3 kg/ha per day. The latter was achieved in practice by increasing the duration of the fertigation cycle by 50 per cent over the medium rate. For example, if the fertigation time to supply the medium rate was 16 minutes, the high rate would receive 24 minutes of fertigation.

Soil moisture monitoring - TDR’s

Table 1.4. Treatment locations for each TDR probe (from 23 August)

Probe number	Bed number	Variety	Covering	Irrigation rate
1	20	Camarosa	Low tunnel	Medium
2	25	Camarosa	Uncovered	Medium
3	29	Camarosa	Low tunnel	High
4	34	Camarosa	Uncovered	High

Soil moisture levels in the root zone (0-15 cm depth) was monitored for the medium and high irrigation rates in covered and uncovered rows continuously throughout the growing cycle. These results were used to monitor the effectiveness of the irrigation schedules and to allow timely adjustments to be made to the irrigation plan if the soil became too dry.

The equipment used was a TDR probe (reflectometer) coupled to a data logger (CR200) and modem (Maxxon) for remote download to a computer on the farm and at the Department of Agriculture office. Table 1.4 and Figure 1.2 show the final locations of each probe after 23 August. Each was sited close to a lysimeter and set to the 0-15 cm depth (angled at 45^0) about half way between a dripper and plant.

The output from this equipment was a table of volumetric soil moisture readings which could be graphed to show a continuous record of soil water content over time. An example output is shown in the results section of this report which follows.

Sap analysis

The two fertiliser schedules were monitored by taking regular samples of plant sap from recently matured petioles from a range of treatments.

Petioles were collected for sap analysis on seven occasions spanning the harvesting period for the crop. Tests were conducted for nitrogen, potassium and phosphorus levels. Approximately 30 petioles (depending on size) were collected from each treatment at intervals down each bed. The samples were kept cool and sap extracted and analysed for nitrate, phosphate and potassium and using an RQflex® reflectometer and Merckoquant® test strips.

At the completion of the series, a profile for each nutrient over the life of the crop was prepared in graph form. Treatments compared in this way included varieties and fertiliser schedules. These profiles were able to be compared with those from past research for Kiewa and other varieties.

1.3 Results

Tables 1.5 and 1.6 summarize the marketable yields from all beds over the 2005 season. Table 1.5 lists total yields for the whole season in descending order while Table 1.6 shows marketable yield until the end of September only. For ease of comparison, yields are given per metre of row to take account of differences in planting density between varieties, because Camino Real and Gaviota were planted at a higher density than the other varieties. In each table, the top ten yielding treatments are highlighted.

The early plantings performed well. Planting earlier, using 'green leaf' plants gave higher yields overall in most cases, although Ventana and Camarosa from the 28 April planting also gave high yields that were probably not significantly different to the others in the top ten. The high irrigation and high fertiliser regime was the only irrigation/fertiliser combination used on the 'green leaf' plots, so the relative effect of other regimes on the performance of plants at this time of planting could not be assessed. Marketable yields from covered beds was also higher, though uncovered Camarosa did well from the second planting. The additional production would have to be weighed against the extra cost of covering.

Table 1.5. Rankings in descending order for total season production from all treatments used in 2005

Variety	Cover	Planting date	Irrigation/fertiliser	Full season marketable yield (g/m of row)
Camarosa gl	Covered	10 April	H/H	3724.52
Ventana	Covered	28 April	H/H	3685.17
Ventana gl	Covered	10 April	H/H	3671.69
Ventana gl	Covered	10 April	H/H	3654.05
Camino Real gl	Covered	10 April	H/H	3519.28
Camino Real gl	Covered	10 April	H/H	3487.95
Camarosa	Covered	28 April	H/H	3485.49
Camarosa gl	Covered	10 April	H/H	3451.85
Camarosa	Covered	20 May	H/M	3320.26
Camarosa	Not	28 April	H/H	3262.43
Camino Real	Covered	20 May	M/M	3134.73
Camino Real	Covered	20 May	H/H	3132.86
Ventana	Not	28 April	H/H	3131.70
Camino Real	Covered	28 April	H/H	3098.24
Camino Real	Covered	28 April	H/M	2896.96
Camarosa	Covered	28 April	M/M	2881.63
Camino Real	Covered	28 April	M/M	2825.64
Ventana	Covered	28 April	H/M	2761.54
Ventana	Covered	28 April	M/M	2756.54
Camarosa	Covered	28 April	H/M	2754.85
Gaviota	Covered	20 May	H/H	2725.60
Camino Real	Covered	20 May	H/M	2616.87
Camino Real	Not	28 April	H/H	2613.28
Camino Real	Covered	20 May	M/H	2586.05
Camarosa	Not	28 April	H/M	2563.36
Ventana	Not	20 May	H/M	2542.19
Ventana	Not	28 April	M/M	2533.09

Table 1.5. Continued

Variety	Cover	Planting date	Irrigation/fertiliser	Full season marketable yield (g/m of row)
Camarosa	Not	28 April	M/M	2486.33
Gaviota	Covered	20 May	H/M	2475.73
Ventana	Not	20 May	M/M	2471.40
Gaviota gl	Covered	10 April	H/H	2408.70
Gaviota	Covered	20 May	M/H	2389.97
Festival gl	Covered	10 April	H/H	2287.45
Gaviota gl	Covered	10 April	H/H	2246.82
Gaviota	Not	28 April	M/M	2229.95
Gaviota	Covered	20 May	M/M	2198.52
Gaviota	Not	28 April	H/M	2089.75
Kiewa	Not	20 May	H/H	2049.22
Camino Real	Not	20 May	M/H	1847.71
Kiewa	Not	20 May	M/H	1745.17
98-030-3	Not	5 May	M/H	1722.87
Gaviota	Not	20 May	M/H	1455.87
00-039-24	Not	5 May	M/H	1066.24
01-001-96	Covered	5 May	M/H	990.17

The picture for early yield (Table 1.6) was similar but the uncovered Camarosa dropped to 19th place with a yield of just over half of the best treatments. Two of the other early green leaf plantings (Festival and Gaviota) showed good early yield but their total season yield was well below average and placed them 31st and 33rd overall. Ventana on the H/M fertiliser regime was the other treatment with good early yield but overall, this treatment placed 18th. Growers not wishing to cover their crop in the early season should plant Camarosa or Ventana in late April using conventional runners.

Covered vs uncovered treatments in early September 2005

Table 1.6. Rankings in descending order for early season production from all treatments used in 2005

Variety	Cover	Planting date	Irrigation/fertiliser	Early season yield (g/m of row)
Ventana gl	Covered	10 April	H/H	1622.92
Camarosa gl	Covered	10 April	H/H	1574.41
Ventana gl	Covered	10 April	H/H	1568.25
Camarosa gl	Covered	10 April	H/H	1457.70
Camino Real gl	Covered	10 April	H/H	1316.37
Camino Real gl	Covered	10 April	H/H	1292.02
Ventana	Covered	28 April	H/H	1180.92
Festival gl	Covered	10 April	H/H	1161.27
Gaviota gl	Covered	10 April	H/H	1101.86
Ventana	Covered	28 April	H/M	1097.17
Camarosa	Covered	28 April	H/H	1086.30
Camino Real	Covered	28 April	H/M	1052.75
Camarosa	Covered	28 April	M/M	1048.86
Camino Real	Covered	28 April	H/H	1036.01
Camarosa	Covered	28 April	H/M	1027.61
Ventana	Covered	28 April	M/M	1001.35
Camino Real	Covered	28 April	M/M	990.61
Gaviota gl	Covered	10 April	H/H	977.06
Camarosa	Not	28 April	H/H	900.16
Camarosa	Not	28 April	H/M	864.71
Ventana	Not	20 May	H/M	842.98
Ventana	Not	28 April	H/H	829.71
Camarosa	Not	28 April	M/M	817.69
Camino Real	Covered	20 May	H/H	755.41
Ventana	Not	28 April	M/M	738.63
Camino Real	Covered	20 May	M/M	725.79
Ventana	Not	20 May	M/M	720.60
Gaviota	Not	28 April	M/M	676.65
Gaviota	Not	28 April	H/M	666.17
Camino Real	Covered	20 May	M/H	646.00
Camino Real	Not	28 April	H/H	639.68
Camino Real	Covered	20 May	H/M	625.14
Camarosa	Covered	20 May	H/M	562.16
98-030-3	Not	5 May	M/H	541.01
Camino Real	Not	20 May	M/H	369.55
Gaviota	Covered	20 May	H/H	349.86
Kiewa	Not	20 May	H/H	330.97
Kiewa	Not	20 May	M/H	314.63
01-001-96	Covered	5 May	M/H	281.77
Gaviota	Covered	20 May	H/M	260.26
00-039-24	Not	5 May	M/H	232.46
Gaviota	Covered	20 May	M/M	232.30
Gaviota	Covered	20 May	M/H	212.70
Gaviota	Not	20 May	M/H	137.30

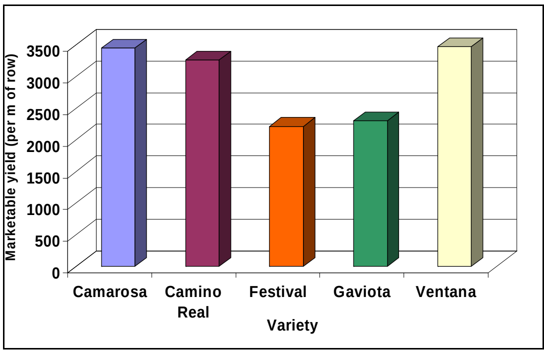


Figure 1.4a. **Comparison of total marketable yield in g/metre of row from five strawberry varieties planted on 10 April (covered, green leaf) under an H/H irrigation and fertiliser regime.**

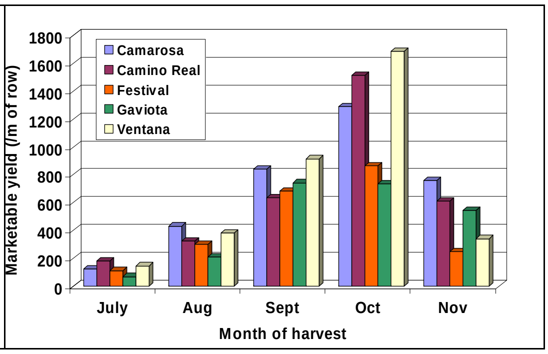


Figure 1.4b. **Comparison of total marketable yield in g/metre of row from a 10 April planting (covered, green leaf) and under an H/H irrigation and fertiliser regime.**

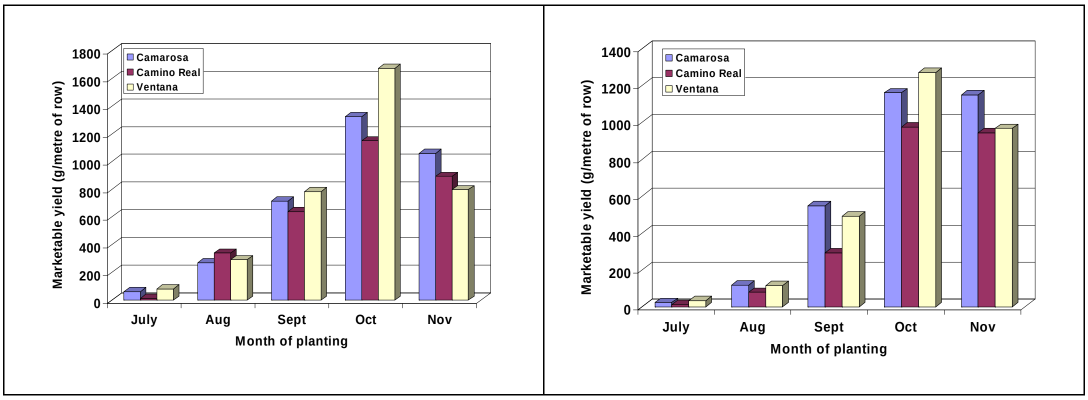
Figures 1.4a and b show the total production per metre of row and production per month for all strawberry varieties planted on 10 April. Camarosa, Camino Real and Ventana both peak heavily in October when prices are dropping, however these same varieties also produced well early in the season.

If prices are factored into the figures for monthly production, on a per metre of row basis (to take account of different planting densities), the best returns are from largely the same varieties and treatments in the 'top ten' for total seasonal production (see Table 1.7).

Table 1.7. Top ten treatments in descending order of gross returns for the 2005 season

Variety	Cover	Planting date	Irrigation/fertiliser	Gross return ($ per metre of row)
Camarosa gl	Covered	10 April	H/H	$18.60
Ventana gl	Covered	10 April	H/H	$18.52
Ventana gl	Covered	10 April	H/H	$18.52
Ventana	Covered	28 April	H/H	$18.20
Camarosa gl	Covered	10 April	H/H	$17.16
Camino Real gl	Covered	10 April	H/H	$16.96
Camarosa	Covered	28 April	H/H	$16.80
Camino Real gl	Covered	10 April	H/H	$16.72
Camino Real	Covered	28 April	H/H	$15.00
Camarosa	Covered	20 May	H/M	$14.96

Effects of covering



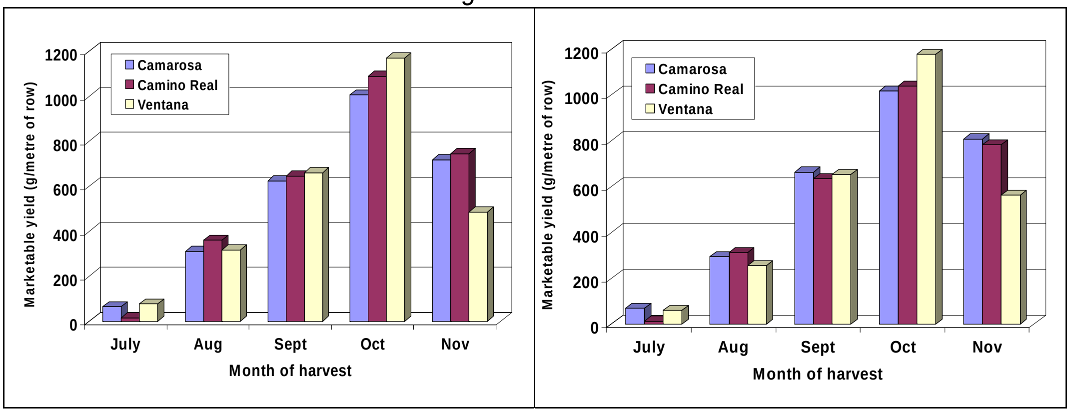
Figures 1.5a,b. Comparison of production in g/metre of row from three strawberry varieties planted on 28 April under covers (left) and uncovered (right).

Covers had a significant effect on early season yield (Figures 1.5a, b). A higher proportion of fruit was marketable (> 90% cf 60-70%) due to a reduction in weather damage (rain) that could cause disease problems. Table 1.8 shows the gross return per metre of row for Camarosa, Camino Real and Ventana planted on 28 April. Yields later in the 2005 season were similar but that would be highly dependent on the prevailing weather for each season.

Table 1.8. Comparison of income per metre of row for three covered versus uncovered strawberry varieties

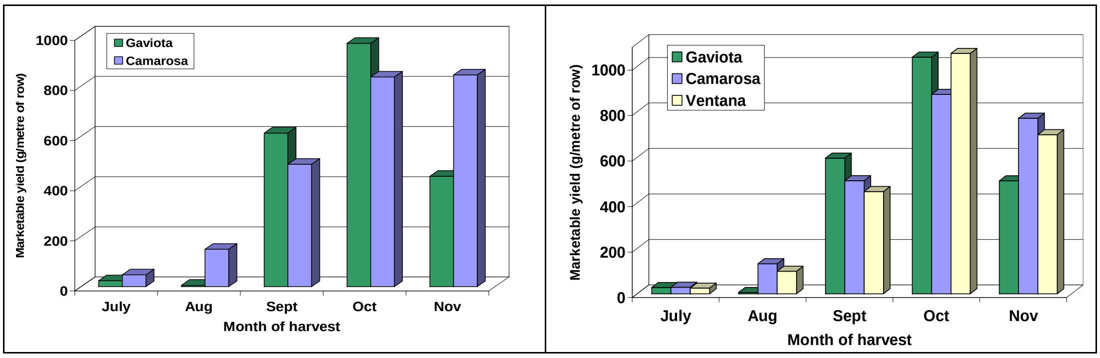
Variety	Covered		Uncovered	
	Early (till end of Sept)	Whole season	Early (till end of Sept)	Whole season
Camarosa	$6.60	$16.80	$4.24	$13.96
Camino Real	$6.28	$15.00	$2.40	$10.44
Ventana	$7.32	$18.20	$4.00	$13.56

Effects of water and fertiliser management



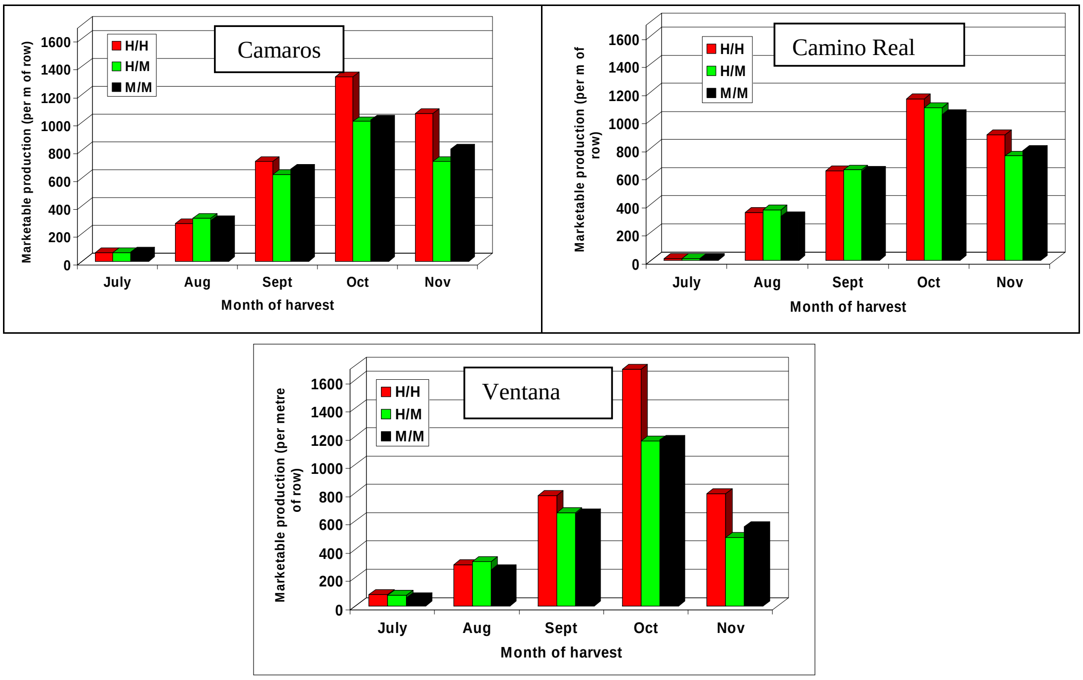
Figures 1.6a,b. Comparison of production in g/metre of row, from three strawberry varieties (covered) planted on 28 April under a high irrigation/medium fertiliser regime (left) and a medium irrigation/medium fertiliser regime (right).

The most notable feature of figures 1.6a, b is that both irrigation/fertiliser combinations gave an almost identical result for covered rows. The fertiliser regime was the same in both cases, whereas 50 per cent more irrigation was applied to the varieties shown in the figure on the left. The extra irrigation did not increase or decrease yields, suggesting that the medium irrigation rate was sufficient and there would be no benefit from applying more water.



Figures 1.7a,b. Comparison of production from selected strawberry varieties in g/metre of row under an high irrigation/medium fertiliser regime (left) and a medium irrigation/medium fertiliser regime (right).

When the comparison was made between high irrigation (left) and medium irrigation (right) for uncovered plots with the same fertiliser rate (medium), the result (Figures 1.7a, b) was the same as for covered plots. The extra water supplied by the high irrigation regime made virtually no difference to yield or distribution of yield over time.



Figures 1.8a-c. Comparison of production from three strawberry varieties (Camarosa, Camino Real and Ventana) under three different irrigation and fertiliser regimes in g/metre of row.

At the high rate of irrigation, a comparison of the two rates of fertiliser for the three varieties Camarosa, Ventana and Camino Real showed that all three produced higher yields with the higher rate of fertiliser. This is shown in Figures 1.8a-c by comparing the red bars (high water and high fertiliser) with the green bars (high water and medium fertiliser).

When the medium irrigation rate was combined with the high fertiliser rate, yields were reduced compared to high irrigation and high fertiliser.

This is illustrated in Figures 1.9a-c by comparing the red (high irrigation and high fertiliser) bars with the blue bars (medium irrigation and high fertiliser). Depressed yields for the latter goes against the trends noted previously for highest yields with high fertiliser. The reason may be a build-up of salts in the root zone when high fertiliser is combined with the lower rate of water due to insufficient flushing of fertiliser salts or a higher water demand by plants on a higher nutrition plane.

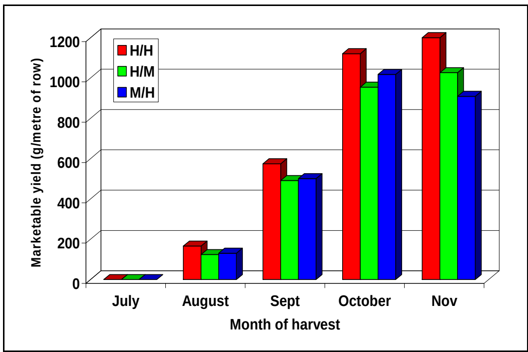


Figure 1.9a. Comparison of production (g/metre of row) from Camino Real planted on 20 May (covered) under three different irrigation and fertiliser regimes.

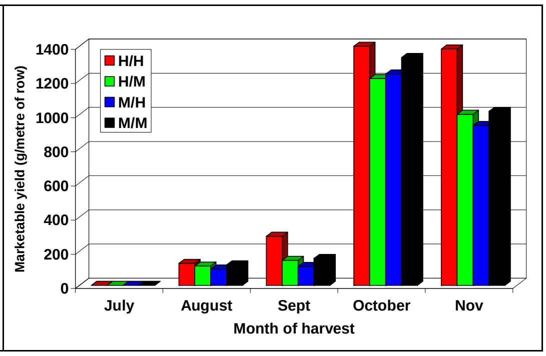


Figure 1.9b. Comparison of production (g/metre of row) from Gaviota planted on 20 May (covered) under four different irrigation and fertiliser regimes.

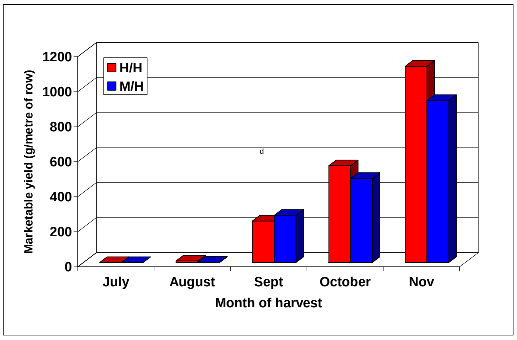
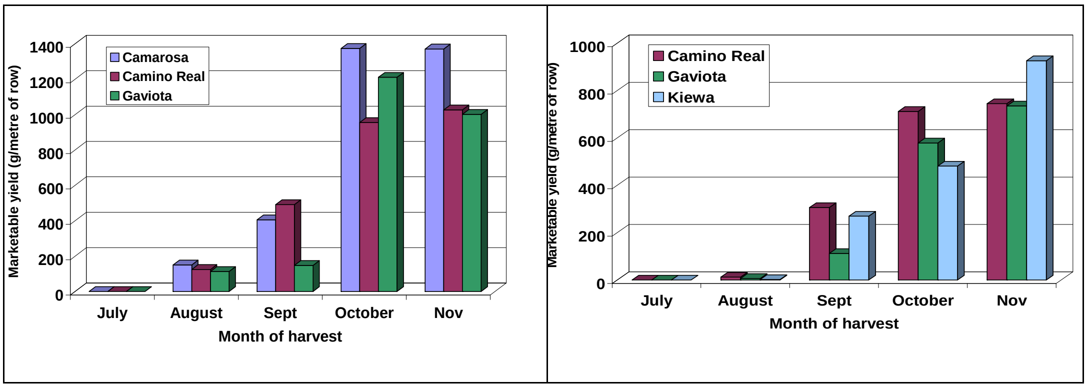


Figure 1.9c. Comparison of production (g/metre of row) from Kiewa planted on 20 May (uncovered) under two different irrigation and fertiliser regimes.

Other comparisons of interest, not previously referred to, are illustrated in Figures 1.10a, b and Figure 1.11.



Figures 1.10a, b. Comparison of production (g/metre of row) from selected strawberry varieties (covered) with a high irrigation/medium fertiliser regime (left) and uncovered with a medium irrigation/high fertiliser regime (right). Planted on 20 May.

The notable result illustrated in Figures 1.10a and b is the higher yield achieved with Camarosa later in the season when planted on May 20 compared to Camino Real and Gaviota and the relatively poor yields for all varieties when left uncovered. Figure 1.11 shows that Ventana performed relatively better than the other three varieties when left uncovered.

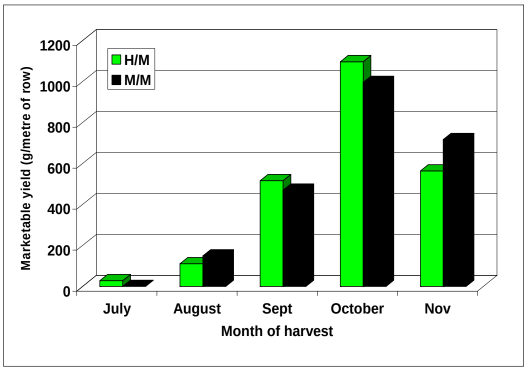
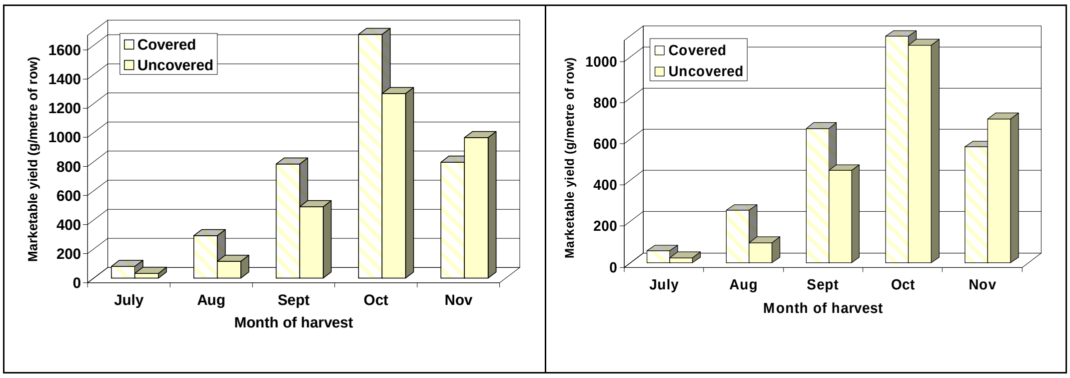


Figure 1.11 Comparison of production (g/metre of row) from Ventana planted on 20 May (uncovered) under two different irrigation and fertiliser regimes.

Combined effects of covering and water and fertiliser management



Figures 1.12a, b. Comparison of production (g/metre of row) from Ventana under a high irrigation/high fertiliser (left) and a medium irrigation/medium fertiliser (right) regime.

Production under covers was higher throughout the season with the exception of November, irrespective of irrigation and fertiliser management, as shown in Figures 1.12a, b for Ventana planted on 28 April. It is possible that the plants under covers are ‘burnt out’ earlier, however prices are usually at their lowest at that time, so the impact on profit is small. Total production is still higher under covers (3.69 vs 3.13 kg/metre of row). Higher prices early in the season mean a return of $7.32 vs $4.00/metre of row during the period up to the end of September.

Lysimeters

Leachate volumes and nitrate for the trial duration are shown in Table 1.9. The total quantity of nitrogen estimated to be leached into each of the 6 lysimeters was calculated using two assumptions. The first assumption was that each lysimeter captured the water and nitrate leached from a single dripper only. Lysimeters were all located directly below a dripper as close to the centre of the lysimeter as possible. The quantity of nitrate captured by each lysimeter was multiplied by the number of drippers per hectare to estimate the total nitrogen leached per hectare for this method. The second assumption was that leachate and nitrate intercepted by the lysimeters was uniform throughout the soil profile and the total loss of both could be calculated from the surface area of a lysimeter. In this method, the leachate levels per hectare were calculated by multiplying the levels in one lysimeter by the number of lysimeter equivalents per hectare on a surface area basis.

Table 1.9. Leachate volumes, nitrate concentrations and estimates of nitrogen leaching for 2005

Lysimeter no.	Total leachate volume (L) and precipitation equivalent (in brackets mm)	Total nitrate (g)	Nitrogen leached (kg/ha) (drippers)	Nitrogen leached (kg/ha) (surface area)
1 (M/M) mid point covered	82.9 (1257.6)	25.21	379.5	861.4
2 (M/M) high point covered	35.0 (529.7)	6.82	102.7	233.1
3 (M/M) mid point uncovered	83.1 (1257.6)	22.64	340.9	773.8
4 (H/M) mid point covered	129.4 (1958.2)	22.76	342.7	777.9
5 (H/M) mid point uncovered	129.9 (1965.0)	26.68	401.6	911.6
6 (H/M) low point uncovered	107.8 (1631.4)	26.67	401.5	911.5

The period of lysimeter monitoring was 182 days, and the approximate rate of nitrogen applied through the drippers in that time was 364 kg/ha and 546 kg/ha for the medium and high fertiliser rates respectively. During this period, the precipitation rate on each block calculated by combining water meter and rainfall data was 816.2 mm for the medium irrigation rate and 908.4 mm for the high rate.

Table 1.9 shows that the volume of water captured in lysimeters over-estimated precipitation (shown in brackets in column 1) by more than 100 per cent when calculated on a surface area basis, except for lysimeter 2 which was sited at the highest point in the block. This suggests that the lysimeters were disproportionately influenced by the presence of a dripper directly above them, and that more leachate was collected at this position in the soil profile than would be expected outside the zone of influence of the drippers.

The two methods for calculating leached nitrogen also showed good agreement between rates of nitrogen applied and those captured in the lysimeter where the dripper method was used (except for lysimeter 2). The surface area method for estimating nitrogen leaching gave levels approximately double the rates of nitrogen applied through drip irrigation.

Accurate estimates of leaching were not possible because the zone of influence of drippers at the depth of the lysimeters is not known. However, the nitrogen levels collected in all lysimeters (except no. 2) were in the same order of magnitude as the rates applied, suggesting that a high proportion of the water from a single dripper was providing the bulk of the leachate recovered from each lysimeter. Water volumes in the lysimeters were higher than could be accounted for by output from a single dripper alone, and much of the difference was probably the contribution of rainfall. The combined effects of rainfall and the output of a single dripper closely approximated volumes collected in lysimeters for the medium irrigation rate, but the lysimeter volumes were about 50 per cent greater for the high irrigation rate.

Soil moisture monitoring

Figure 1.13 shows an example of the output for a two week period from the installed TDR's. A general drying trend is evident and slightly more pronounced for the probes in the uncovered area. To curb this slow drying a small peak from an extra irrigation is evident on 16 October.

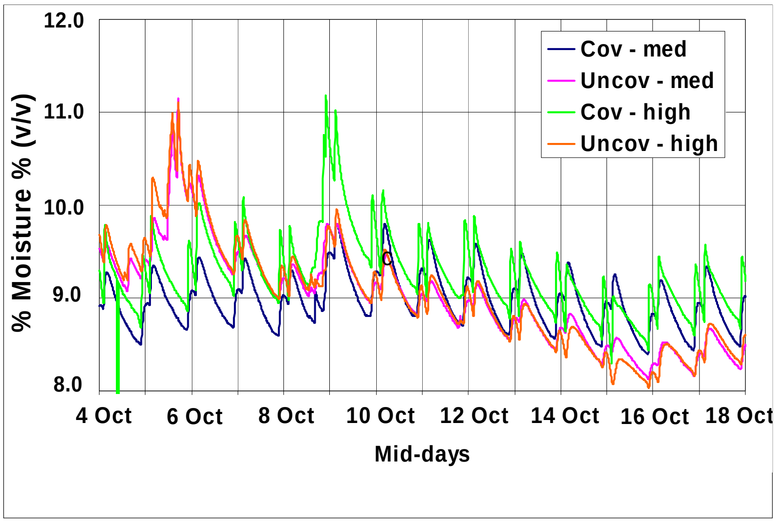


Figure 1.13. TDR scan for each of the four probes for the fortnight from 4-18 October 2005.

There was a rainfall event on 6 October which is reflected in the trace, particularly for the uncovered area. There is a lesser, delayed response in the covered area. There were some smaller rainfall events a few days later, which this time show more in the covered plots. This is likely to be due to the shedding effect of the covers, resulting in water draining onto the bed above the probe.

Water meters

Table 10 shows the recorded water supplied to each of the irrigation blocks (presented as mm/ha), as measured by water meters installed on each sub-main, compared to the planned irrigation rate using the two crop factor formulas. There were clearly large differences between the measured volumes of water applied and the planned volumes, and the rates varied over time. The cumulative effect of these differences may have been that the actual irrigation rates were approximately only 70 per cent of the planned (and expected) rates during the period that water meter data was recorded.

Table 1.10. Planned and actual water supplied (measured by water meters) expressed mm/ha, as well as planned and actual total water use per hectare (L) of plastic surface (67 beds)

Week no.	Week ending	Water meter number (irrigation regime)						
		1(High)	2(High)	4(High)	Planned High	3(Med)	5(Med)	Planned Medium
0	9-23 May	0.9	0.9	1.0	2.7	0.9	0.9	2.7
1	31 May	0.9	0.9	1.0	2.4	0.9	0.9	2.4
2	7 Jun	1.6	1.4	1.5	2.4	1.3	1.0	1.6
3	14 Jun	1.5	0.7	1.4	1.4	1.1	1.0	0.9
4	21 Jun	0.3	0.1	0.0	1.4	0.1	0.0	0.9
5	27 Jun	0.7	0.6	0.6	1.4	0.5	0.6	0.9
6	4 Jul	0.7	0.6	0.6	1.4	0.5	0.6	0.9
7	11 Jul	0.7	0.6	0.6	1.4	0.5	0.6	0.9
8	18 Jul	2.1	1.7	1.6	1.4	1.6	1.5	0.9
9	25 Jul	2.4	1.7	1.6	1.4	1.6	1.5	0.9
10	2 Aug	2.2	1.6	1.5	1.4	1.5	1.4	0.9
11	8 Aug	1.5	1.2	1.1	1.4	0.9	0.9	0.9
12	15 Aug	1.9	1.7	3.0	2.1	1.1	1.0	1.4
13	23 Aug	1.9	1.9	3.2	2.1	1.3	1.2	1.4
14	30 Aug	2.2	2.1	2.0	2.4	1.5	1.5	1.6
15	5 Sep	2.3	2.3	2.5	2.4	1.6	1.5	1.6
16	12 Sep	2.4	2.4	2.3	3.2	1.7	1.7	2.2
17	19 Sep	3.2	2.8	2.7	3.2	1.9	1.9	2.2
18	26 Sep	2.9	2.8	2.6	4.2	1.9	1.8	2.9
19	3 Oct	3.8	3.7	3.5	4.2	2.6	2.6	2.9
20	10 Oct	3.8	3.9	3.6	4.9	2.7	2.7	3.3
21	17 Oct	4.0	3.9	3.7	5.5	3.1	2.7	3.7
22	24 Oct	3.9	3.7	3.5	6.9	2.5	2.6	4.8
23	31 Oct	4.2	4.0	3.8	6.9	3.0	2.9	4.8
24	7 Nov	4.4	4.2	4.0	6.9	3.0	3.1	4.8
25	14 Nov	4.3	4.1	3.9	9.6	3.2	3.1	6.4
26	21 Nov	4.4	4.3	4.0	9.6	3.4	3.1	6.4
Total per ha (67 beds) – kilolitres		**5143.9**	**4808.5**	**4792.1**	**7292.0**	**3648.4**	**3529.3**	**4907.0**

The total irrigation applied for the high treatment over the crop's life averaged 491.5 mm and for the medium treatment it was 358.9 mm. The average daily water volume applied through irrigation was 188 ml/plant/day for the high rate and 137 ml/plant/day for the medium rate.

The same data is presented as percentages of the long term average evaporation used to develop the irrigation plan (Crop Factor) in Table 1.11, and graphically as water use on the irrigation blocks in Figure 1.13.

The water meter data shows that the high irrigation plan was only achieved on block 1 (first planting with green leaf plants) during June and July. During July, the two medium irrigation blocks were slightly over watered compared to the plan. After July, none of the blocks consistently achieved the planned irrigation targets. From September to November, the actual irrigation rates fell progressively further behind the planned rates, to the point that the actual medium rates were consistently only one third of the planned rate, and even the actual high rates did not reach more than 70 per cent of the planned medium rate.

Table 1.11. Planned and actual crop factors during the 2005 season for the five irrigation blocks (9 beds each). Actual crop factors were calculated from recorded water meter data. Numbers are presented as percentages

Week no.	Week ending	Water meter number (irrigation regime)						
		1(High)	2(High)	4(High)	Planned High	3(Med)	5(Med)	Planned Medium
0	9-23 May	33	32	38	96	34	33	96
1	31 May	37	36	43	96	38	38	96
2	7 Jun	67	60	63	92	82	65	62
3	14 Jun	105	50	99	82	119	116	53
4	21 Jun	19	5	1	82	12	1	53
5	27 Jun	48	41	42	82	60	63	53
6	4 Jul	48	41	42	82	60	63	53
7	11 Jul	48	41	42	82	60	63	53
8	18 Jul	150	119	114	82	177	170	53
9	25 Jul	174	119	114	82	176	169	53
10	2 Aug	157	111	106	82	164	158	53
11	8 Aug	110	89	82	82	105	97	53
12	15 Aug	92	83	144	95	78	69	64
13	23 Aug	91	91	151	95	90	88	64
14	30 Aug	92	87	83	92	96	93	62
15	5 Sep	95	96	102	92	100	94	62
16	12 Sep	76	76	72	107	80	76	73
17	19 Sep	101	88	84	107	87	85	73
18	26 Sep	69	67	63	105	65	63	73
19	3 Oct	91	88	83	105	90	90	73
20	10 Oct	78	79	74	123	82	80	83
21	17 Oct	72	70	68	125	83	72	84
22	24 Oct	56	53	51	138	51	53	96
23	31 Oct	61	58	55	138	62	61	96
24	7 Nov	63	60	57	138	62	65	96
25	14 Nov	45	43	41	157	50	48	105
26	21 Nov	46	45	42	157	54	49	105

The same data is presented graphically in Figure 1.14, and this illustrates the growing divergence between the planned and actual schedules as the season progressed. The reason or reasons for the discrepancy have not been found, but possibilities include, variable pressure and flow rates in the main irrigation supply line or progressive blockage of the filter and or dripper outlets. There was some doubt over the accuracy of the water meters at first, but calibration against new meters in the 2006 season suggests that they were working properly. The water meter data was fairly consistent between meters and the relativity between high and medium rates was as expected.

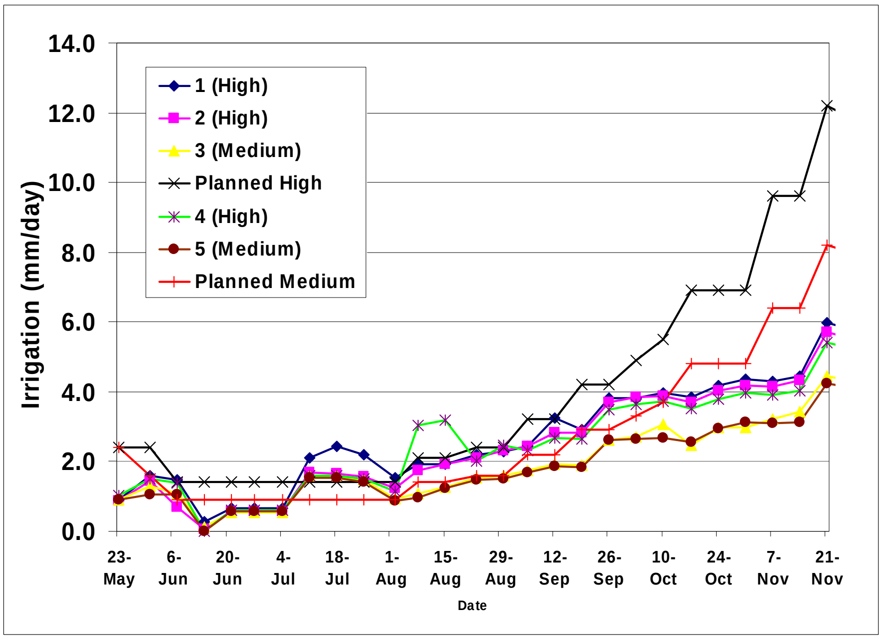
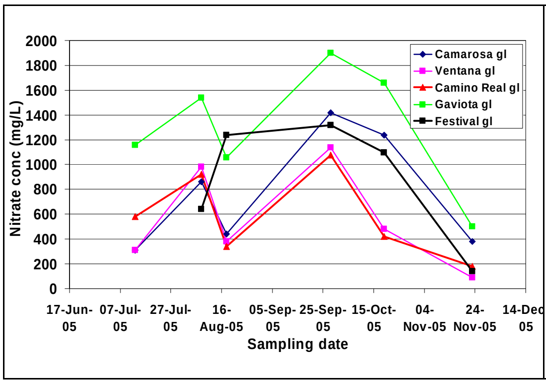


Figure 1.14. Planned and actual irrigation volumes for the five irrigation blocks and two schedules (L/week/block).

Sap analysis

Sap analysis for nitrate showed similar trends to previous years. Nitrate fluctuated more than phosphorus or potassium during the season but did decline later as the plants became depleted towards the end of the season (Figures 1.15a-c). Gaviota showed a trend towards higher nitrate levels throughout whilst Camino Real and Ventana both had similar, lower levels. Early in the season, nitrate levels were volatile and appeared to respond to variations in soil temperature. Elevated levels on 8 August coincided with soil temperatures ranging from 12°C to 24°C. A dip in sap nitrate on 18 August coincided with slightly lower soil temperatures of 10°C to 20°C.

Phosphorus levels showed a steady decline over the season as did potassium levels.



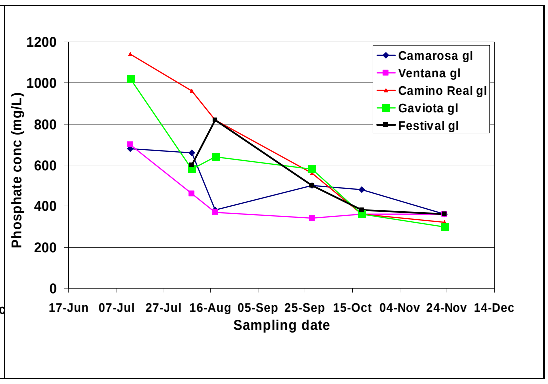


Figure 1.15a. **Nitrate sap concentrations for selected strawberry selected strawberry varieties during the 2005 season.**

Figure 1.15b. **Phosphate sap concentrations for strawberry varieties during the 2005 season.**

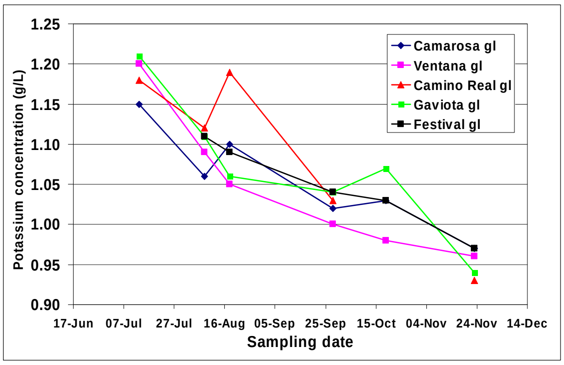


Figure 1.15c. **Potassium sap concentrations for selected strawberry varieties during the 2005 season.**

The following set of graphs track nitrate, phosphorus and potassium sap levels for Camarosa in the three irrigation and fertiliser treatments over the season (Figures 1.16a-c). There were no consistent, significant differences between treatments. The levels all followed the same general pattern as before but there was a tendency for the sap nitrate levels to be slightly higher with the H/H treatment.

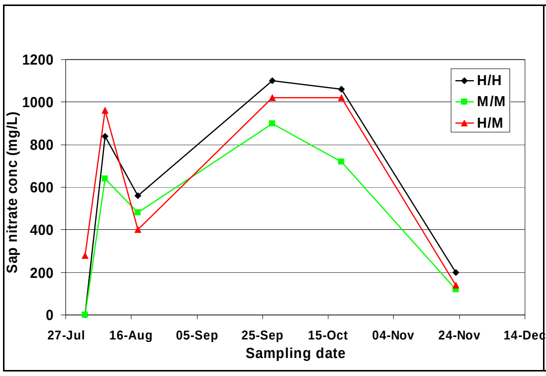


Figure 1.16a. Comparison of sap nitrate levels in Camarosa under three different irrigation and fertiliser regimes.

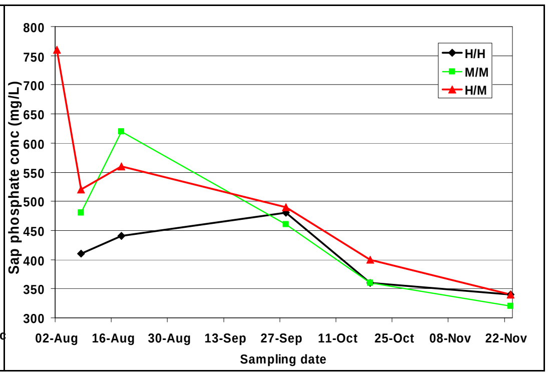


Figure 1.16b. Comparison of sap phosphate levels in Camarosa under three different irrigation and fertiliser regimes.

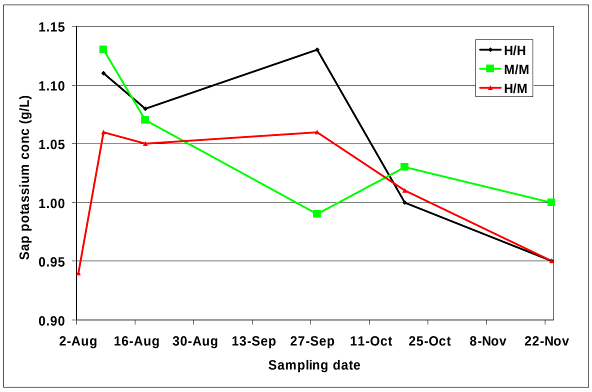


Figure 1.16c. Comparison of sap potassium levels in Camarosa under three different irrigation and fertiliser regimes.

Field days

Four field days were held at the site during the 2005 season (10 August, 9 September, 14 October and 2 December). Each field day was of half day duration. PowerPoint presentations on the project and progressive results were given on each occasion. The presentations are available together with any field day notes that were handed out to growers.

Field days included presentations of results and field inspections.

The first field day was held in conjunction with Bayer who launched Flint™, a new fungicide for the control of powdery mildew. Time was allocated for growers to view the treatment site during each field day.

1.4 Discussion and Conclusions

The results from this year's work showed that both Camarosa and the new variety Ventana were the most highly productive, all round varieties for commercial growers. There were also distinct yield and income benefits from covering plants, however further 'in depth' economic analysis of the cost of covers is required before a carte blanche recommendation for covering can be given.

The use of greenleaf plants combined with covers, for early planting resulted in earlier cropping which has the potential to capture higher prices at the start of the season. Interestingly, this early production was not achieved at the expense of later yields. These plants went on to produce the highest seasonal yields overall.

Other varieties such as Gaviota and Camino Real should not be discounted. Each has particular traits that may suit growers in certain situations. Gaviota, can have superior flavour to other varieties and Camino Real produced competitive early and full season yields when planted in early April with 'green leaf' runners.

The two irrigation schedules used proved to be successful in producing high yields throughout the season. No additional benefit could be shown from irrigating with more water than the 'medium' schedule when 2 kg/ha nitrogen per day was used. Yields were highest when 3 kg/ha of nitrogen per day was applied throughout the season, but this result was only achieved at the high rate of irrigation.

Although the irrigation scheduling methods produced high yields of good quality marketable fruit, monitoring results from water meters installed on each irrigation block showed that the planned irrigation schedules were not actually achieved. Irrigation times late in the season exceeded the original crop factor plan because extra water was given in each irrigation cycle to flush the lines after fertigation, and after 20 September this was done twice per day and later 3 times per day. Most of the extra water would have drained back out of the lines through flushing valves and would not be available to the plants.

Despite the extra watering time to flush irrigation lines, water volumes applied in 2005 averaged 60-70 per cent of the original plan overall, and declined steadily from August until they were as low as 45 per cent by November. This may explain the observed reduction in yield late in the season when the high fertiliser rate was combined with the medium irrigation rate. Nevertheless, the high yields achieved with the combined high irrigation and high fertiliser regimes were encouraging. Total seasonal water supplied to the high irrigation treatments was around 37 litres per plant compared to 27 litres for the medium irrigation treatment.

Nitrate leaching as shown by the lysimeter data was within reasonable limits and did not differ a great deal between irrigation treatments. The data suggested that siting lysimeters directly below a dripper at 40 cm depth was a good way of capturing the leachate from that dripper, but it was difficult to estimate the total nitrogen loss on a per hectare basis without knowing more about the shape and size of the wetting pattern under drippers.

In 2006 we will try to fine tune irrigation and fertiliser treatments and achieve further savings in leaching of water and fertiliser. Selected new named varieties will also be included for comparison in 2006 and the evaluation of Australian breeding lines will continue.

2. Year 2 Annual Report (2006/07)

2.1 Introduction

This is the second of three annual reports for the Horticulture Australia project BS05001 – 'Facilitating the development of the strawberry industry in Western Australia'. The project has been funded for three years, 2005, 2006 and 2007. This report is for work done in the second year of the project.

This year, one block (19 beds – 24,000 plants) was grown under high tunnels (Haygrove™) covered with clear diffusing plastic (luminence B), representative of the type used extensively in Spain and the United Kingdom, while most of the remaining crop was grown under low cloches covered with clear polythene in the early part of the season. Results from 2005/06 showed a clear yield and quality benefit from row covers, hence only six beds (7,500 plants) were grown without any row covers in 2006/07.

As was the case in 2005/06, four fertigation regimes were compared, comprising two rates of irrigation in combination with two rates of fertiliser. The planned irrigation schedules were the same as those for 2005/06, but were moderated by more intensive soil moisture monitoring using electronic TDR probes. Whilst evaporation data was still the primary means of scheduling, we used TDR data to fine-tune application rates.

Only minor changes to the fertiliser programmes were implemented – an increase in the ratio of potassium to nitrogen to see if that might result in improved berry flavour, and some changes to the actual injection rate, but no change in the two final application rates of nitrogen of 2 kg and 3 kg per hectare per day .

Lysimeters were again installed under selected beds and used to monitor the volume of water and total quantity of nitrate leached. This data was complemented by weekly recording of water supplied through water meters fitted to the drip lines.

A range of named varieties as well as numbered new selections were compared in the demonstration blocks. Times of planting and runner type (conventional and green leaf) were also included, as in 2005/06.

All fruit grown at this demonstration site was packed and marketed to ensure it met commercial standards. Prices obtained during the season were used to superimpose economic data onto the trial results. Marketing allowed for a more commercially meaningful interpretation of yield results because higher yields may not always benefit the grower if they occur at times of low prices.

Three field days were held on a monthly basis during the harvest season from August to November at the Wanneroo site to show growers how the various new methods and varieties performed over time.

2.2 Materials and Methods

Layout

The demonstration block consisted of 47 beds, each 125 m long. Each bed was 1.2 m wide with 30 cm wheel tracks between each bed. The beds were covered with black plastic. There were four rows of plants per bed spaced at 30 cm. Two lines of Netafim® inline drip (25 cm spacing, dripper output 0.90 L/hour) irrigation were buried below the plastic, between the two outer rows of plants. In line plant spacing was 38 cm for all varieties.

The area was divided into three irrigation blocks of nine beds and two of ten beds. A water meter was installed at the inlet end of one drip line in each of the five blocks. Each irrigation block allowed for a different combination of irrigation and fertiliser rate (fertigation treatment) to be applied to the whole block of nine or ten beds.

Soil preparation

The soil was fumigated with Telone C-35® at 350 kg/ha prior to planting. No lime, trace elements or other base dressings were applied.

Pest and disease control

Predators were introduced into the crop for two spotted mite control. Applications of fungicide for powdery mildew and Botrytis, and pesticides for mites and caterpillars were also applied as required throughout the season.

Lysimeters

Six round PVC lysimeters (29 cm internal diameter) were buried below the crop (Figure 1). One was placed in each of the rows 5,6, 15, 26, 35 and 46. Each was positioned such that the centre of the lysimeter was directly located under one dripper outlet. The top of each lysimeter was approximately 40 cm below the soil surface. Soil removed in order to bury the lysimeters was replaced in the reverse order to maintain the soil profile as much as possible. The soil was watered in for compaction at the time of installation.

Each lysimeter was pumped out weekly from 3 May and leachate volumes recorded. Samples were retained for nitrate analysis. These were analysed using an RQflex® reflectometer and Merckoquant® indicator strips.

Trial plan

The demonstration block compared combinations of variety, planting date, row covers, irrigation and fertiliser regimes. Principally, there were four varieties, three planting dates, two row covering methods (high tunnels and conventional cloches) and two fertigation schedules compared in the majority of the beds, while a small number of beds were set aside for other work such as Australian breeding line evaluation, small plot evaluation of new varieties from non traditional origins and plug plant trials. All possible combinations of these variables could not be compared with only 47 beds available, so some low priority treatments were excluded. The range of fertigation options that could be compared for example was limited by the minimum size of a fertigation block being 9 or 10 beds. No replication of the treatments was possible because of the limitation of plot numbers and the large plot size (1250 plants each).

The bulk of the planting consisted of either high tunnels or conventional cloches (19 and 22 beds respectively). Within the high tunnels, the only irrigation/fertiliser regime was M/M (described in irrigation and fertiliser sections that follow), and apart from two beds planted on 27 May, the remaining beds were either greenleaf plantings (11 April) or conventional (leaves off) plantings on 2 May.

Under the conventional cloches there was a similar pattern except the beds were split between H/H and M/M irrigation and fertiliser regimes. Plots without row covers were planted either on the 2 or 27 May. These were under a M/M irrigation and fertiliser regime and comprised a mixture of deflowered and not deflowered treatments.

Table 2.1 details the full list of treatments. Figure 2.2 is a schematic representation.

Table 2.1. Treatments compared at the Wanneroo demonstration site, gl = green leaf runners; c = conventional runners

Bed no.	Planting date	Variety	Irrigation regime	Fertiliser regime	Covers	Runner source, other treatments and equipment locations
1*						Unplanted
2	11 Apr	Ventana	Medium	Medium	High tunnel	gl
3	11 Apr	Gaviota	Medium	Medium	High tunnel	gl
4	11 Apr	Camino Real	Medium	Medium	High tunnel	gl
5	11 Apr	Camarosa	Medium	Medium	High tunnel	Lysimeter 1 and TDR 1 (gl)
6	2 May	Camarosa	Medium	Medium	High tunnel	Lysimeter 2 (c)
7	2 May	Camino Real	Medium	Medium	High tunnel	c
8	2 May	Gaviota	Medium	Medium	High tunnel	c
9	2 May	Ventana	Medium	Medium	High tunnel	c
10	27 May	Camino Real	Medium	Medium	High tunnel	c
11	11 Apr	Ventana	Medium	Medium	High tunnel	gl
12	11 Apr	Gaviota	Medium	Medium	High tunnel	gl
13	11 Apr	Camino Real	Medium	Medium	High tunnel	gl
14	11 Apr	Camarosa	Medium	Medium	High tunnel	TDR 2 (gl)
15	2 May	Camarosa	Medium	Medium	High tunnel	Lysimeter 3 (c)
16	11 Apr	Breeding lines, and named varieties incl. Albion	Medium	Medium	High tunnel	Queensland Intermediate gl
17	2 May	Camino Real	Medium	Medium	High tunnel	c
18	2 May	Gaviota	Medium	Medium	High tunnel	c
19	2 May	Ventana	Medium	Medium	High tunnel	c
20	27 May	Gaviota	Medium	Medium	High tunnel	c
21*						Unplanted
22	11 Apr	Ventana	Medium	Medium	Low tunnel	gl
23	11 Apr	Gaviota	Medium	Medium	Low tunnel	gl
24	11 Apr	Camino Real	Medium	Medium	Low tunnel	gl
25	11 Apr	Camarosa	Medium	Medium	Low tunnel	gl
26	2 May	Camarosa	Medium	Medium	Low tunnel	Lysimeter 4 and TDR 3 (c)
27	2 May	Camino Real	Medium	Medium	Low tunnel	c
28	2 May	Gaviota	Medium	Medium	Low tunnel	c
29	2 May	Ventana	Medium	Medium	Low tunnel	c
30	25 Apr – May 4	Australian Breeding lines	Medium	Medium	Low tunnel	Victorian Stage 4 & Intermediate (c)
31	11 Apr	Ventana	High	High	Low tunnel	gl
32	11 Apr	Gaviota	High	High	Low tunnel	gl
33	11 Apr	Camino Real	High	High	Low tunnel	gl
34	11 Apr	Camarosa	High	High	Low tunnel	TDR 4 (gl)
35	2 May	Camarosa	High	High	Low tunnel	Lysimeter 5 (c)
36	2 May	Camino Real	High	High	Low tunnel	c
37	2 May	Gaviota	High	High	Low tunnel	c
38	2 May	Ventana	High	High	Low tunnel	c

Table 2.1. Continued …

Bed no.	Planting date	Variety	Irrigation regime	Fertiliser regime	Covers	Runner source, other treatments and equipment locations
39	2 May	Ventana	High	High	Low tunnel	c
40	2 May + 27 May	Other named varieties	High	High	Low tunnel	100 plant plots (c)
41	27 May	Camino Real	Medium	Medium	Low tunnel	c
42	27 May	Gaviota	Medium	Medium	Low tunnel	c
43	27 May	Australian Breeding selections	Medium	Medium	Low tunnel	Temperate Advanced (3) (c)
44	27 May	Camino Real	Medium	Medium	No covers	Deflowered (c)
45	27 May	Gaviota	Medium	Medium	No covers	Deflowered (c)
46	2 May	Camarosa	Medium	Medium	No covers	Lysimeter 6 (c)
47	2 May	Camino Real	Medium	Medium	No covers	Deflowered (c)
48	2 May	Gaviota	Medium	Medium	No covers	Deflowered (c)
49	2 May	Ventana	Medium	Medium	No covers	c

Low tunnels in the foreground and high tunnels in the background.

Inside a high tunnel in November.

Comment [U1]: I cant move this arrow to be next to Bed 1

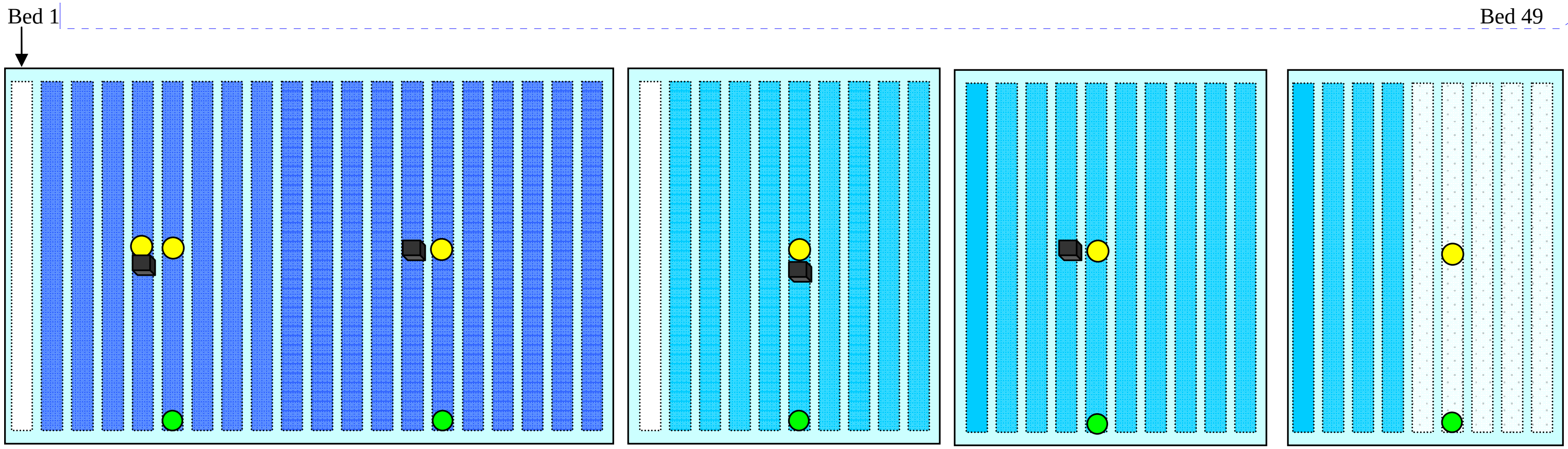


Figure 2.1. A schematic drawing of all 49 beds with lysimeter, water meter and TDR placements marked.

Denotes lysimeter, 1-6 left to right

Denotes water meter on one dripline in each bed

Denotes TDR, 1-4 left to right

Denotes high tunnels

Denotes cloches

Denotes uncovered bed

Denotes row used for tunnel legs – unplanted

Irrigation

The irrigation regime was based on long term evaporation replacement adjusted with a crop factor according to growth stage.

High regime: 75 per cent increasing to 175 per cent, commencing in June and July at 75 per cent and rising at approximately 15 per cent each month until November (175 per cent).

Medium regime: 50 per cent increasing to 117 per cent commencing in June and July at 50 per cent and rising at approximately 10 per cent each month until November (117 per cent).

The medium regime was applied to all treatments until 13 July when a review of 2005/06 results was completed and it was decided that a high irrigation rate treatment really was necessary again in 2006/07. Irrigation was applied once per day until 20 September when it was increased to twice a day and then three times a day from 15 November.

Table 2.2 Irrigation schedule for 2006/07

Date	Irrigation rate	Long term average daily evaporation data (Medina 30 years)	Planned crop factor (%)	Planned daily irrigation (mm)	Planned daily irrigation time (min)	Planned daily fertigation time (min)	Actual mean daily irrigation (mm)	Actual crop factor % from water meters
01 Apr	High*	4.1	100	4.1	41	16		
	Medium	4.1	100	4.1	41	11		
01 May	High*	2.7	100	2.7	27	17	2.4	
	Medium	2.7	100	2.7	27	11	2.5	
15 May	High*	2.4	90	2.4	24	17	1.8	
	Medium	2.4	60	1.6	16	11	1.9	
01 Jun	High*	1.7	75	1.4	14	14	1.9	100
	Medium	1.7	50	0.9	9	9	1.9	99
01 Jul	High*	1.7	75	1.4	14	14	2.4	105
	Medium	1.7	50	0.9	9	9	2.2	94
01 Aug	High	2.2	90	2.1	21	18	1.8	100
	Medium	2.2	60	1.4	14	11	1.3	71
15 Aug	High	2.6	90	2.4	24	18	2.7	122
	Medium	2.6	60	1.6	16	11	2.1	93
01 Sep	High	3.0	105	3.2	32	17	3.4	108
	Medium	3.0	70	2.2	22	11	2.6	82
15 Sep	High	4.0	105	4.2	42	17	3.9	125
	Medium	4.0	70	2.9	29	11	3.0	95
01 Oct	High	4.4	125	5.5	55	17	6.3	137
	Medium	4.4	85	3.7	37	11	4.8	105
15 Oct	High	5.0	140	6.9	69	17	8.2	180
	Medium	5.0	95	4.8	48	11	6.2	136
01 Nov	High	6.1	157	9.6	96	18	8.8	138
	Medium	6.1	105	6.4	64	12	6.6	104
15 Nov	High	7.0	175	12.2	122	18	8.2	129
	Medium	7.0	117	8.2	82	12	6.2	97

* The high irrigation rate did not commence until 13 July.

The evaporation figures used in conjunction with these crop factors were ‘long term averages’ from the Medina Research Station weather station. In June and July, the monthly average was applied throughout the month, but in August and subsequent months, the averages used were for the first two weeks and second two weeks of the month. Irrigation rates were thus adjusted every two weeks from August onwards. The figures were an average over 30 years of recordings. Table 2.2 shows the evaporation data that schedules were based on and the actual crop factors and irrigation times used in each fortnight of the crop’s life. The actual figures vary at times, from those planned for a variety of reasons. Sometimes irrigation was with-held or increased due to local weather conditions such as abnormally cold or hot days. For example during the second half of November, irrigation was not increased as it was not as hot as expected. The actual quantity of water used is also expected to be higher at times if the lines have drained and have to be refilled before water can reach the plants. Approximately 25 L water was required to fill each 125 m line once it had drained.

Water meters

Water meters were installed on one line of drip tape in each of the five irrigation blocks. Due to doubts concerning the operation of the water meters last season (there was a risk they may have been able to run backwards when the lines drained), this year, at the beginning of August, we installed some additional water meters of a different type in the same blocks as some of the original meters and removed the flushing valves at the ends of the lines.

Fertigation

Plants were fertigated during each irrigation with a stock nutrient solution supplied from two 1000 litre tanks. The total quantities of nutrients supplied from these two tanks were as follows:

Nutrient solution composition (g/L) of the stock solutions:

- Calcium nitrate 50.0
- Magnesium sulphate 24.9
- Mono-ammonium phosphate 12.7
- Potassium nitrate 50.0

All of the calcium nitrate and half of the potassium nitrate was dissolved in Tank A and the other fertilisers were dissolved in Tank B. Each tank had its own injection pump, and the injection rate of stock solution from each tank during the fertigation cycle was 1 litre per minute.

Where multiple daily irrigations were applied during the warmer months, the fertigation was applied in the first half of each irrigation. In each irrigation cycle, water and fertiliser were applied in two phases. A typical cycle would start with water only for a number of minutes to fill the lines and then followed by the required time to inject the nutrient solution through the drip lines.

The fertigation plan in 2006/07 was again based on the results of past research at Medina Research Station with the variety Kiewa. This program showed that strawberries were very responsive to nitrogen, and a high yielding crop, with good flavour could be produced with around 450 kg/ha (N) for the season. This result could be achieved by injecting approximately 2 kg/ha per day of N into the drip lines. This program was the standard treatment tested here and is described in the text that follows as the ‘medium’ fertiliser program. This program was compared with a ‘high’ schedule which supplied 150 per cent of the ‘medium’ N rate, i.e. approximately 3 kg/ha per day. The latter was achieved in practice by increasing the duration of the fertigation cycle by 50 per cent over the medium rate. For example, if the fertigation time to supply the medium rate was 16 minutes, the high rate would receive 24 minutes of fertigation.

This year, however, potassium rates were increased from 2.1 to 2.4 kg/ha per day (medium program) and 3.6 kg/ha per day (high program) in response to comments that flavour may be improved by having a higher ratio of potassium to nitrogen.

Soil moisture monitoring - TDRs

Table 2.3. Treatment locations for each TDR probe

Probe number	Bed number	Variety	Covering	Irrigation rate
1	5	Camarosa	High tunnel	Medium
2	14	Camarosa	High tunnel	Medium
3	26	Camarosa	Low tunnel	Medium
4	34	Camarosa	Uncovered	High

Soil moisture levels in the root zone and below (0-60 cm depth) were monitored for the medium and high irrigation rates in high and low tunnels continuously throughout the growing cycle. These results were used to monitor the effectiveness of the irrigation schedules and to allow timely adjustments to be made to the irrigation plan if the soil became too dry.

The equipment used was a TDR probe coupled to a data logger and modem for remote download to a computer on the farm and at the DAFWA office. Table 2.3 and Figure 2.2 show the locations of each probe. Groups of four sensors (reflectometers) were sited close to a lysimeter at four depths, 0-15 cm (angled 45°) about half way between a dripper and plant, 15-30 cm (angled 45°), 0-30 cm inserted in the soil vertically and 30-60 cm inserted vertically.

The output from this equipment was a table of volumetric soil moisture readings which could be graphed to show a continuous record of soil water content over time. An example output is shown in the results section of this report which follows.

2.3 Results

Tables 2.4 and 2.5 summarize the marketable yields from all beds over the 2006/07 season. Table 2.4 lists total yields for the whole season in descending order while Table 2.5 shows marketable yield until the end of September only.

This year, the green leaf plantings (11 April planting) did not perform as well as 2005/06 though there were still three greenleaf treatments in the 'top ten'.

Table 2.4. Rankings in descending order for total season marketable yield from all treatments used in 2006/07

Variety	Cover	Planting date	Irrigation/fertiliser	Full season marketable yield (g/plant)
Ventana	Low tunnel	2 May	HH	1400.57
Ventana	High tunnel	2 May	MM	1287.28
Ventana	Low tunnel	2 May	MM	1271.53
Camarosa	Low tunnel	11 April	HH	1263.79
Ventana	Low tunnel	11 April	HH	1257.28
Ventana	Low tunnel	2 May	HH	1247.12
Camarosa	Low tunnel	2 May	HH	1245.56
Camarosa	High tunnel	2 May	MM	1237.12
Camino Real	High tunnel	11 April	MM	1233.13
Camarosa	Low tunnel	2 May	MM	1232.84
Camino Real	Low tunnel	11 April	HH	1215.42
Camino Real	High tunnel	2 May	MM	1201.86
Camarosa	Low tunnel	11 April	MM	1196.47
Camarosa	High tunnel	11 April	MM	1188.03
Ventana	High tunnel	2 May	MM	1177.38
Ventana	Low tunnel	11 April	MM	1146.17
Camino Real	Low tunnel	11 April	MM	1107.88
Ventana	High tunnel	11 April	MM	1101.73
Camarosa	High tunnel	11 April	MM	1068.56
Camino Real	High tunnel	2 May	MM	1065.60
Gaviota	High tunnel	11 April	MM	1064.24
Camino Real	Low tunnel	2 May	MM	1023.48
Gaviota	Low tunnel	2 May	MM	1001.08
Camarosa	Not deflowered, no covers	2 May	MM	1000.30
Ventana	High tunnel	11 April	MM	995.42
Camarosa	High tunnel	2 May	MM	993.93
Gaviota	Low tunnel	11 April	HH	992.44
Camino Real	Low tunnel	2 May	HH	989.11

Table 2.4 Continued …

Variety	Cover	Planting date	Irrigation/fertiliser	Full season marketable yield (g/plant)
Camino Real	High tunnel	2 May	MM	987.31
Gaviota	High tunnel	2 May	MM	954.58
Camino Real	Low tunnel	25 May	MM	939.60
Ventana	No covers	2 May	MM	921.46
Gaviota	Low tunnel	11 April	MM	918.14
Gaviota	Low tunnel	2 May	HH	910.45
Camino Real	Deflowered, no covers	2 May	MM	875.99
Camino Real	High tunnel	25 May	MM	843.59
Gaviota	High tunnel	2 May	MM	819.40
Gaviota	High tunnel	11 April	MM	774.40
Camino Real	Deflowered, no covers	25 May	MM	738.29
Gaviota	Low tunnel	25 May	MM	728.35
Gaviota	Deflowered, no covers	25 May	MM	685.80
Gaviota	High tunnel	25 May	MM	674.75

With the exception of the top ranked treatment, one could probably assume there was no significant difference between any of the next 10 or so treatments.

With respect to early season plant yield, Ventana planted in early May from 'leaves off' runners is capable of equalling early greenleaf plantings of either Ventana or Camarosa. However, early season production does not equate to higher dollar returns. Table 2.6 shows that returns per plant are closely related to yield over the entire season.

Table 2.5. Rankings in descending order for early season marketable yield from all treatments used in 2006/07

Variety	Cover	Planting date	Irrigation/fertiliser	Early season yield (g/plant)
Ventana	High tunnel	2 May	MM	716
Camarosa gl	Low tunnel	11 April	HH	708
Ventana	High tunnel	2 May	MM	688
Ventana gl	Low tunnel	11 April	HH	659
Camarosa gl	Low tunnel	11 April	MM	653
Camarosa gl	High tunnel	11 April	MM	646
Ventana gl	Low tunnel	11 April	MM	639
Ventana	Low tunnel	2 May	HH	632
Gaviota gl	High tunnel	11 April	MM	621
Gaviota gl	Low tunnel	11 April	HH	621
Ventana	Low tunnel	2 May	MM	619
Camino Real gl	High tunnel	11 April	MM	605
Ventana gl	High tunnel	11 April	MM	600
Camarosa gl	High tunnel	11 April	MM	581
Ventana	Low tunnel	2 May	HH	577
Gaviota gl	Low tunnel	11 April	MM	570

Table 2.5 continued

Variety	Cover	Planting date	Irrigation/fertiliser	Early season yield (g/plant)
Camino Real gl	Low tunnel	11 April	HH	543
Camino Real gl	High tunnel	11 April	MM	527
Camino Real gl	Low tunnel	11 April	MM	513
Ventana gl	High tunnel	11 April	MM	509
Gaviota gal	High tunnel	11 April	MM	503
Camarosa	High tunnel	2 May	MM	440
Camarosa	Low tunnel	2 May	MM	434
Camino Real	High tunnel	2 May	MM	431
Camarosa	Low tunnel	2 May	HH	423
Camino Real	High tunnel	2 May	MM	375
Camino Real	Low tunnel	2 May	MM	358
Camarosa	High tunnel	2 May	MM	350
Camino Real	Low tunnel	2 May	HH	335
Gaviota	Low tunnel	2 May	MM	322
Gaviota	High tunnel	2 May	MM	306
Camarosa	Not deflowered no covers	2 May	MM	295
Gaviota	Low tunnel	2 May	HH	287
Gaviota	High tunnel	2 May	MM	277
Ventana	No covers	2 May	MM	265
Camino Real	Low tunnel	25 May	MM	237
Camino Real	High tunnel	25 May	MM	202
Camino Real	Deflowered no covers	2 May	MM	148
Gaviota	Deflowered no covers	2 May	MM	143
Gaviota	Low tunnel	25 May	MM	140
Gaviota	High tunnel	25 May	MM	134
Camino Real	Deflowered no covers	25 May	MM	127
Gaviota	Deflowered no covers	25 May	MM	80

Table 2.6. Top ten treatments in descending order of gross returns for the 2006 season

Variety	Cover	Planting date	Irrigation/fertiliser	Gross return (g/plant)
Ventana	Low tunnel	2 May	HH	$6.31
Ventana	High tunnel	2 May	MM	$5.88
Ventana	Low tunnel	2 May	MM	$5.74
Camarosa gl	Low tunnel	11 April	HH	$5.84
Ventana gl	Low tunnel	11 April	HH	$5.82
Ventana	Low tunnel	2 May	HH	$5.61
Camarosa	Low tunnel	2 May	HH	$5.34
Camarosa	High tunnel	2 May	MM	$5.36
Camino Real gl	High tunnel	11 April	MM	$5.51
Camarosa	Low tunnel	2 May	MM	$5.33

Effects of covering

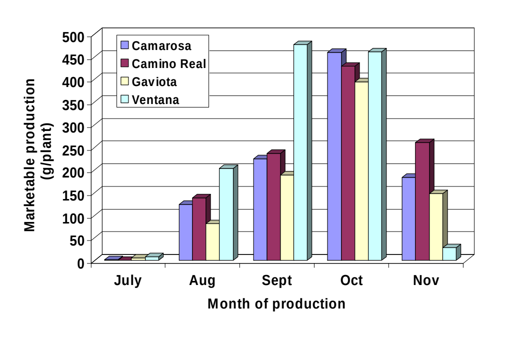


Figure 2.2a. Comparison of production from four strawberry varieties planted on 11 April (greenleaf) under high tunnels.

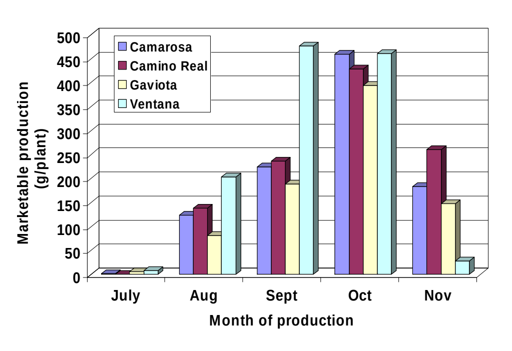


Figure 2.2b. Comparison of production from four strawberry varieties planted on 11 April (greenleaf) under low tunnels.

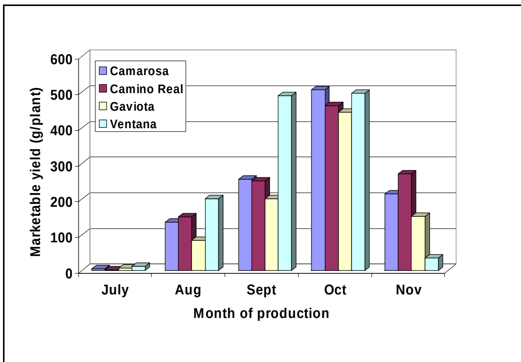


Figure 2.2c. Comparison of production from four strawberry varieties planted on 2 May under high tunnels and a M/M irrigation and fertiliser regime.

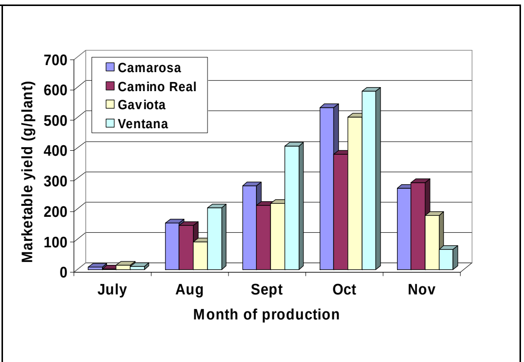


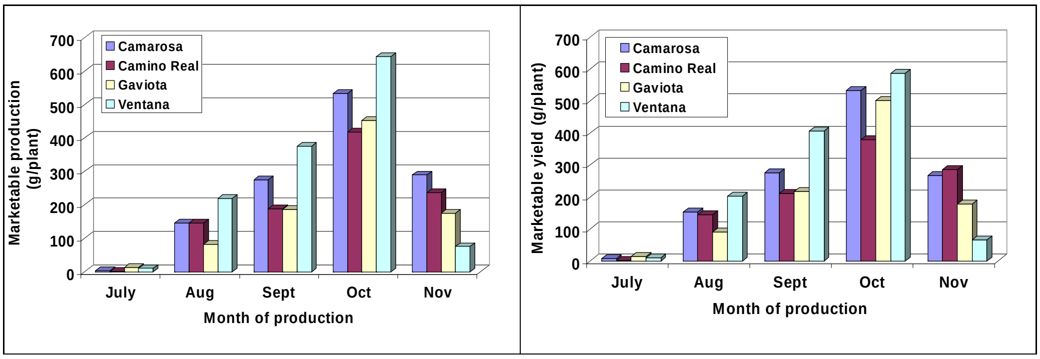
Figure 2.2d. Comparison of production from four strawberry varieties planted on 2 May under low tunnels and a M/M irrigation and fertiliser regime.

High tunnels did not appear to offer any clear yield advantage in the 2006/07 season (Figures 2.2a-d). Camino Real was the only variety for which they appeared beneficial. Table 2.7 shows the gross return per plant for Camarosa, Camino Real and Ventana planted on 28 April. Yields for the whole season showed a similar pattern to the early (prior to October) yield but would be dependent on the prevailing weather for each season.

Table 2.7. Comparison of income per plant for three high tunnel versus low tunnel strawberry varieties

Variety	High tunnel		Low tunnel	
	Early (till end of Sept)	Whole season	Early (till end of Sept)	Whole season
Camarosa	$3.14	$5.18	$3.35	$5.50
Camino Real	$2.80	$4.97	$2.53	$4.91
Ventana	$2.75	$4.82	$3.23	$5.37

Effects of water and fertiliser management



Figures 2.3a,b. Comparison of production from three strawberry varieties (low tunnels) planted on 2 May under a high irrigation/high fertiliser regime (left) and a medium irrigation/medium fertiliser regime (right).

The difference between M/M and H/H regimes was minimal for most varieties (Figures 2.3a,b; Table 2.8). Ventana showed the greatest benefit from the H/H regime but the advantage was not huge. During the peak season, Camarosa was virtually identical. Camino Real showed a slight yield advantage in October under an H/H regime, but this was reversed in November. Gaviota showed a moderate yield benefit from a M/M regime.

Table 2.8. Monthly marketable yield per plant (g) under an high irrigation/high fertiliser regime compared to a medium irrigation/medium fertiliser regime for four strawberry varieties

Variety	Regime	July	Aug	Sept	Oct	Nov	Total
Camarosa	HH	3.2	145.9	274.3	532.9	289.2	1245.6
Camarosa	MM	7.4	152.1	274.5	532.2	266.5	1232.8
Camino Real	HH	1.3	146.5	187.7	417.7	235.9	989.1
Camino Real	MM	1.1	145.4	211.7	379.3	286.0	1023.5
Gaviota	HH	13.6	83.0	187.1	452.7	174.1	910.4
Gaviota	MM	14.1	90.5	216.9	501.8	177.8	1001.1
Ventana	HH	10.0	219.2	375.7	643.5	75.5	1323.8
Ventana	MM	9.8	203.5	405.4	586.4	66.3	1271.5

The effect of planting time and deflowering

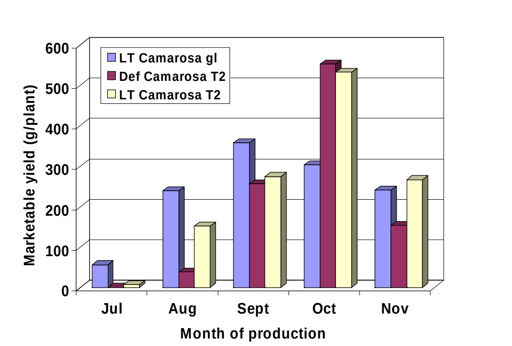


Figure 2.4a. **Marketable yields of Camarosa planted on 11 April under low tunnels (gl) compared with a 2 May planting uncovered and deflowered (Def) or covered and not deflowered. All under a MM irrigation and fertiliser regime.**

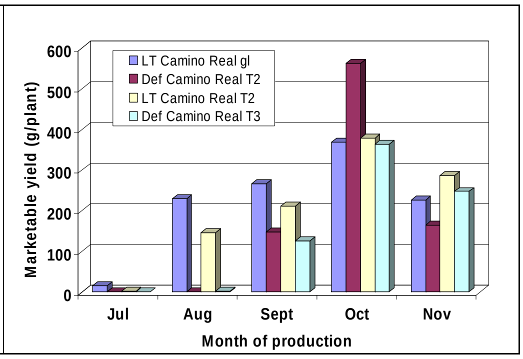


Figure 2.4b. **Marketable yields of Camino Real planted on 11 April (gl), 2 and 27 May deflowered) and 2 May (not deflowered). All under a MM irrigation and fertiliser regime.**

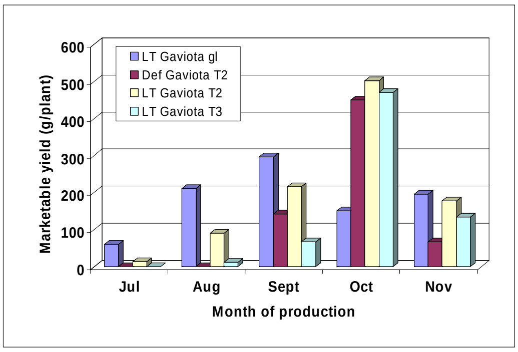


Figure 2.4c. **Marketable yields of Gaviota planted on 11 April under low tunnels (gl), 2 May uncovered and deflowered (Def –T2) vs 2 May covered and not deflowered (LT – T2) and 27 May covered and not deflowered (LT–T3) under a MM irrigation and fertiliser regime.**

In 2006/07 the yield advantage of the earlier greenleaf plantings over the whole season was not as clear cut as it was in 2005/06. There may still be a benefit from having the yield spread more evenly over the season. Yields are higher, early in the season, when prices are likely to be better.

Figures 2.4a-c show there is no benefit from leaving plants uncovered and deflowering to offset the worst effects of rain and bad weather, compared to covering them and not deflowering. Total yield is decreased by the former practice and the seasonal yield pattern shows a more defined peak at what is often the poorest price point of the season and yield is poor, if not almost non existent at the times of higher prices early in the season.

Later plantings simply yield less overall. There is no early yield to capture better prices and their peak of production is no better than for any of the other planting times.

Water meters

Table 2.9 shows a summary of the water supplied to each of the irrigation blocks as measured by water meters installed on individual drip lines. The data in the table represents the mean of each irrigation treatment. There was good agreement between both types of meters so we are confident that this year's data is an accurate reflection of the water applied.

Table 2.9. Mean quantity of water supplied (measured by water meters) (L) during the 2006 season for 125m length of drip line and estimated total use per hectare of plastic surface (67 beds). Note there are two drip lines per bed

Week no.	Week ending	Mean volume applied per day (L) Medium irrigation	Mean volume applied per day (L) High irrigation
1	8-May	219.6	205.5
2	15-May	150.2	147.2
3	22-May	148.1	144.6
4	29-May	130.6	129.6
5	5-Jun	139.0	134.9
6	12-Jun	137.6	137.2
7	19-Jun	104.1	107.4
8	26-Jun	142.7	144.9
9	3-Jul	142.7	144.9
10	10-Jul	174.5	170.8
11	17-Jul	122.9	128.7
12	24-Jul	116.1	155.8
13	27-Jul	95.5	111.9
14	7-Aug	114.5	160.1
15	14-Aug	122.7	175.0
16	21-Aug	145.8	196.4
17	28-Aug	165.1	215.2
18	4-Sep	179.7	234.1
19	11-Sep	207.1	274.7
20	18-Sep	206.8	269.7
21	25-Sep	242.8	317.1
22	2-Oct	277.0	367.2
23	9-Oct	366.6	484.4
24	16-Oct	355.7	456.6
25	23-Oct	461.6	617.8
26	30-Oct	469.3	618.7
27	6-Nov	531.2	701.2
28	13 Nov	462.8	615.8
29	20 Nov	462.8	615.8
Total volume /125 m line (L)		**45948.0**	**57076.3**
Total volume (kL/ha)		**6157.0**	**7648.2**

Total volume per hectare was obtained by doubling the line figure to obtain a volume per bed and then converting that to a per hectare figure (beds are 1.2 m wide x 125 m long or 150 m^2 so 67 beds will fit into 10,000 m^2 or one hectare).

The total volumes applied for the season equate to 616 mm for the medium rate and 765 mm for the high rate respectively at an average application rate of 360 mL/plant/day (Medium) and 448 mL/plant/day (High).

Table 2.10 compares water applied (as per the water meters) to long term evaporation data for Medina and local daily evaporation data for the Wanneroo area for the duration of the trial.

Table 2.10. Comparison of applied irrigation (mm) to evaporation data (mm) and calculated crop factors (%)

Month	Long term average evap (Medina)	Actual evap in 2006 (Wanneroo)	Medium irrigation actual	High irrigation actual	Crop factor Medium*	Crop factor High*
May	64.4	101	66	64	65	65
June	53.5	78	53	53	66	66
July	55.4	76	61	68	80	90
August	69.4	92	60	81	62	88
September	94.2	124	91	119	73	96
October	142	180	171	224	95	131
November (20th)	127	131	143	189	109	144
Total	**670**	**782**	**616****	**765****		

* Crop factors are calculated on from the evaporation figures for the Wanneroo weather station.
**Monthly figures do not add to these totals as there are approximations to generate monthly totals.

It is apparent from these figures, that for most of the season, strawberries can be grown successfully on 65-70% of evaporation, rising to around 100% for the peak cropping time.

In addition to the water applied through the driplines, additional water was applied for two weeks via overhead irrigation to establish each planting as it occurred. This year an additional 284 mm was applied in this manner, this represents 75% more precipitation over and above rainfall. In part this was due to the very dry May and June (see Table 2.11). Normally enough rain would fall in these months to obviate the need for large quantities of overhead watering. In addition, since this planting is a trial with plantings staggered, both in time and place, often overhead irrigation was required to establish only one or two beds out of nine or ten at a time. In normal commercial plantings, all planting would occur over a short period of say 2-3 weeks and so the requirement for overhead irrigation would be substantially less. Most of the overhead irrigation was required for the ‘green leaf’ plantings. Overhead irrigation is also used at times in winter for frost protection.

Lysimeters

Total water volumes from the lysimeters this year were substantially less than last year, despite the additional overhead irrigation during establishment. Table 2.11 outlines rainfall and lysimeter drainage for each month over 2005 and 2006. There seems little correlation for most months, especially given that supplementary overhead irrigation would have been applied in May and June during establishment and that should have brought the figures closer together. Likewise in the following months of the season, even where rainfall is greater in 2006 cf 2005, drainage to the lysimeters is still substantially less.

Table 2.11. Comparison of leachate volumes (total of all lysimeters) and rainfall for 2005 and 2006

Month	2005		2006	
	Rain (mm)	Drainage (L)	Rain (mm)	Drainage (L)
May	190.2	216	21.8	109
June	232.2	147	29.4	51
July	51.8	88	70.2	59
August	98.9	85	104.6	25
September	72.4	80	51.4	27
October	51	98	25.6	36
November	16	39	24.2	20

Leachate volumes and nitrate for the total trial duration are shown in Table 2.12. Accurate estimates of leaching are difficult because the zone of influence of drippers at the depth of the lysimeters is not known, as described in the 2005/06 report.

The total quantity of nitrogen estimated to be leached into each of the six lysimeters was calculated using two assumptions. The first assumption was that each lysimeter captured the water and nitrate leached from a single dripper only. Lysimeters were all located directly below a dripper as close to the centre of the lysimeter as possible. The quantity of nitrate captured by each lysimeter was multiplied by the number of drippers per hectare to estimate the total nitrogen leached per hectare for this method. The second assumption was that leachate and nitrate intercepted by the lysimeters was uniform throughout the soil profile and the total loss of both could be calculated from the surface area of a lysimeter. In this method, the leachate levels per hectare were calculated by multiplying the levels in one lysimeter by the number of lysimeter equivalents per hectare on a surface area basis.

Table 2.12. Leachate volumes and nitrate concentrations for 2006 (MM plots had 404 kg/ha applied N, HH had 606 kg/ha)

Lysimeter no.	Total leachate volume (L) and precipitation equivalent in brackets (mm)	Total nitrate (g)	Nitrogen (kg/ha)/hectare (drippers)	Nitrogen (kg/ha)/hectare (surface area)
1 (M/M) high tunnel	88.3 (1337)	22.43	338.00	767.38
2 (M/M) high tunnel	76.9 (1165)	20.11	303.13	688.16
3 (M/M) high tunnel	37.4 (566.7)	13.76	207.30	470.61
4 (M/M) low tunnel	33.2 (761.0)	14.72	221.86	503.66
5 (H/H) low tunnel	38.8 (633.6)	11.28	170.00	385.92
6 (M/M) uncovered	53.6 (719)	11.81	177.91	403.88

Neither of the two methods for calculating leached nitrogen showed good agreement with those captured in the lysimeter. The period of lysimeter monitoring was 202 days, and the approximate rate of nitrogen applied through the drippers in that time was 404 kg/ha and 606 kg/ha for the medium and high fertiliser rates respectively. The surface area method for estimating nitrogen leaching gave levels often higher than the rates of nitrogen applied through drip irrigation. Even the dripper method showed up to 75% of the applied nitrogen, leaching.

Volumes for two of the lysimeters in the tunnels were somewhat higher than the rest. This is difficult to explain, particularly since the third lysimeter was next to a tunnel leg and therefore most likely of all the three to have been subjected to water shedding during rainfall events. Lysimeter 5 was also amongst those with the lowest recorded volumes of leachate yet was in the high irrigation high fertiliser regime.

Soil moisture monitoring

Figures 2.5 – 2.8 show the output for the duration of the trial from the installed TDRs.

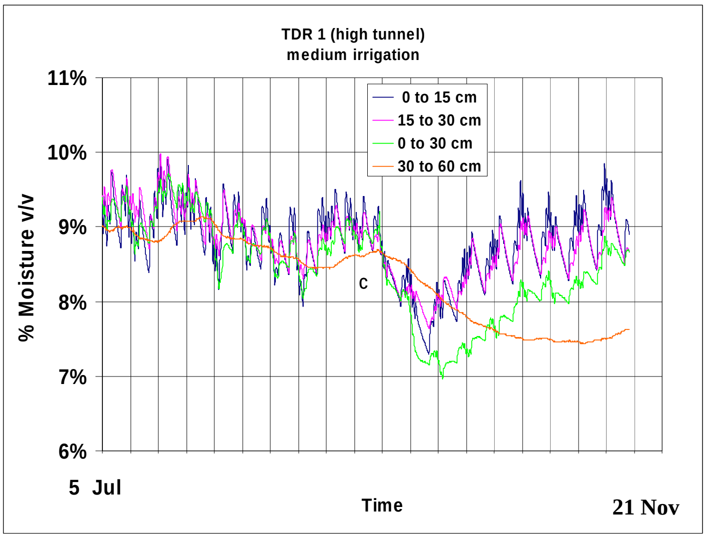


Figure 2.5. Scan for TDR installed under the high tunnel in a M/M irrigation and fertiliser regime.

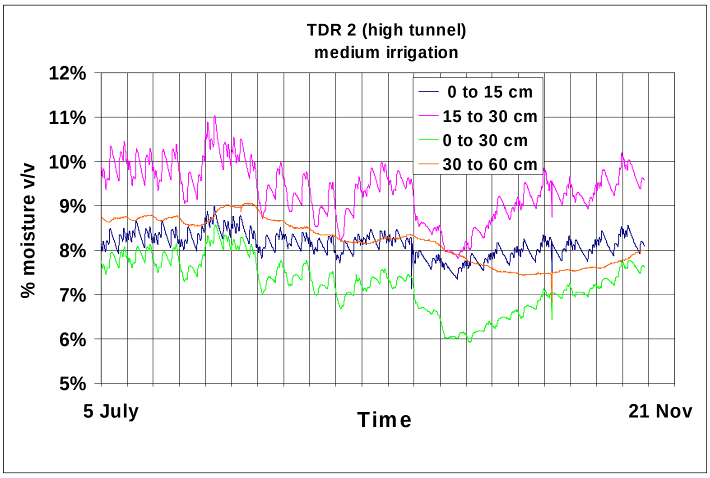


Figure 2.6. Scan for second TDR installed under the high tunnel in a M/M irrigation and fertiliser regime.

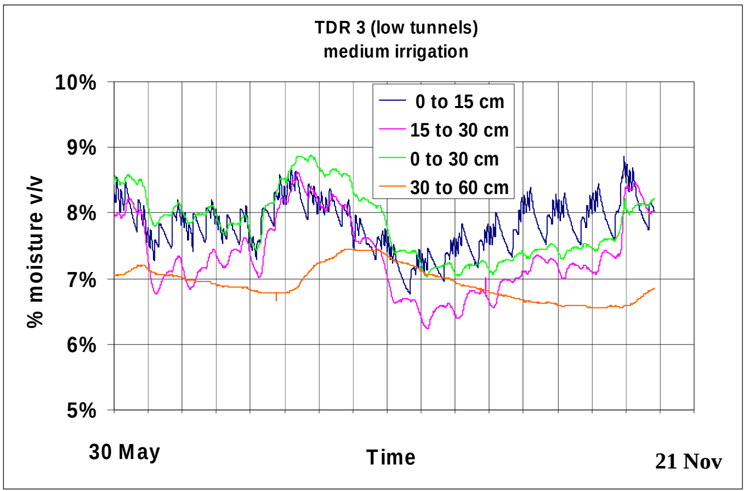


Figure 2.7. Scan for TDR installed under the low tunnels in a M/M irrigation and fertiliser regime.

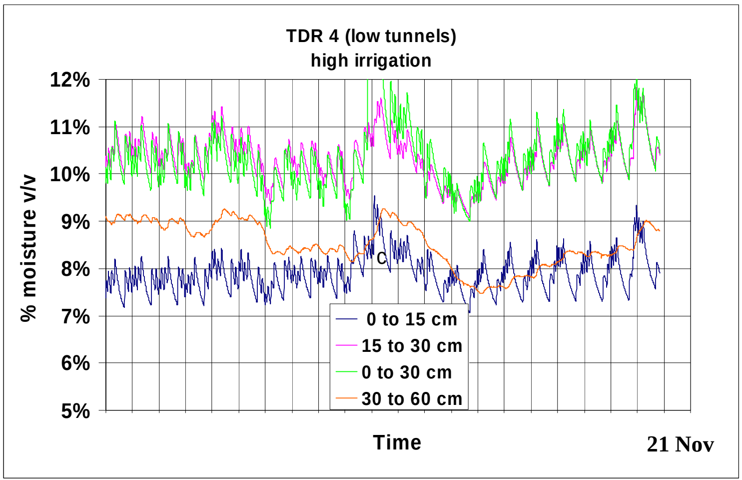


Figure 2.8. Scan for TDR installed under a low tunnel in a H/H irrigation and fertiliser regime.

The soil moisture monitoring data for the four irrigation blocks (Figures 2.5-2.8) show similar trends over the course of the season. The data collected from the TDR scans proved to be helpful for decision making about varying irrigation times to take account of particular weather conditions. An example is a notable drying trend in the soil at all depths over the last two weeks of September. This phenomenon is evident about the mid point of each graph and most noticeable in figures 2.5, 2.7 and 2.8. This was corrected by extra irrigation on 8 and 9 October which helped to recover soil moisture levels to around those that prevailed earlier in the crop's life.

The monitoring data for soil moisture casts a shadow of doubt over putting too much faith in the TDRs as the sole method for scheduling irrigation, because the soil moisture percentages recorded vary greatly between probes at the same depth. This point is illustrated by the consistently low levels recorded by the probe at 0-15 cm depth in Figure 2.8, compared to the probes near it in the 15-30 cm and 0-30 cm zones. In contrast, a probe at the 0-15 cm depth in Figures 2.5 and Figure 2.7 mirrors the probes at 15-30 and 0-30 fairly closely for most of the season. Another example of this inconsistency between probes can be seen by comparing Figures 2.5 and 2.6 which were both exposed to the same irrigation regime throughout the season, but gave quite different soil moisture profiles. In this case, the 0-15 cm probe consistently showed moisture levels intermediate between the 15-30 and 0-30 cm probes, and the three probes diverged widely.

What the data from the four banks of probes does suggest, is that if the TDR is to be used to assist in irrigation scheduling for strawberries irrigated with drip, more work needs to be done to identify the best place to site them in the root zone and that the chosen site must always have the same spatial relationship to drippers and plants and be representative of the whole crop. The other important factors are that a bank of probes in close proximity as we had here is a much better way to interpret trends rather than relying on a single probe at one depth, and there should be more than one monitoring station in a crop in each irrigation shift.

Field days, reports and extension

Three field days were held at the site during the 2006 season (11 August, 6 October and 1 December). Those in August and December were scheduled for late afternoon. The October field day (all day) was held in conjunction with a Strawberries Australia meeting and a presentation by marketing expert Grant Vinning in the morning. PowerPoint presentations on the project and progressive results were given on each occasion. The presentations are available together with any field day notes that were handed out to growers.

Two milestone reports on the project were completed and submitted to Horticulture Australia during 2006/07 as well as a report to the voluntary contributor, The WA Agricultural Produce Commission. A story on the project was published in the Nov/Dec issue of ‘Wild about Strawberries’ newsletter.

2.4 Discussion and Conclusions

This year's work confirms that yields approaching 1500 grams per plant are not only achievable but repeatable between seasons. Yields under the high tunnels were equally good but at this stage do not justify the additional cost of the tunnels. However, this year was exceptionally dry. A different year with more inclement, wet weather may yield different results.

Some of the benefits of green leaf plantings were not so evident this year, as in 2005. Last year the early start provided additional yield but not so this year. The main benefit was more even crop production over the whole season that would enable growers to have fruit available during periods of high prices.

Whilst some varieties can have high early yields, this alone does not always produce a better result for the whole season.

The new variety from California, Ventana again showed that it has high yield potential, at least as good or better than Camarosa, and this can be achieved from conventional runners planted in early May with medium or high fertiliser rates. The downside of Ventana has been it's relatively poor flavour and a poor shelf life when shipped long distances in other commercial trials in WA. Camino Real and Gaviota were not as early as Ventana and Camarosa and they both yielded about 20% less.

This year's data has helped clarify both nutrition and irrigation of this crop. We are now certain that last year, the irrigation application rates were much lower than we'd intended. This better explains some of the responses – such as that where high fertiliser and medium irrigation seemed to have an adverse effect. The osmotic effect of high fertiliser with inadequate irrigation now seems the most likely reason.

This year's medium irrigation rate is equivalent to last year's high rate, with the high rate being 50 per cent above that again. So the fact that yields for both M/M and H/H are so similar now indicates that some of the extra fertiliser in the H/H treatment may have been leached or is not needed by the crop. This is not backed up by the lysimeter data because, nitrate leaching for the sole H/H treatment was actually marginally less than for the M/M regimes.

It is also evident that we need better data on nitrate leaching. The question of catchment area for the lysimeters needs resolving. Without better data we will be unable to quantify the percentage of applied nitrogen that is being leached through the profile.

It is apparent from some ad hoc investigation with a moisture probe, that the soil moisture levels within the beds are quite uneven. This needs to be quantified since without improving efficiencies in irrigation uniformity, it will not be possible to also maximise fertiliser and water use efficiency.

In conclusion, yields approaching 1500 grams per plant are achievable with both Ventana and Camarosa using as little as 2 kg/ha/day of N and associated other nutrients, with good irrigation management. Further efficiency gains are still possible.

2.5 Appendix

Water supplied (measured by water meters) (L) during the 2006 season for each irrigation block (9 beds) and estimated total use per hectare of plastic surface (67 beds).

Week No.	Week ending	Water meter number (irrigation regime)							
		1	**1 (new)**	**2**	**3**	**3(new)**	**4**	**4(new)**	**5**
0	2-May	1812011		4035110	3189022		3773437		2888070
1	8-May	1825272		4048266	3202039		3785766		2901342
2	15-May	1835930		4058602	3212562		3796071		2911891
3	22-May	1845986		4068815	3223014		3806194		2922631
4	29-May	1854946		4077901	3232206		3815268		2931970
5	5-Jun	1864549		4087560	3241964		3824708		2941871
6	12-Jun	1873983		4097126	3251649		3834313		2951723
7	19-Jun	1881533		4104538	3258528		3841830		2959033
8	26-Jun			no reading					
9	3-Jul	1 900 940		4 123 859	3 278 641		3 862 119		2 980 103
10	10-Jul	1 913 430		4 135 887	3 290 545		3 874 072		2 992 533
11	17-Jul	1 923 089		4 143 978	3 298 648		3 883 081		3 001 102
12	24-Jul	1 930 888		4 152 168	3 306 808		3 893 988		3 009 448
13	27-Jul	1 937 957	0	4 158 671	3 313 233	0	3 901 818	0	3 016 193
14	7-Aug	1 945 843	7 811	4 166 759	3 321 105	7 854	3 913 024	11 000	3 024 399
15	14-Aug	1 954 646	16 556	4 175 228	3 329 457	16 202	3 925 271	23 263	3 033 136
16	21-Aug	1 965 867	27 638	4 185 033	3 339 126	25 845	3 939 017	37 095	3 043 269
17	28-Aug	1 978 606	40 225	4 196 116	3 350 133	36 820	3 954 078	52 255	3 054 678
18	4-Sep	1 992 620	54 120	4 208 146	3 361 971	48 550	3 970 463	68 720	3 067 121
19	11-Sep	2 006 551	67 970	4 222 455	3 376 914	63 350	3 989 695	88 050	3 081 919
20	18-Sep	2 020 924	82 240	4 236 859	3 391 108	77 370	4 008 576	107 050	3 096 857
21	25-Sep	2 037 559	98 775	4 253 894	3 407 798	93 835	4 030 773	129 390	3 114 486
22	2-Oct	2 056 363	117 445	4 273 311	3 427 095	112 775	4 056 477	155 255	3 134 537
23	9-Oct	2 081 457	142 315	4 299 346	3 450 780	139 095	4 090 388	189 375	3 162 364
24	16-Oct	2 105 589	165 125	4 323 351	3 477 341	162 275	4 122 347	221 585	3 187 264
25	23-Oct	2 136 267	196 215	4 356 168	3 508 859	193 195	4 165 594	265 415	3 221 505
26	30-Oct	2 168 128	227 385	4 389 136	3 540 804	224 575	4 208 901	309 355	3 256 137
27	6-Nov	2 204 430	263 021	4 426 688	3 576 602	259 615	4 257 984	359 133	3 295 232
28	13-Nov								
29	20-Nov	2 268 260	325 110	4 491 778	3 638 795	320 225	4 344 200	447 445	3 363 300
Total to 27 July		456 249		456 668	449 773		570 763		475 230
Total after 27 Jul		330 303	325 110	333 107	325562	320 225	442 382	447 445	347 107
mm irrigation for season		**608.3**		**608.9**	**599.7**		**761.0**		**633.6**

3. Year 3 Annual Report (2007/08)

3.1 Introduction

This is the last of three annual reports for the Horticulture Australia project BS05001 – 'Facilitating the development of the strawberry industry in Western Australia'. The project was an initiative of the Strawberry Growers Association of WA Inc. and this field demonstration site was managed by the industry's development officer, Gerry Verheyen in collaboration with the Department of Agriculture and Food WA (DAFWA). The project has been funded by voluntary contributions from the W.A. Strawberry Producers Committee, Toolangi Strawberry Runner Growers Co-operative and DAFWA with matching funding from Horticulture Australia Ltd (HAL). The project has been funded for three years, 2005, 2006 and 2007. This report is for work done in the third year of the project.

For the second consecutive year, one block of strawberries (19 beds – 24,000 plants) was grown under high tunnels (Haygrove™) covered with clear diffusing plastic (luminence B), representative of the type used extensively in Spain and the United Kingdom, while the remaining crop was grown under low cloches covered with clear polythene in the early part of the season. Results from the work done in years 1 and 2 of the project showed a clear yield and quality benefit from row covers so no uncovered plots were grown this year.

This year we aimed to further improve the efficiency of the irrigation and fertiliser regimes that were tested in years 1 and 2 of the project. Results from previous years suggested that nutrient leaching was a problem that needed further improvement. It was also clear that soil moisture content within the bed was far from uniform. It is commonly believed that the roots of plants grown with drip irrigation selectively establish themselves in moist soil around drippers. However, we had no real proof of this and it was felt that the poor lateral spread of water we had observed in these sandy soils created considerable potential for nutrient laden water to pass beyond the root zone. We decided to trial two methods by which irrigation uniformity might be improved. These included increasing the frequency of irrigation with the conventional dripper spacing and output rate and secondly increasing the number of point sources of water (by using a 10 cm drip spacing to compare with the conventional 25 cm spacing).

The effects of these irrigation regimes on the soil were continuously measured at four monitoring stations in the field. Each station consisted of four TDR probes coupled to a data logger and a phone modem for automatic downloading of soil moisture data.

In combination with this we trialled three rates of fertiliser injected into the drip irrigation lines at every irrigation. The fertiliser solution used was a mixed N, P, K, Ca, Mg formulation that was injected for different lengths of time each day to supply nitrogen at 1.5, 2.0 or 3.0 kg per hectare per day together with the other nutrients in a fixed ratio. Not all treatment combinations were used, the emphasis was on matching fertiliser rates with irrigation with the aim of reducing inputs of both compared to rates that had been used in previous years.

Lysimeters were again installed under selected beds and used to monitor the volume of water and total quantity of nitrate leached. This data was complemented by weekly recording of water supplied through water meters fitted to the drip lines.

A range of new and established named varieties as well as numbered new selections were compared in the demonstration blocks. Times of planting and runner type (conventional and green leaf) were also included.

All fruit grown at this demonstration site was packed and marketed to ensure it met commercial standards. Prices obtained during the season were used to superimpose economic data onto the trial results. Marketing allowed for a more commercially meaningful interpretation of yield results because higher yields may not always benefit the grower if they occur at times of low prices.

Three field days were held on a monthly basis during the harvest season from August to November at the Wanneroo site to show growers how the various new methods and varieties performed over time.

3.2 Method

Layout

The demonstration block consisted of 45 planted beds, each 125 m long. Each bed was 1.2 m wide with 30 cm wheel tracks between each bed. The beds were covered with black plastic. Four rows of plants were planted on each bed spaced at 30 cm between rows. Two lines of Netafim™ inline drip (25 cm spacing, dripper output 0.98 L/hour) irrigation were buried below the plastic, between the outer and inner rows of plants, i.e. there was no drip line between the inner two rows of plants. This was the case for 35 of the 45 planted beds, while the remaining 10 beds had TTape ™ dripline (10 cm spacing, dripper output 0.75 l/hour) laid in the same way. The spacing between plants within rows was 38 cm for all varieties.

The area was divided into three irrigation blocks of 7-9 beds each and two of five beds for the 10 cm drippers. A water meter was installed at the inlet end of one drip line in each of the five blocks. Each irrigation block had a different combination of irrigation and fertiliser rate (fertigation treatment) applied to the whole block of nine or ten beds.

Soil preparation

The soil was fumigated with Telone C-35® at 350 kg/ha prior to planting. No lime, trace elements or other base dressings were applied.

Pest and disease control

Predators were introduced into the crop for two spotted mite control. Applications of fungicide for powdery mildew and Botrytis, and pesticides for mites and caterpillars were also applied as required throughout the season.

Lysimeters

Six round PVC lysimeters (29 cm internal diameter) of the type used at this site in 2005 and 2006 were buried below the crop (Figure 1). A lysimeter was placed in each of the rows 5,6, 15, 26, 35 and 46 soon after the plastic was laid. Each was positioned such that the centre of the lysimeter was directly located under a dripper outlet. The top of each lysimeter was approximately 40 cm below the soil surface. Soil removed in order to bury the lysimeters was replaced in the reverse order to maintain the soil profile as much as possible. The soil was watered in for compaction at the time of installation.

Each lysimeter was pumped out weekly from 3 May and leachate volumes recorded. Samples were retained for nitrate analysis. These were analysed using an RQflex® reflectometer and Merckoquant® test strips.

Field plan

The demonstration block compared combinations of variety, planting date, row covers, irrigation and fertiliser regimes. Principally, there were three main varieties, two planting dates, two row covering methods (high tunnels and conventional cloches) and two fertigation schedules compared in the majority of the beds, while a small number of beds were set aside for other work such as Australian breeding line evaluation and ‘plug plant’ trials. All possible combinations of these variables could not be compared with only 47 beds available, so some treatment combinations that were unlikely to be successful were excluded. The range of fertigation options that could be compared for example was limited by the minimum size of a fertigation block being 9-10 beds. Replication of the treatments was considered to be of limited value because of the large plot size (1250 plants each) which allowed for a meaningful estimate of commercial yields to be made with a high degree of confidence, given the uniformity of the site.

The whole planting consisted of either high tunnels or conventional cloches (17 and 28 beds respectively). Within the high tunnels, four irrigation/fertiliser regimes were tested, and apart from a few small plots planted in May, the remaining beds were either greenleaf plantings (10 April) or conventional (leaves off) plantings.

Under the conventional cloches there was a similar pattern except the beds were split between H/H, M/M and M/L irrigation and fertiliser regimes (described later). Table 3.1 details the full list of treatments and figure 3.1 is a schematic representation.

Table 3.1. Treatments compared at the Wanneroo demonstration site, gl = green leaf runners; c = conventional runners

Bed no.	Planting date	Variety	Irrigation rate, frequency and fertiliser rate	Dripper spacing	Covers	Runner source, other treatments and equipment locations
1*						Tunnel legs
2	10-Apr	Camino Real	M1M	25 cm	High tunnel	Green leaf (gl)
3	10-Apr	Camarosa	M1M	25 cm	High tunnel	Green leaf (gl)
4	10-Apr	Albion	M1M	25 cm	High tunnel	Green leaf (gl)
5	25-Apr	Albion	M1M	25 cm	High tunnel	Conventional
6	10-Apr	Albion	H1H	25 cm	High tunnel	Green leaf (gl)-bags
7	10-Apr	Camino Real	H1H	25 cm	High tunnel	Green leaf (gl)
8	10-Apr	Camarosa	H1H	25 cm	High tunnel	Green leaf (gl)
9	10-Apr	Albion	H1H	25 cm	High tunnel	Green leaf (gl)
10	25-Apr	Albion	H1H	25 cm	High tunnel	Conventional (c)
11						Tunnel legs
12	10-Apr	Camino Real	M2M	25 cm	High tunnel	Green leaf (gl)
13	10-Apr	Camarosa	M2M	25 cm	High tunnel	Green leaf (gl)
14	10-Apr	Albion	M2M	25 cm	High tunnel	Green leaf (gl)
15	25-Apr	Albion	M2M	25 cm	High tunnel	Conventional (c)
16						Tunnel legs
17	10-Apr	Camino Real	M2L	25 cm	High tunnel	Green leaf (gl)
18	10-Apr	Camarosa	M2L	25 cm	High tunnel	Green leaf (gl)
19	10-Apr	Albion	M2L	25 cm	High tunnel	Green leaf (gl)
20	25-Apr	Albion	M2L	25 cm	High tunnel	Conventional (c)
21*						
22	25-Apr	Albion	M2L	25 cm	Low tunnel	Conventional (c)
23	25-Apr	Camino Real	M2L	25 cm	Low tunnel	Conventional (c)
24	25-Apr	Camarosa	M2L	25 cm	Low tunnel	Conventional (c) Lysimeter 4, Water meter 4
25	10-Apr	Camarosa	M2L	25 cm	Low tunnel	Green leaf (gl)
26	10-Apr	Camarosa	M2M	25 cm	Low tunnel	Green leaf (gl)
27	25-Apr	Camino Real	M2M	25 cm	Low tunnel	Conventional (c)
28	25-Apr	Camarosa	M2M	25 cm	Low tunnel	Conventional (c) Lysimeter 3 Water meter 3 TDR 1
29	25-Apr	Albion	M2M	25 cm	Low tunnel	Conventional (c)

Table 3.1. Continued

Bed no.	Planting date	Variety	Irrigation rate, frequency and fertiliser rate	Dripper spacing	Covers	Runner source, other treatments and equipment locations
30		Camarosa, Camino Real, Albion	M2M + H1H	25 cm	Low tunnel	Conventional (c) No fumigation
31	25-Apr	Albion	H1H	25 cm	Low tunnel	Conventional (c)
32	25-Apr	Camino Real	H1H	25 cm	Low tunnel	Conventional (c)
33	25-Apr	Camarosa	H1H	25 cm	Low tunnel	Conventional (c) Lysimeter 2 Water meter 2 TDR 2
34	10-Apr	Camarosa	H1H	25 cm	Low tunnel	Green leaf (gl)
35	10-Apr	Camarosa	M1M	25 cm	Low tunnel	Green leaf (gl)
36	25-Apr	Camino Real	M1M	25 cm	Low tunnel	Conventional (c)
37	25-Apr	Camarosa	M1M	25 cm	Low tunnel	Conventional (c) Lysimeter 1 Water meter 1 TDR 3
38	25-Apr	Albion	M1M	25 cm	Low tunnel	Conventional (c)
39	25-Apr	Breeding lines	M1M	25 cm	Low tunnel	Conventional (c)
40	25-Apr	Camarosa	M1M	10 cm	Low tunnel	Conventional (c)
41	25-Apr	Albion	M1M	10 cm	Low tunnel	Conventional (c)
42	25-Apr	Camarosa	M1M	10 cm	Low tunnel	Conventional (c) Lysimeter 5 Water meter 5 TDR 4
43	25-Apr	Camino Real	M1M	10 cm	Low tunnel	Conventional (c)
44	25-Apr	Camarosa	M1M	10 cm	Low tunnel	Conventional (c)
45		Breeding lines	M1L	10 cm	Low tunnel	Conventional (c)
46	25-Apr	Albion	M1L	10 cm	Low tunnel	Conventional (c)
47	25-Apr	Camarosa	M1L	10 cm	Low tunnel	Conventional (c) Lysimeter 6 Water meter
48	25-Apr	Camino Real	M1L	10 cm	Low tunnel	Conventional (c)
49	25-Apr	Camarosa	M1L	10 cm	Low tunnel	Conventional (c)

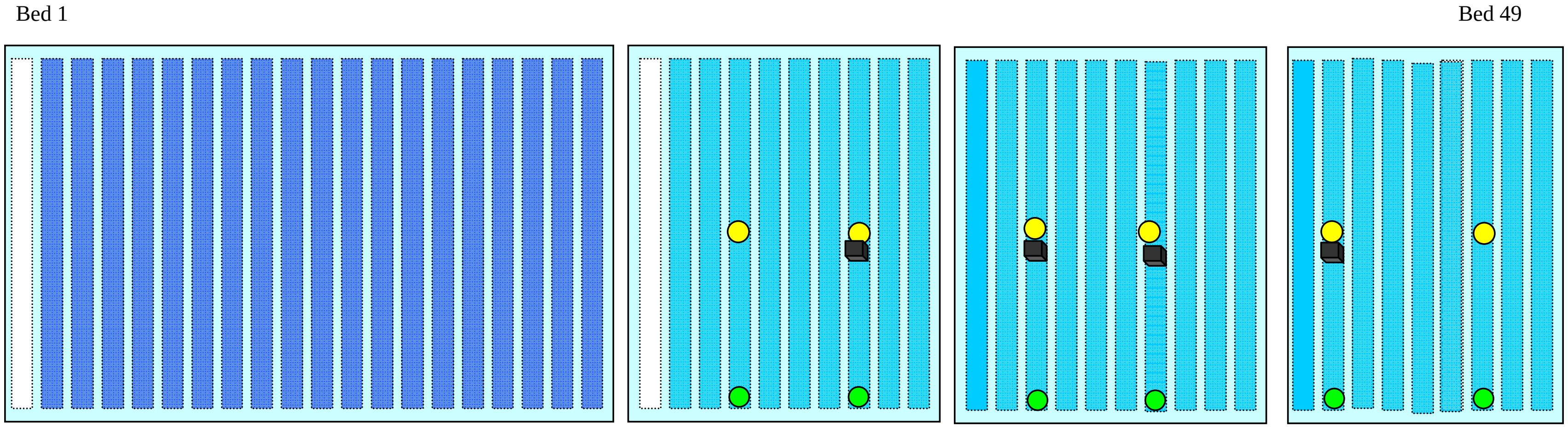
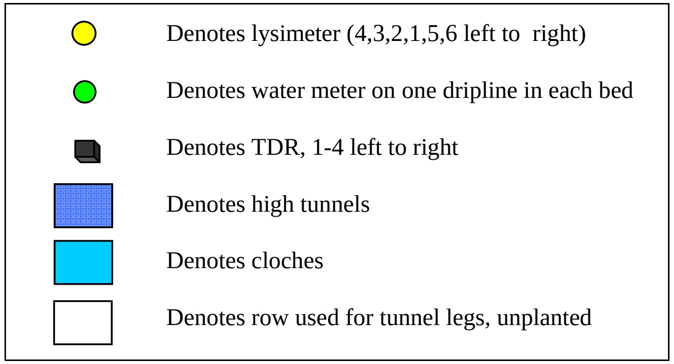


Figure 3.1 A schematic drawing of all 49 beds with lysimeter, water meter and TDR placements marked.



Irrigation

The irrigation regime was based on long term evaporation replacement adjusted with a crop factor according to growth stage. Two rates of irrigation, High (H) and Medium (M) were combined with two frequencies over the course of the season. The medium regime was the method developed in replicated field research at Medina Research Station from 2001 – 2002.

Rates

High regime (H): A crop factor commencing in June and July at 75 per cent and rising at approximately 15 per cent each month until November (175 per cent).

Medium regime (M): A crop factor commencing in June and July at 50 per cent and rising at approximately 10 per cent each month until November (117 per cent).

Table 3.2 Irrigation schedule for 2007/08

Date	Irrigation rate	Long term average daily evaporation data (Medina 30 years)	Planned crop factor (%)	Planned daily irrigation (mm)	Planned daily irrigation time (minutes) 25 cm drippers	Planned frequency 1 (start times x minutes)	Planned frequency 2 (start times x minutes)	Planned daily irrigation time (minutes) 10 cm drippers (Frequency 1 only)
01 Apr	High*	4.1	100	4.1	41	2 x 20	3 x 13	
	Medium	4.1	100	4.1	41	2 x 20	3 x 13	20
01 May	High*	2.7	100	2.7	27	2 x 14	3 x 9	
	Medium	2.7	100	2.7	18	2 x 9	3 x 6	9
15 May	High*	2.4	90	2.4	24	2 x 12	3 x 8	
	Medium	2.4	60	1.6	16	2 x 8	3 x 5	8
01 Jun	High*	1.7	75	1.4	14	1 x 14	1 x 14	
	Medium	1.7	50	0.9	9	1 x 9	1 x 9	4
01 Jul	High*	1.7	75	1.4	14	1 x 14	1 x 14	
	Medium	1.7	50	0.9	9	1 x 9	1 x 9	4
01 Aug	High	2.2	90	2.1	21	1 x 21	2 x 11	
	Medium	2.2	60	1.4	14	1 x 14	2 x 7	7
15 Aug	High	2.6	90	2.4	24	1 x 24	2 x 12	
	Medium	2.6	60	1.6	16	1 x 16	2 x 8	8
01 Sep	High	3.0	105	3.2	32	1 x 32	2 x 16	
	Medium	3.0	70	2.2	22	1 x 22	2 x 11	11
15 Sep	High	4.0	105	4.2	42	2 x 21	4 x 10	
	Medium	4.0	70	2.9	29	2 x 15	4 x 7	14
01 Oct	High	4.4	125	5.5	55	2 x 27	4 x 14	
	Medium	4.4	85-+-	3.7	37	2 x 19	4 x 9	18
15 Oct	High	5.0	140	6.9	69	2 x 35	4 x 17	
	Medium	5.0	95	4.8	48	2 x 24	4 x 12	23
01 Nov	High	6.1	157	9.6	96	3 x 32	6 x 16	
	Medium	6.1	105	6.4	64	3 x 21	6 x 10	31
15 Nov	High	7.0	175	12.2	122	3 x 41	6 x 20	
	Medium	7.0	117	8.2	82	3 x 27	6 x 13	39

Frequencies of irrigation

Two irrigation frequencies were compared in combination with the two rates outlined above using drippers spaced at 25 cm. The plan was to irrigate once daily in June and July to apply fertigation. Commencing in August, a daily irrigation frequency was compared to twice daily application. The frequencies of irrigation rose progressively as the season progressed as shown in Table 3.2

Only the single frequency of irrigation could be applied with drippers spaced at 10 cm because the output rate of this drip tape was too high to allow double frequency irrigation at some times of year.

Table 3.3. Fertigation schedule for 2007/08

Date	Irrigation rate	Planned daily irrigation time (minutes) 25 cm drippers	Planned daily fertigation time (minutes) 25 cm drippers	Planned daily irrigation time (minutes) 10 cm drippers	Planned daily fertigation time (minutes) 10 cm drippers
01 Apr	**High***	41	16		
	Medium	41	10	20	5
01 May	**High***	27	16		
	Medium	18	10	9	5
15 May	**High***	24	16		
	Medium	16	10	8	5
01 Jun	**High***	14	13		
	Medium	9	9	4	5
01 Jul	**High***	14	14		
	Medium	9	9	4	5
01 Aug	**High**	21	17		
	Medium	14	11	7	6
15 Aug	**High**	24	17		
	Medium	16	11	8	6
01 Sep	**High**	32	16		
	Medium	22	11	11	6
15 Sep	**High**	42	16		
	Medium	29	11	14	6
01 Oct	**High**	55	17		
	Medium	37	11	18	6
15 Oct	**High**	69	17		
	Medium	48	11	23	6
01 Nov	**High**	96	18		
	Medium	64	12	31	6
15 Nov	**High**	122	18		
	Medium	82	12	39	6

The evaporation figures used in conjunction with these crop factors were 'long term averages' from the Medina Research Station weather station. In June and July, the monthly average was applied throughout the month, but in August and subsequent months, the averages used were for the first two weeks and second two weeks of the month. Irrigation rates were thus adjusted every two weeks from August onwards. These figures were an average over 30 years of recordings. Table 3.3 shows the evaporation data that schedules were based on and the actual crop factors and irrigation times used in each fortnight of the crop's life. The actual figures varied at times, from those planned for a variety of reasons. Sometimes irrigation was with-held or increased due to local weather conditions such as abnormally cold or hot days.

Water meters

Water meters were installed on one line of drip tape in each of the six irrigation blocks.

Fertigation

Plants were fertigated during each irrigation with a stock nutrient solution supplied from two 1000 litre tanks. The total quantities of nutrients supplied from these two tanks were as follows:

Nutrient solution composition (g/L) of the stock solutions:

- Calcium nitrate 50.0
- Magnesium sulphate 24.9
- Mono-ammonium phosphate 12.7
- Potassium nitrate 50.0

All of the calcium nitrate and half of the potassium nitrate was dissolved in Tank A and the other fertilisers were dissolved in Tank B. Each tank had its own injection pump, and the injection rate of stock solution from each tank during the fertigation cycle was 1 litre per minute.

Where multiple daily irrigations were applied during the warmer months, the fertigation was applied in the first half of each irrigation. In each irrigation cycle, water and fertiliser were applied in two phases. A typical cycle would start with water only for a number of minutes to fill the lines and then followed by the required time to inject the nutrient solution through the drip lines.

The nutrient solution used in 2007/08 and the control fertiliser treatment (Medium Rate – M) was identical to that used in 2006/07. This treatment was created by injecting the stock solution into the drip lines to supply approximately 2 kg/ha per day of Nitrogen.(N). This program was compared with a 'High Rate – H' schedule which supplied approximately 3 kg/ha per day of N. A 'Low' fertiliser rate supplying 1.5 kg/ha per day (N) was added to the treatment list this year. The reason for this was to try and achieve additional efficiencies in fertiliser use, in particular, by matching this rate with lower rates and higher frequencies of irrigation. The low fertiliser rate was only used in combination with the medium rate of irrigation using the 25 cm drippers, and with the 10 cm drippers (which were only irrigated at the medium rate and frequency 1).

The high rate was achieved in practice by increasing the duration of the fertigation cycle by 50 per cent over the medium rate. For example, if the fertigation time to supply the medium rate was 16 minutes, the high rate would receive 24 minutes of fertigation. Conversely the low rate was achieved by a 25 per cent reduction in fertigation time.

The convention for describing these treatments in this report are in order, Irrigation Rate: Irrigation Frequency and Fertiliser Rate. For example the shorthand representation of the Medium rate of Irrigation combined with Irrigation Frequency 2 and the Medium Rate of Fertiliser is M2M.

Soil moisture monitoring - TDR's

Table 3.4. Treatment locations for each TDR probe

Probe number	Bed number	Variety	Covering	Dripper spacing	Irrigation rate and frequency
1	28	Camarosa	Low tunnel	25 cm	M2
2	33	Camarosa	Low tunnel	25 cm	H1
3	37	Camarosa	Low tunnel	25 cm	M1
4	42	Camarosa	Low tunnel	10 cm	M1

Soil moisture levels in the root zone and below (0-60 cm depth) were monitored for the medium and high irrigation rates in high and low tunnels continuously throughout the growing cycle. These results were used to monitor the effectiveness of the irrigation schedules and to allow timely adjustments to be made to the irrigation plan if the soil became too dry.

The equipment used was a TDR probe coupled to a data logger and modem for remote download to a computer on the farm and at the DAFWA office. Table 3.4 and Figure 3.1 show the locations of each probe. Groups of four sensors (reflectometers) were sited close to a lysimeter at four depths, 0-15 cm (angled 45°) about half way between a dripper and plant, 15-30 cm (angled 45°), 0-30 cm inserted in the soil vertically and 30-60 cm inserted vertically. Three of the loggers also had a continuously recording tensiometer attached at a depth of 15 cm.

The output from this equipment was a table of volumetric soil moisture readings which could be graphed to show a continuous record of soil water content over time. An example output is shown in the results section of this report which follows.

3.3 Results

Tables 3.5 and 3.6 summarize the marketable yields from all beds over the 2007/08 season. Table 3.5 lists total yields for the whole season in descending order while Table 3.6 shows marketable yield until the end of September only.

Table 3.5. Rankings in descending order for total season marketable yield from all treatments used in 2007/08

Variety	Cover	Planting date	Irrigation rate and frequency	Dripper spacing	Nitrogen rate (kg/ha/day)	Full season marketable yield per plant (g)
Camino Real	High	April 10	M2	25 cm	2	1542.0
Camino Real	High	April 10	M2	25 cm	1.5	1475.1
Camino Real	High	April 10	H1	25 cm	3	1407.7
Galexia	Low	May 15	M1	10 cm	1.5	1210.5
Camarosa	Low	April 10	H1	25 cm	3	1209.4
Camarosa	Low	April 25	M1	10 cm	2	1172.7
Camino Real	Low	April 25	M1	10 cm	2	1170.3
Camino Real	High	April 10	M1	25 cm	2	1158.9
Camino Real	Low	April 25	H1	25 cm	3	1157.8
Camarosa	Low	April 25	M1	10 cm	2	1156.2
Camarosa	Low	April 25	H1	25 cm	3	1152.8
Camarosa	High	April 10	M2	25 cm	1.5	1134.3
Camarosa	Low	April 10	M1	25 cm	2	1130.1
Camarosa	Low	April 10	M2	25 cm	2	1113.7
Camarosa	High	April 10	H1	25 cm	3	1110.0
Camino Real	Low	April 25	M1	10 cm	1.5	1099.9
Camarosa	High	April 10	M2	25 cm	2	1095.0
Camarosa	Low	April 25	M1	25 cm	2	1085.0
Camarosa	Low	April 25	M1	10 cm	1.5	1083.2
Camarosa	Low	April 10	M2	25 cm	1.5	1077.6
Camarosa	Low	April 25	M2	25 cm	2	1075.2
Camino Real	Low	April 25	M1	25 cm	2	1073.3
Camino Real	Low	April 25	M2	25 cm	2	1072.4
Camarosa	High	April 10	M1	25 cm	2	1054.2
Camarosa	Low	April 25	M2	25 cm	1.5	1039.6
Albion	High	April 10	M2	25 cm	1.5	1023.8
Camino	Low	April 25	M2	25 cm	1.5	974.4
Albion	High	April 10	H1	25 cm	3	946.6
Albion	High	April 10	M2	25 cm	2	930.5
Treasure (plugs)	Low	May 15	M1	10 cm	1.5	902.3
Camarosa	Low	April 25	M1	10 cm	1.5	887.3
Treasure (b/root)	Low	May 15	M1	10 cm	1.5	807.5
Albion	High	April 10	M1	25 cm	2	785.9
Albion	High	April 25	M2	25 cm	2	781.3
Albion	High	April 25	M2	25 cm	1.5	780.4
Albion	High	April 25	H1	25 cm	3	767.0
Albion	Low	April 25	M1	10 cm	1.5	764.6

Table 3.5. Continued

Variety	Cover	Planting date	Irrigation rate and frequency	Dripper spacing	Nitrogen rate (kg/ha/day)	Full season marketable yield per plant (g)
Albion	Low	April 25	M1	10 cm	2	754.9
Albion	Low	April 25	M2	25 cm	2	687.7
Albion	High	April 25	M1	25 cm	2	662.7
Albion	Low	April 25	M2	25 cm	1.5	631.8
Albion	Low	April 25	M1	25 cm	2	625.8
Albion	Low	April 25	H1	25 cm	3	599.2
Camarosa	Low	April 25	M1	10 cm	2	573.3
Albion	High	April 10	H1	25 cm	3	372.6

Camino Real under the high tunnels outperformed Camarosa this year and despite high yields did not appear to require high rates of nitrogen or irrigation. Camarosa under low tunnels was the next best performer, not doing as well in 2007 as in previous years. Galexia, another new variety also yielded well despite being planted relatively late on May 15.

When early yield (until the end of September) was considered, Camarosa improved its position relative to Camino Real. High tunnels also gave better early yield. The new variety Treasure also cropped well early in the season but again these were not full beds of that variety.

Albion yielded poorly and did not feature in the top ten, or even twenty from either time of planting.

Delivering the take home message at the final field day in the project series.

Table 3.6. Rankings in descending order for early season marketable yield from all treatments used in 2007/08

Variety	Cover	Planting date	Irrigation rate and frequency	Dripper spacing	Nitrogen rate (kg/ha/day)	Early season marketable yield per plant (g)
Camino Real	High	Apr 10	M2	25 cm	1.5	**711.1**
Camino Real	High	Apr 10	M2	25 cm	2	**696.6**
Camarosa	High	Apr 10	H	25 cm	3	**666.4**
Camarosa	High	Apr 10	H	25 cm	3	**632.2**
Camarosa	High	Apr 10	M2	25 cm	1.5	**624.1**
Camarosa	High	Apr 10	M2	25 cm	2	**623.5**
Camarosa	High	Apr 10	M1	25 cm	2	**622.9**
Camarosa	Low	Apr 10	H	25 cm	3	**613.2**
Camarosa	Low	Apr 10	M1	25 cm	2	**570.5**
Camino Real	Low	May 5-15	M1	25 cm	2	**537.0**
Camarosa	High	Apr 10	M1	25 cm	2	**537.0**
Camarosa	Low	Apr 25	M1	10 cm	2	**530.3**
Camino	Low	Apr 10	M2	25 cm	1.5	**507.6**
Camarosa	Low	Apr 25	M1	10 cm	2	**505.7**
Albion	Low	Apr 25	M1	10 cm	1.5	**502.4**
Camarosa	High	Apr 10	H	25 cm	3	**500.2**
Camarosa	Low	Apr 25	M1	25 cm	2	**497.2**
Camarosa	Low	Apr 25	H	25 cm	3	**494.9**
Camino Real	Low	May 5-15	M1	25 cm	2	**484.0**
Albion	Low	Apr 25	M1	10 cm	1.5	**481.0**
Camino Real	High	Apr 10	M2	25 cm	1.5	**476.7**
Camino Real	Low	Apr 25	M1	25 cm	2	**473.3**
Camarosa	Low	Apr 25	H	25 cm	3	**472.4**
Camarosa	Low	Apr 25	M1	10 cm	1.5	**464.0**
Albion	Low	Apr 25	M2	25 cm	1.5	**455.3**
Camarosa	High	Apr 10	M2	25 cm	2	**449.3**
Albion	Low	Apr 25	M2	25 cm	2	**448.4**
Camino Real	High	Apr 10	M1	25 cm	2	**432.8**
Camino Real	Low	Apr 25	M2	25 cm	2	**414.1**
Treasure (b/root)	Low	Apr 25	M2	25 cm	1.5	**412.3**
Galexia	Low	May 5-15	M1	25 cm	2	**358.0**
Albion	Low	May 15	M1	10 cm	1.5	**347.0**
Camarosa	Low	Apr 25	M1	10 cm	1.5	**336.5**
Albion	Low	Apr 25	M1	10 cm	2	**332.5**
Albion	High	Apr 25	M2	25 cm	1.5	**324.6**
Albion	High	Apr 25	M2	25 cm	2	**314.3**
Albion	High	Apr 25	H	25 cm	3	**313.6**
Albion	Low	May 5-15	M1	25 cm	2	**274.0**
Albion	Low	Apr 25	M2	25 cm	2	**270.9**
Albion	High	Apr 25	M1	25 cm	2	**269.8**
Treasure (plugs)	Low	May 5-15	M1	25 cm	2	**269.0**
Albion	Low	May15	M1	10 cm	1.5	**268.0**
Albion	Low	Apr 25	H	25 cm	3	**262.7**
Albion	Low	Apr 25	M2	25 cm	1.5	**218.4**

Table 3.7. Top ten treatments in descending order of gross returns for the 2007/08 season

Variety	Cover	Planting date	Irrigation	Dripper spacing (cm)	Nitrogen rate (kg/ha/day)	Gross return per plant
Camino Real	High	April 10	M2	25	2	$8.40
Camino Real	High	April 10	L2	25	2	$8.05
Camino Real	High	April 10	H1	25	3	$7.69
Camarosa	Low	April 10	H1	25	3	$6.74
Camarosa	High	April 10	L2	25	2	$6.47
Camarosa	High	April 10	H1	25	3	$6.39
Camarosa	Low	April 25	M1	10	2	$6.32
Camarosa	Low	April 10	M1	25	2	$6.29
Camino Real	High	April 10	M1	25	2	$6.27
Camarosa	High	April 10	M2	25	2	$6.26

The four highest yielding varieties were also the four highest in terms of gross returns. The advantage of high tunnels promoting early cropping and thus achieving higher prices, meant Camarosa went from 14th and 11th (ML2 and HH1 respectively) in terms of yield but fifth and sixth highest in terms of dollar return.

Table 3.8. Top ten treatments in descending order of gross returns to the end of September 2007

Variety	Cover	Planting date	Irrigation	Dripper spacing (cm)	Nitrogen rate (kg/ha/day)	Gross return per plant
Camino Real	High	April 10	M2	25	2	$3.97
Camino Real	High	April 10	L2	25	2	$3.90
Camino Real	High	April 10	H1	25	3	$3.74
Camarosa	Low	April 10	H1	25	3	$3.52
Camarosa	High	April 10	L2	25	2	$3.46
Camarosa	High	April 10	H1	25	3	$3.44
Camarosa	Low	April 25	M1	10	2	$3.43
Camarosa	Low	April 10	M1	25	2	$3.42
Camino Real	High	April 10	M1	25	2	$3.19
Camarosa	High	April 10	M2	25	2	$3.04

The advantage of early yields and higher prices means the table for yield and price for the early part of the season are almost identical, the only exception being that the 5th and 7th places swapped. Again, the differences were so small as to be insignificant.

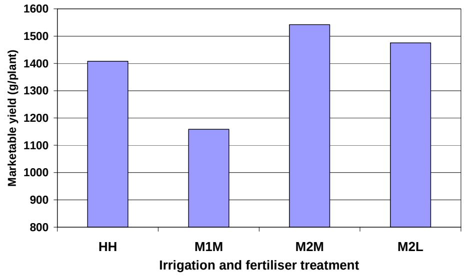


Fig 3a. Comparison of Camino Real planted on 10 April, grown under high tunnels using 25 cm drippers and subjected to various irrigation and fertiliser regimes.

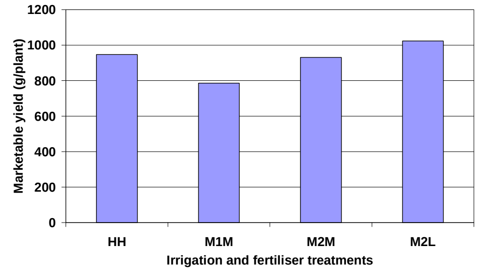


Fig 3b. Comparison of Albion planted on 10 April in high tunnels, using 25 cm drippers and subjected to various irrigation and fertiliser regimes.

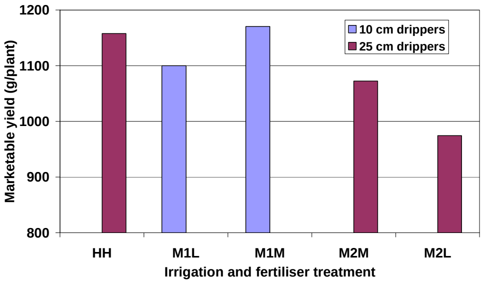


Fig 3c. Comparison of Camino Real planted on 10 April, grown under low tunnels using 10 or 25 cm drippers and subjected to various irrigation and fertiliser regimes.

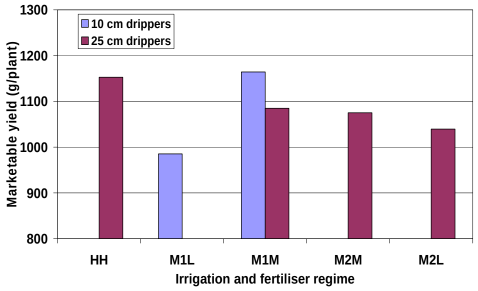


Fig 3d. Comparison of Camarosa planted on 25 April, grown under low tunnels and subjected to various irrigation and fertiliser regimes

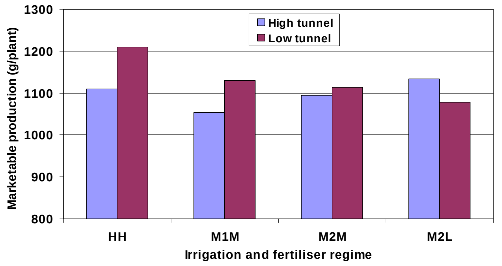


Fig 3e. Comparison of Camarosa planted on 10 April, grown under high and low tunnels using 25 cm drippers and subjected to various irrigation and fertiliser regimes

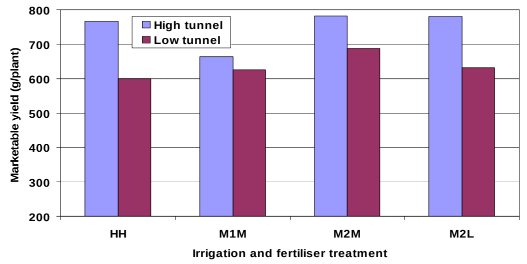


Fig 3f. Comparison of Albion planted on 25 April under low tunnels, using 25 cm drippers and subjected to various irrigation and fertiliser regimes

Figures 3.2a-f Effects of water and fertiliser management.

The best treatment under high tunnels for Camino Real was M2M, closely followed by M2L. This result suggested that the crop benefited from more frequent irrigation than once or twice per day and that 1.5 kg/ha/day of nitrogen was nearly adequate. The result for Albion was similar, but in this case, 1.5 kg/ha/day was adequate. However, Albion yields were 50% lower than Camino Real for the best treatments. The two lower rates of fertiliser were not adequate for Camino Real under low tunnels except the medium rate supplied through 10 cm drippers. This result suggests that rainfall effects on low tunnels may increase fertiliser leaching and reduce crop recovery efficiencies, but these can be partially overcome by delivering water more uniformly under the beds with 10 cm drippers. Albion showed the same response except for relatively lower yields noted with the low rate of fertiliser through 10 cm drippers.

The highest yield overall of Camarosa was obtained using HH irrigation and fertiliser under the low tunnels. Under high tunnels the picture was quite different with the best yields being from the M2L treatment. Overall Camarosa did better under low tunnels than high tunnels, except for the latter treatment. By contrast, Albion and Camino Real were relatively favoured by high tunnels.

Certainly under the high tunnels there was no suggestion that yield was reduced in any of the lower rate irrigation treatments or with reduced rates of fertiliser. This suggests that efficiencies in both irrigation and fertiliser were achieved without loss of yield under high tunnels.

The effect of dripper spacings

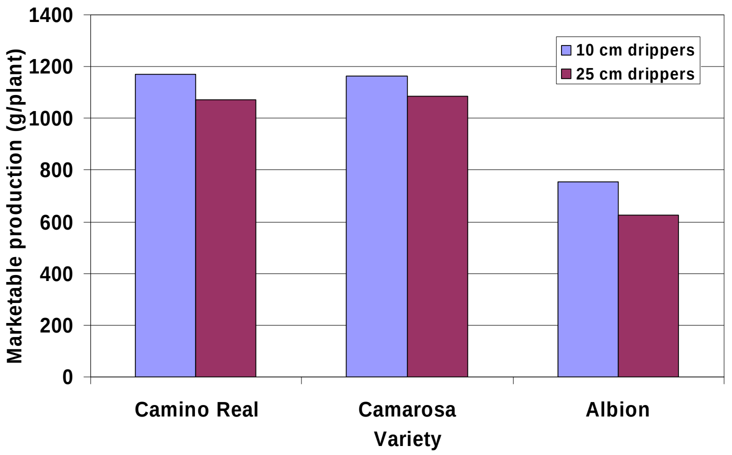


Figure 3.3. Comparative production of Camino Real, Camarosa and Albion planted on 25 April at two dripper spacings with a medium irrigation and fertiliser regime.

For each of the three main varieties used in the trial there seems to be an advantage in using the 10 cm dripper spacing for the medium irrigation and medium fertiliser regime (Figure 3.3). Ten cm drippers were not trialled with the high irrigation regime since the object of the exercise was to improve irrigation efficiencies at lower rates of water use.

Delivering the message on soil moisture monitoring and irrigation scheduling.

Variety performance under high tunnels

Camino Real performed well under high tunnels. Unfortunately we have no direct comparison this year of Camino Real planted on 10 April with green leaf runners under low tunnels.

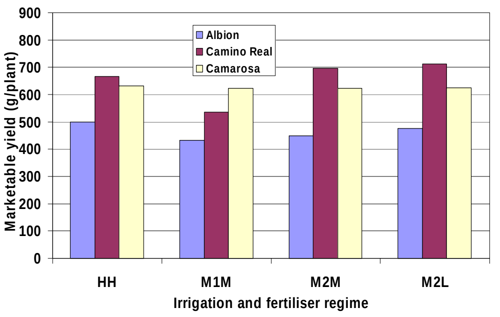


Figure 3.4a. Early yield (end September) comparisons for three strawberry varieties planted on 10 April and grown under high tunnels using 25 cm drippers under various irrigation and fertiliser regimes.

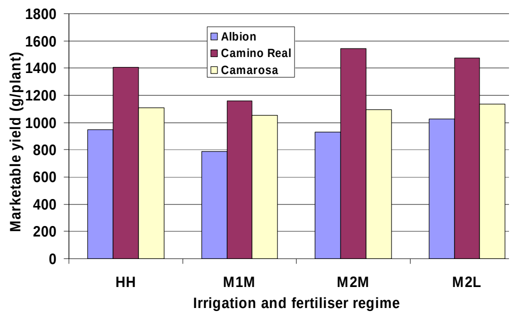


Figure 3.4b. Yield comparisons for three strawberry varieties planted on 10 April and grown under high tunnels using 25 cm drippers under various irrigation and fertiliser regimes.

Variety performance under low tunnels

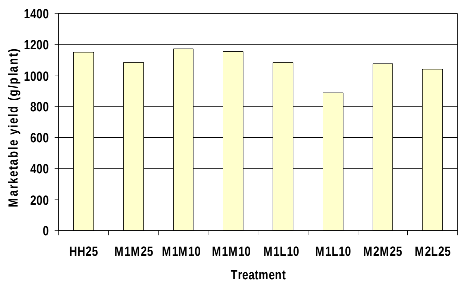


Figure 3.5a. Effect of various irrigation and fertiliser regimes on Camarosa planted on 25 April under low tunnels. Note there were two beds each of M1M10 and MIL10.

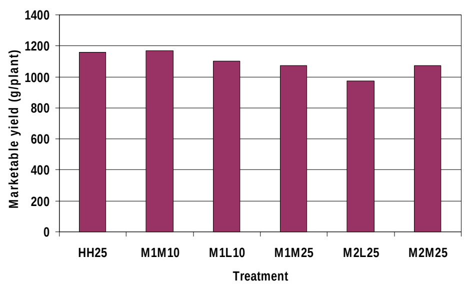


Figure 3.5b. Effect of various irrigation and fertiliser regimes on Camino Real planted on 25 April under low tunnels.

Under low tunnels there is a similar pattern where there does not seem to be any yield disadvantage in using a medium irrigation and fertiliser regime, especially when it is combined with a 10 cm dripper spacing (Figures 3.5a,b). There seems to be no particular advantage in using the higher frequency irrigation regime.

Water meters

Table 3.9 shows a summary of the water supplied to each of the irrigation blocks as measured by water meters installed on each sub-main. The data in the table represents the mean of each irrigation treatment. There was good agreement between both types of meters last year so we are confident that this year's data is an accurate reflection of the water applied.

Table 3.9. Mean daily irrigation (mm) applied to strawberry beds and season total according to water meters for 2007.

Week no.	Week ending	Mean mm applied per day (medium irrigation)	Mean mm applied per day (high irrigation)
1	7-May	2.5	2.9
2	14-May	2.1	2.9
3	21-May	2.2	3.0
4	28-May	2.0	2.8
5	4-Jun	1.7	2.3
6	11-Jun	1.1	1.5
7	18-Jun	1.1	1.5
8	25-Jun	1.2	1.5
9	2-Jul	1.3	1.6
10	9-Jul	1.2	1.6
11	16-Jul	1.1	1.6
12	23-Jul	1.1	1.6
13	30-Jul	1.1	1.6
14	6-Aug	1.4	1.9
15	13-Aug	1.7	2.4
16	20-Aug	1.7	2.4
17	27-Aug	1.8	2.5
18	3-Sep	1.8	2.5
19	10-Sep	2.1	3.3
20	17-Sep	2.1	3.3
21	24-Sep	2.2	3.4
22	1-Oct	3.5	4.4
23	9-Oct	4.3	5.9
24	15-Oct	3.8	5.2
25	22-Oct	4.0	5.5
26	29-Oct	4.2	5.5
27	5-Nov	4.8	6.4
28	12-Nov	6.7	9.7
29	19-Nov	5.6	7.9
30	26 Nov	5.9	8.0
Total mm		**534.8**	**747.6**

The irrigation rates for the medium and high treatments were similar to those in 2006 (616 mm and 765 mm). The average daily irrigation rate for 2007 was 304 mL per plant per day for the medium rate and 425 mL per plant per day for the high rate.

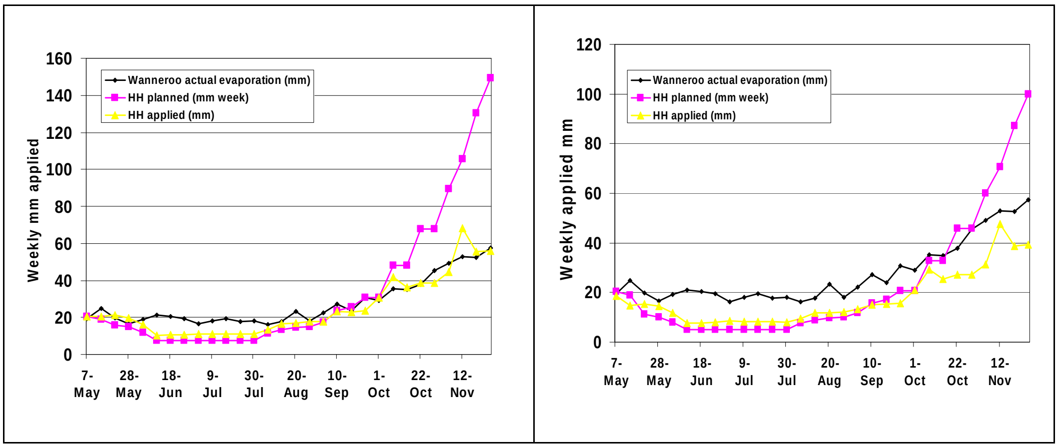


Figure 3.6a,b. Comparison of actual irrigation to planned irrigation rates for high (left) and medium (right) irrigation rates.

Had irrigation been applied to the crops purely as proposed, then total seasonal irrigation in mm would have been 1030 mm for the high rate and 705 mm for the medium rate. However as the above graphs (Figures 3.6a, b) illustrate, particularly towards the end of the season, applied irrigation fell progressively behind that which was planned. This was because our monitoring with the TDR probes was consistently showing that we were overwatering and so irrigation rates were reduced to compensate.

These figures confirm last years data – that strawberries can be grown successfully on only 62% of evaporation as a season average. Our estimates of water use for strawberry crops later in the season can be reduced considerably, from in excess to 100% of evaporation to around 70% provided this is backed up with soil moisture monitoring equipment.

Lysimeters

Total water volumes from the lysimeters this year were again, substantially less than last year, which was in turn, less than the previous year. Table 3.10 outlines rain fall and lysimeter drainage for each month over 2006 and 2007. There seems little correlation for most months, especially given that rainfall in 2007 was substantially greater in all months of the season than 2006. It seems likely that rainfall does not penetrate the beds, instead falling and draining mostly into the wheeltracks between the beds. To what degree it then becomes available to the plants is questionable. Certainly, the TDR graphs do not always show peaks of wetting when rainfall occurs. The other consideration is that, during most of the months in which rainfall does occur, the plants are under cover for much of the time. Graphs to illustrate this point may be found under the section dealing with the TDR's.

It is likely then, that the lysimeters do reflect movement of irrigation water per se, to a much greater degree that we initially thought. In which case we may well be making significant efficiencies in irrigation by using the TDR scans to modify our irrigation scheduling and also by changing to 10 cm drippers.

Table 3.10. Comparison of leachate volumes (total of all lysimeters) and rainfall for 2006 and 2007

Month	2006		2007	
	Rain (mm)	Drainage (L)	Rain (mm)	Drainage (L)
May	21.8	109	49.8	86.6
June	29.4	51	67.8	32.0
July	70.2	59	171.2	15.9
August	104.6	25	115	14.4
Sept	51.4	27	90.4	12.7
Oct	25.6	36	45.8	25.3
Nov	24.2	20	1.8	18.0

Leachate volumes and nitrate for the total trial duration are shown in Table 3.11. Estimates of leaching are still difficult because the zone of influence of drippers at the depth of the lysimeters is not known. We have used the same method as last year to calculate two possible estimates.

Table 3.11. Leachate volumes and nitrate concentrations for 2006 MM plots had 404 kg/ha applied N, HH had 606 kg/ha

Lysimeter no.	Total leachate volume (L) and precipitation equivalent (in brackets mm)	Total nitrogen (g)	Nitrogen (kg/ha)/hectare (drippers)	Nitrogen (kg/ha)/hectare (surface area)
1 (M1M) low tunnel	45.7 (691.9)	3.6	191.9	545.2
2 (H1H) low tunnel	58.8 (889.5)	5.18	276.0	784.2
3 (M2M) low tunnel	29.0 (438.3)	1.31	70.1	199.2
4 (M2L) low tunnel	17.7 (271.0)	1.18	63.1	179.2
5 (M1M – 10cm) low tunnel	29.1 (440.6)	1.98	105.8	300.5
6 (M1L – 10 cm) low tunnel	24.4 (369.7)	1.93	103.2	293.0

As might be expected, the HH regime yielded the highest volume of leachate and the highest quantity of leached nitrogen whilst M2L recorded the lowest volume of leachate and the least amount of nitrate leached. In this case, the combined effect of a lower irrigation rate applied more frequently appeared to result in less leaching.

Lysimeters 5 and 6 were sited below treatments irrigated with 10 cm drippers and they both received the same irrigation rate (M). The volumes of water leached below each were similar, as they were for the volumes collected in lysimeter 3 (M2M) which had the same rate of irrigation. All three of these leached much lower volumes than the same rate of irrigation applied less frequently (lysimeter 1). The conclusion that could be drawn from this is that applying irrigation through 10 cm drippers was equally as effective in reducing leaching as irrigating more frequently with 25 cm drippers.

Soil moisture monitoring

Figures 3.7 – 3.10 show the output for a short period from October to November (the end of the trial) from the installed TDR's.

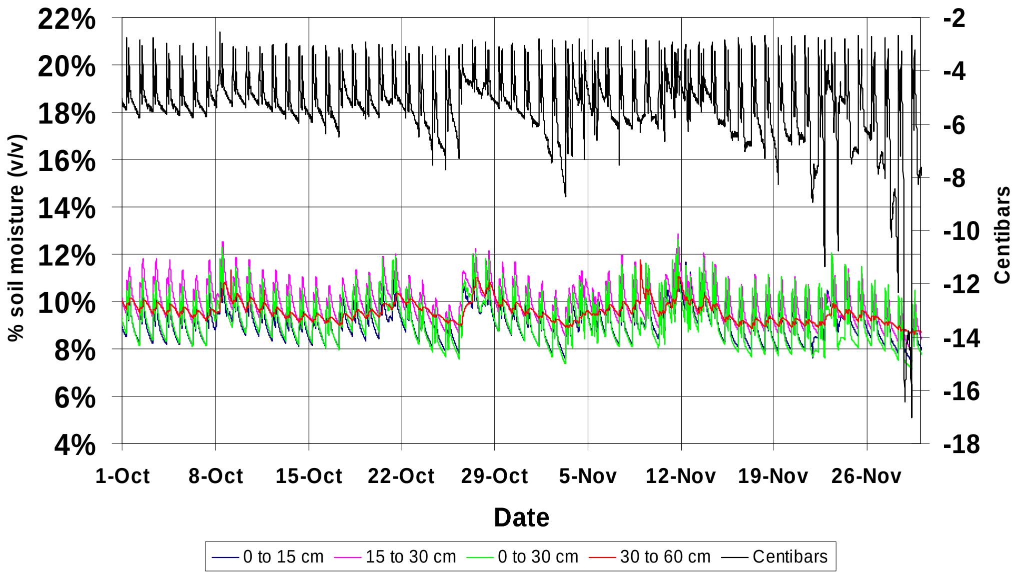


Figure 3.7 Scan for TDR installed under Camarosa in a low tunnel in the M2M irrigation regime using a 25 cm dripper spacing.

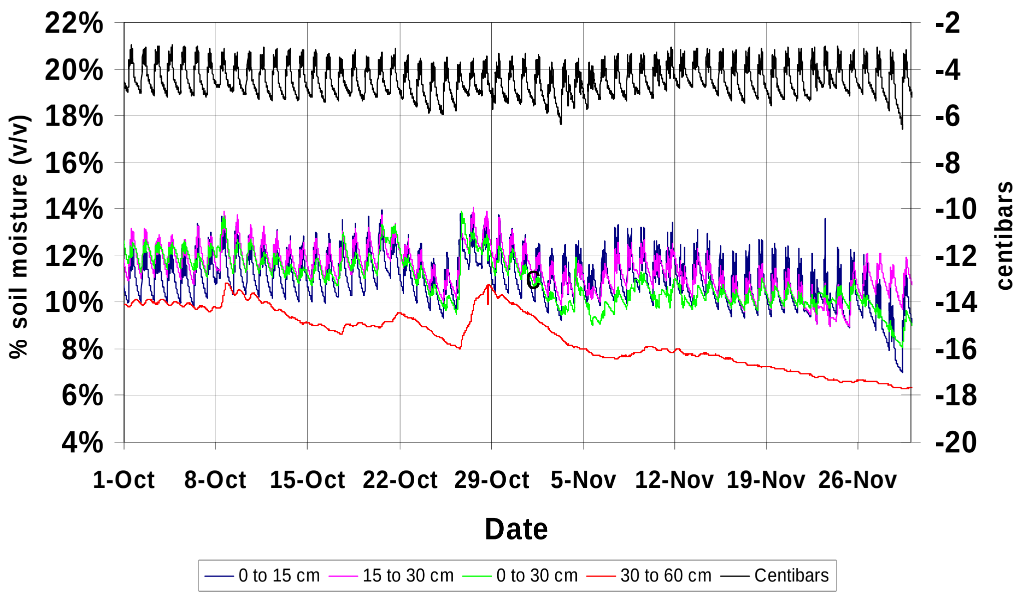


Figure 3.8 Scan for TDR 2 installed under Camarosa in a low tunnel in a H1H irrigation regime and using 25 cm drippers.

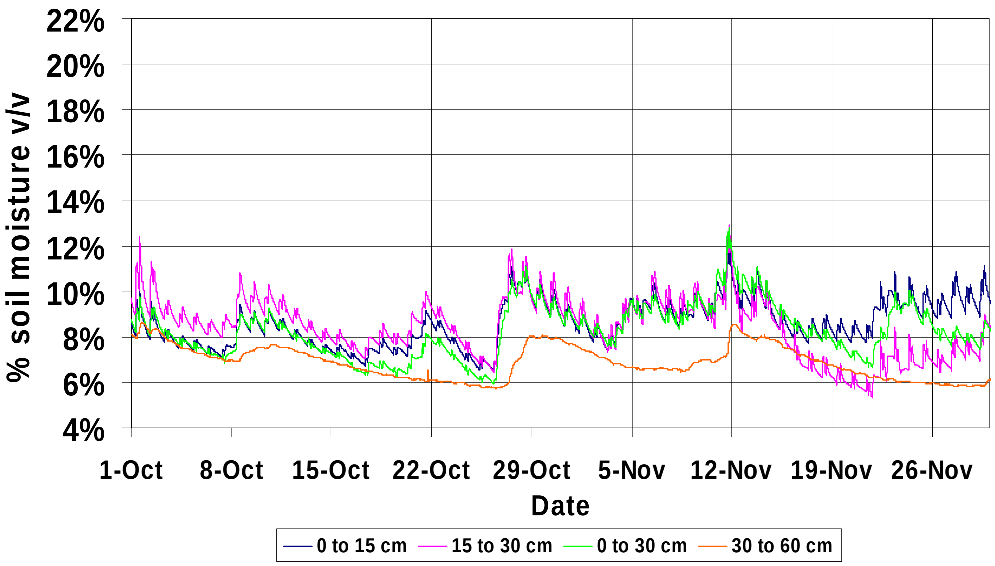


Figure 3.9 Scan for TDR 3 installed under a low tunnel in a M1M irrigation regime and using a 25 cm dripper spacing.

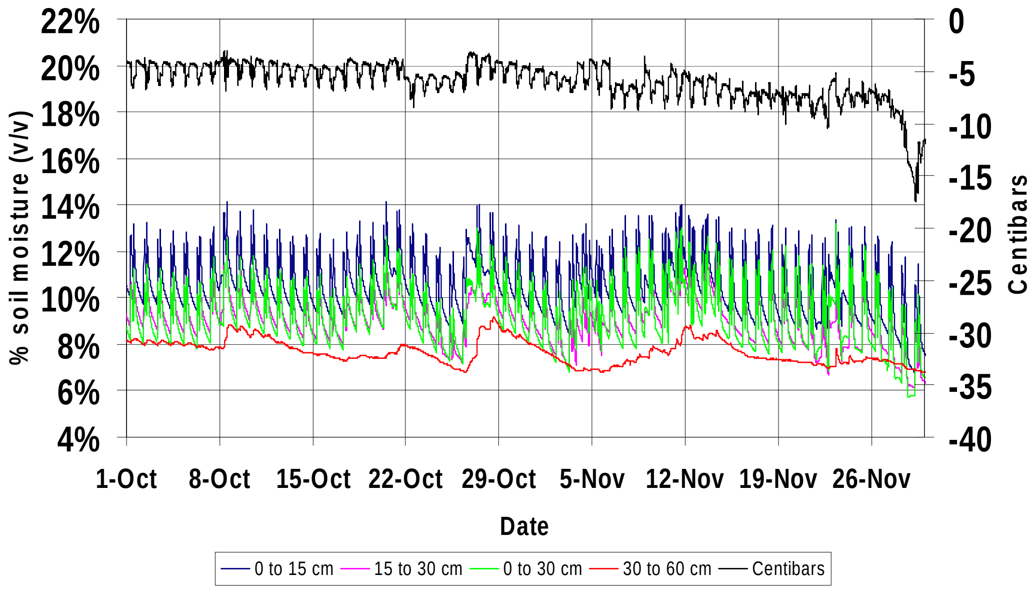


Figure 3.10 Scan for TDR 4 installed under a low tunnel in a H1H irrigation regime using 10 cm dripper spacing.

The soil moisture monitoring data for the October November period for the four irrigation blocks (Figures 3.8-3.11) is presented above. The deep probe (30-60 cm) for the high irrigation treatment (TDR2) can be seen to sit at about 10% moisture content compared to 7-8% for TDR's 3 and 4.

Rainfall does not affect soil moisture to any great degree for much of the year. During the winter spring period, the crop is covered with low cloches for much of the day so any rain falls mostly in the wheeltracks. Contrast Figures 3.10 and 3.11 where a small amount of rain has quite a significant effect on the TDR scan during the late spring period but during winter, much larger falls affect mostly the deeper probes – presumably as soil moisture drains laterally into the beds from the wheeltracks, and have little effect, if any on the shallow probes.

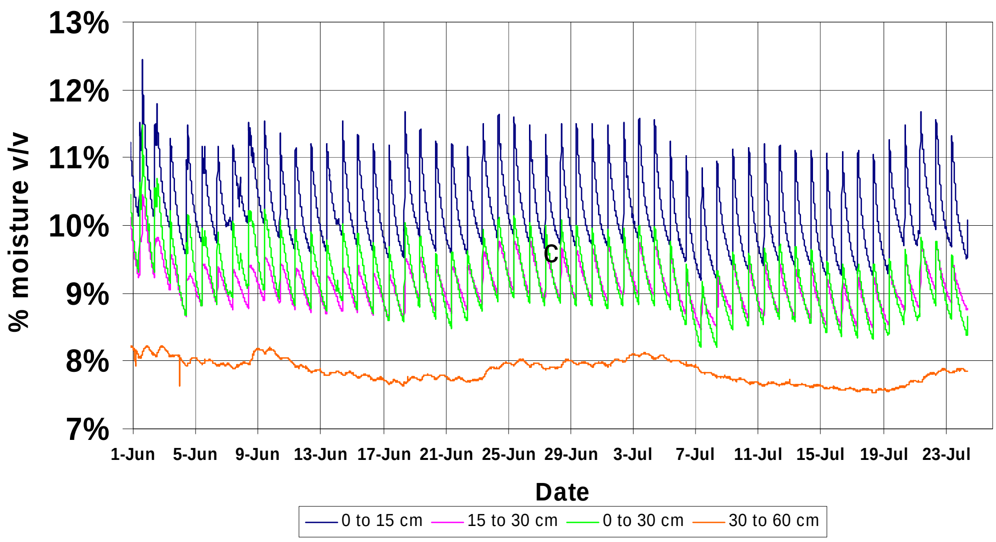


Figure 3.11. Scan for TDR 4 for June July period when covers were over crop for most of the day but reasonably heavy rainfalls occurred.

Soil and air temperatures

Soil and air temperatures were monitored throughout the season. A pair of probes were in each of the open air, low tunnel and high tunnel. Graphs are presented for a 24 hour period on one summer day and one winters day.

Air temperatures

During winter, the traces for both the high and low tunnels were almost identical. Air temperatures were fractionally higher under the high tunnels, where they didn't fall quite as low over night and rose more quickly in the day. They were higher overall than the open air temperatures – peaking at 3-4 degrees higher overnight and decreasing to about 2 degrees difference during the day.

Over summer, the main difference was that open air temperatures peaked earlier and higher during the day. There was little difference in night time temperatures.

Soil temperatures (Figures 3.12a-f)

During winter the traces for both the low and high tunnels were almost identical. Soil temperatures in the open air did not climb as high as those under covers and rose after midnight to be slightly higher by less than one degree for a short time – possibly until the first irrigation.

Over summer, soil temperatures in the high tunnels were higher overall by about three degrees. They rose more quickly in the morning but fell away sooner at night but not to the same degree as those in the low tunnels. Soil temperatures in the open air mirrored those under the low tunnels quite closely.

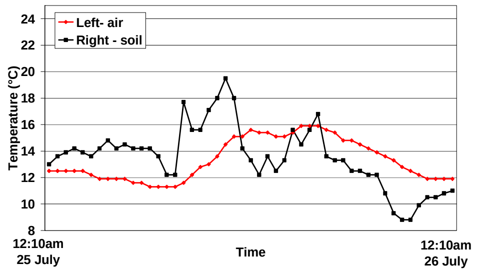


Fig 3.12a. Winter temperatures in the open air for a 24 hours period in July 2008.

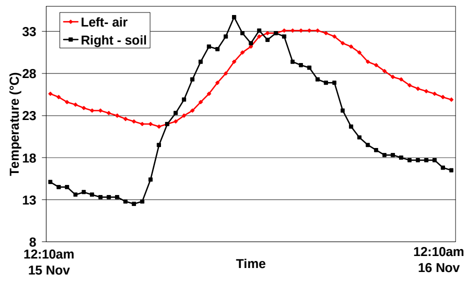


Fig 3.12b. Summer temperatures in the open air for a 24 hours period in November 2008.

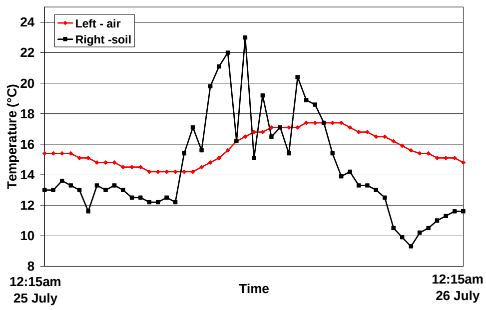


Fig 3.12c. Winter temperatures under low tunnels for a 24 hours period in July 2008.

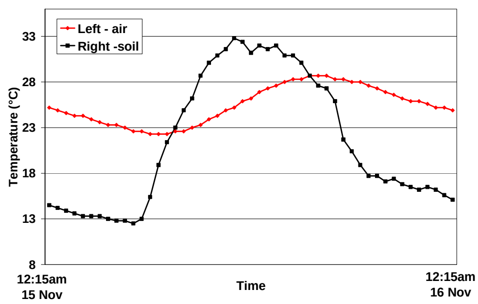
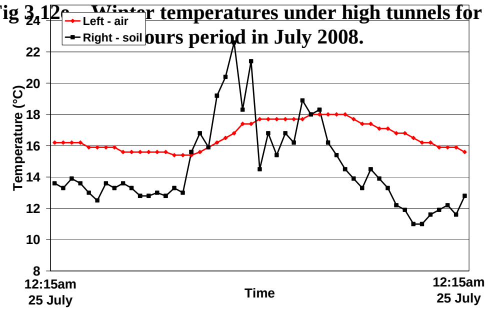


Fig 3.12d. Summer temperatures under low tunnels for a 24 hours period in November 2008.

Fig 3.12e. Winter temperatures under high tunnels for 24 hours period in July 2008.



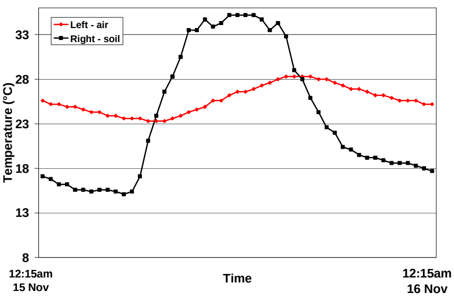


Fig 3.12f. Summer temperatures under high tunnels for a 24 hours period in November 2008.

Field days, Reports and Extension

Three field days were held at the site during the 2007 season (27 July, 7 September and 16 November). As part of the funding agreement with HAL the Victorian industry IDO, Chloe Thomson was an invited speaker at the September field day. Representatives from the Toolangi Co-op were also present on that day, making the trip from Victoria to attend. PowerPoint presentations on the project and progressive results were given at the first two days and a handout presentation was used for the November day. Invitations to all field days were mailed to members of the Strawberry Growers Association each time and on two occasions, the flyer announcing field days were printed in English and Vietnamese. On one occasion, a tasting of new varieties was undertaken with the grower audience.

The presentations are available together with any field day notes that were handed out to growers.

Two milestone reports on the project were completed and submitted to Horticulture Australia during 2007/08 as well as a report to the voluntary contributor, The WA Agricultural Produce Commission.

Scenes from the 2007 field day.

3.4 Discussion and Conclusions

New varieties and covering

Yields from this year's work were similar to those in 2006 and showed that marketable yields of around 1500 grams per plant are achievable. Yields under the high tunnels were as good, if not better than those from covered plots, especially for some varieties such as Camino Real and Albion but at this stage, the yield differences alone are unlikely to justify the additional cost of the high tunnels compared to low tunnels.

Camarosa performed better under low tunnels than high tunnels except where the fertiliser rate was low, suggesting that fertiliser use efficiencies may be better under high tunnels in the absence of rainfall effects.

Galexia showed promise for full season yield, but it's early yield was well behind the other varieties. This variety deserves to be evaluated further at a comparable planting time to Camino Real and Camarosa.

For the 2007 season, high early yields correlated well with better financial returns for the season, and Camino Real was very competitive with Camarosa for this. The new 'day neutral' variety from California, Albion, did not yield well, usually 400 – 500 grams per plant less than Camarosa and Camino Real.

Time of planting

All the highest yielding, most profitable and earliest treatments were planted as 'greenleaf' plants on 10 April and most of the earliest treatments were grown under high tunnels.

Irrigation and nutrition

There were not huge yield differences between many of the irrigation and nutrition treatments for a given variety or covering method. This seems to suggest we are close to the optimum in terms of irrigation and fertigation for this crop within the constraints of the irrigation systems in current use.

As a general rule, more frequent irrigation lifted yields, improved fertiliser use efficiency and reduced leaching with 25 cm drippers. The yield effect was enhanced in high tunnels for Camarosa and Albion, but there was no suitable treatment for comparison of Camino Real under low tunnels at the earliest time of planting.

A similar effect was noted under low tunnels with 10 cm dripper outlets. The magnitude of the yield improvement attributable to the 10 cm spacing was larger than that attributable to more frequent irrigation with 25 cm drippers for both Camarosa and Albion under low tunnels, suggesting that a better soil wetting pattern leads to water and fertiliser efficiencies. The closer spaced drippers had an inconsistent effect on yields for all varieties, with the low rate of nitrogen under low tunnels varying from equal to or less than the medium fertiliser rate with frequent irrigation. This suggests that strawberries grown under low tunnels require a rate of nitrogen around 2.0 kg/ha/day as a minimum. The yield reducing effect of fertiliser rates less than this was not evident for Albion or Camarosa grown in high tunnels, but it did apply to Camino Real.

Water volumes leached under 10 cm drippers were similar to higher frequency irrigation with 25 cm drippers (Camarosa), but the quantity of nitrogen lost from 10 cm drippers was greater. This observation is difficult to explain, but it may be a consequence of unreplicated leachate data.

In conclusion, to maximise yields and minimise nutrient and water leaching, we can now say that our medium rate of both irrigation (65% of evaporation averaged over the season) and fertiliser (2.0 kg/ha N/ha/day) are close to optimal for high yielding strawberry varieties. There is ample evidence that these fertiliser and water efficiencies may be enhanced by irrigating multiple times daily in warm weather with 25 cm dripper outlets, and or irrigating with drippers spaced at 10 cm. The yield enhancement effects from the latter practice may be greater than the former. High tunnels are also associated with fertiliser and water use efficiencies, probably due to the absence of rain. The optimal rate of nitrogen may be closer to 1.5 kg/ha/day under high tunnels for Camarosa, but not Camino Real, which appears to need a higher rate.

3.5 Appendix

Water supplied (measured by water meters) (L) during the 2007 season for each irrigation block (9 beds) and estimated total use per hectare of plastic surface (67 beds)

Week no.	Week ending	Water meter number (irrigation regime)					
		1	2	3	4	5	6
0	1-May	378215	373318	521175	4548664	3697344	4420808
1	7-May	392175	388595	535165	4563228	3709440	4432393
2	14-May	403350	404025	547580	4576220	3718865	4441363
3	21-May	414795	419865	560190	4589661	3728625	4450686
4	28-May	425610	434780	572215	4602156	3737568	4459236
5	4-Jun	434400	446865	581880	4612246	3745422	4466883
6	11-Jun	440075	454610	587485	4618161	3750960	4472197
7	18-Jun	445855	462485	593125	4624148	3756554	4477565
8	25-Jun	451930	470585	599085	4630455	3762615	4483364
9	2-Jul	458335	478795	605474	4637131	3769548	4489935
10	9-Jul	464525	487120	611555	4643544	3775540	4495749
11	16-Jul	470635	495485	617475	4649806	3781466	4501429
12	23-Jul	476735	503845	623385	4656081	3787414	4507119
13	30-Jul	482795	512150	629250	4662339	3793348	4512788
14	6-Aug	489978	522290	636665	4670289	3800412	4519502
15	13-Aug	498810	534710	646083	4680390	3808891	4527506
16	20-Aug	507680	547530	655720	4690752	3817538	4535684
17	27-Aug	516845	560835	665630	4701423	3826388	4544015
18	3-Sep	526930	574085	675635	4712152	3835276	4552416
19	10-Sep	538310	591580	686775	4724180	3846156	4562678
20	17-Sep	549865	608855	697590	4735854	3856679	4572596
21	24-Sep	561635	626500	709335	4748558	3868214	4583449
22	1-Oct	577320	649455	726035	4766758	3888913	4602746
23	9-Oct	599265	680655	749710	4793074	3910071	4622411
24	15-Oct	618405	707945	771940	4817748	3927663	4638707
25	22-Oct	638835	737005	794820	4843118	3946439	4656130
26	29-Oct	659200	766025	817565	4868533	3968329	4676329
27	5-Nov	682675	799435	841945	4895842	3994061	4700138
28	12-Nov	718270	850425	874825	4933428	4030393	4733854
29	19-Nov	747315	892035	904260	4967482	4058030	4759678
30	26-Nov	776820	934015	933910	5002158	4089323	4788597
Total		**398605**	**560697**	**412735**	**453494**	**391979**	**367789**
mm irrigation for season		**531.4733**	**747.596**	**550.313**	**604.6587**	**522.6387**	**490.3853**

Acknowledgments

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