



# Preliminary Investigations into Open Hydroponics Irrigation for the Citrus Industry

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## Introduction

An open hydroponics system aims to increase productivity by high frequency application of irrigation water and nutrients to the soil. Such a system is sometimes also called advanced fertigation.

Conventional fertigation involves adding a balanced amount of nutrient in the irrigation water, approximately once a month. This management system can be intensified by more sophisticated monitoring of water and nutrient use, and increasing the frequency of water and nutrient application. Systems where applications may be daily, or several times a day, are known as open hydroponics. A wide range of intensity of fertigation management has been adopted by irrigators.

Under open hydroponics the root-zone is kept restricted by increasing the number of drippers and using low application rates per tree. The root-zone volume may be only 0.5 m<sup>3</sup> compared to 6-10 m<sup>3</sup> for conventional fertigation. This concentrates the applied nutrients and potentially increases fertilizer use efficiency. Soil moisture content is maintained close to field capacity.

The benefits of open hydroponics may include some or all of the following:

- earlier fruit production from establishing trees;
- higher fruit production from mature trees;
- a higher percentage of fruit suitable for the fresh fruit market (pack-out percentage).

Globally 46,500 ha of permanent horticulture are grown under open hydroponics. In Australia it has been estimated there are a total of 3,800 ha under citrus, avocados, almonds, table and wine grapes, mango, banana, blue berries, olives and stone fruits.

With funding from Horticulture Australia Ltd (HAL), and the former Land and Water Australia (LWA) through the National Program for Sustainable Irrigation (NPSI), the South Australian Research and Development Institute (SARDI) has carried out preliminary investigations. These have included an economic analysis, and some field observations of plantings under conventional fertigation and open hydroponics. The work has been done in collaboration the Corporate Strategy and Policy Branch of Primary Industries SA (PIRSA), and NSW Department of Primary Industries (NSWPDI) officers at Dareton Agricultural Research and Advisory Station.

In assessing any new technology it can be difficult to substantiate assumptions or claims made for the new systems being investigated. In the case of open hydroponics SARDI did not have the background data to rigorously test these assumptions, for example increased yield or a higher pack-out percentage. The assumptions used were based on field anecdotal evidence and research done outside Australia.

Other local anecdotal evidence suggests that with current lower juice prices, the advantage for open hydroponics may be almost entirely from increased pack-out percentage rather than any yield increase.

## **Economic analysis of open hydroponics systems**

Most irrigators will need to address the question, “is it economic to up-grade from conventional fertigation to open hydroponics?”. This is best answered by an analysis that looks at the returns from additional capital invested. An economic model to do this for Washington Navel oranges growing in the Sunraysia district of NSW/Vic, has been developed by PIRSA and NSW DPI. The model calculates a cumulative cash-flow and an associated internal rate of return (IRR).

IRR is a technique used to evaluate or compare different cash flows over extended time periods. The IRR is the interest rate at which the investment just breaks even. For instance if the investment had an IRR of 8% and you borrowed all of the capital for the investment at 8%, it would take all of the cash surplus generated by the investment to just pay off the loan at the end of the investment (in this example 25 years). If the IRR is less than the interest rate on borrowed funds, the cash surplus from the investment will be insufficient to repay the loan.

Most investors would look for an IRR in excess of the cost of borrowed capital before committing funds. For example if money could be borrowed at 8%, an investor might look for an IRR of perhaps 15% to provide a fair return on the money invested and to cover the risks involved

A CD disc containing the economic model is included with this booklet, to allow irrigators to make their own calculations.

### **A worked example**

The model on the CD uses standard Micro-Soft Excel Spreadsheets that run with XP or later versions of the Windows Operating System. Three spreadsheets can be accessed from the task bar within the program:

1. An introductory text,
2. Scenario 1 - replanting an existing orchard and
3. Scenario 2 converting an existing 10 year old orchard to an open hydroponics system.

The two scenarios each have an initial set of inputs and calculated results. The example for scenario 1 is described below.

#### a) Assumptions.

These can be altered to suit local situations. By selecting “enter” after a change has been made, the program automatically recalculates all figures. A set of conservative assumptions are as follows;

- Capital invested
  - Scenario 1 is a replanting example comparing the cash flows and IRR from a conventional fertigation system with an open hydroponics system. The example only considers the costs and returns from replanting and does not include the

value of land, irrigation head works, equipment and water entitlement. It is assumed these assets are already in place and are the same for both examples. This example should not be interpreted as an evaluation of developing a new orchard on a green field site.

- **Area**  
The new planting is assumed to be 30 ha.
- **Fruit price**  
Fresh fruit (\$480/t) and juice (\$60/t) is the same for conventional fertigation and open hydroponics
- **Productivity**  
Mature Yield of conventional fertigation is 36t/ha, and 43t/ha for open hydroponics, an increase of 20%.  
The proportion of fresh fruit (70%) to juice (30%) is the same for both systems.
- **Yield and water use assumptions.**  
A table is presented of percentage changes in yield and water use as the young trees develop. The rate of development under open hydroponics is several years earlier than conventional fertigation. At maturity the season water use (10ML/ha) is the same for both systems.
- **Establishment costs**  
Costs are presented, which include either an additional amount for conventional fertigation of \$20,000 for 30 ha (\$666/ha), or an additional amount for open hydroponics of \$90,000 for 30 ha (\$3000/ha).
- **Water costs**  
Those used in the model (scroll right to view these figures) are based on current water charges in the Sunraysia district. Water charges across different districts vary and can be complex. For the purposes of this model, only a single set of water charges is needed.

#### b) Analysis.

For this set of assumptions the model calculates the IRR for conventional fertigation to be 6.9%, and for open hydroponics 10.1%. The IRR for the marginal investment to up-grade to open hydroponics is 30.0%

The model presents a forecast production schedule (Figure 1) that is a graphical presentation of the percentage change in yield of the young trees, and the final mature yield value.

Figure 1

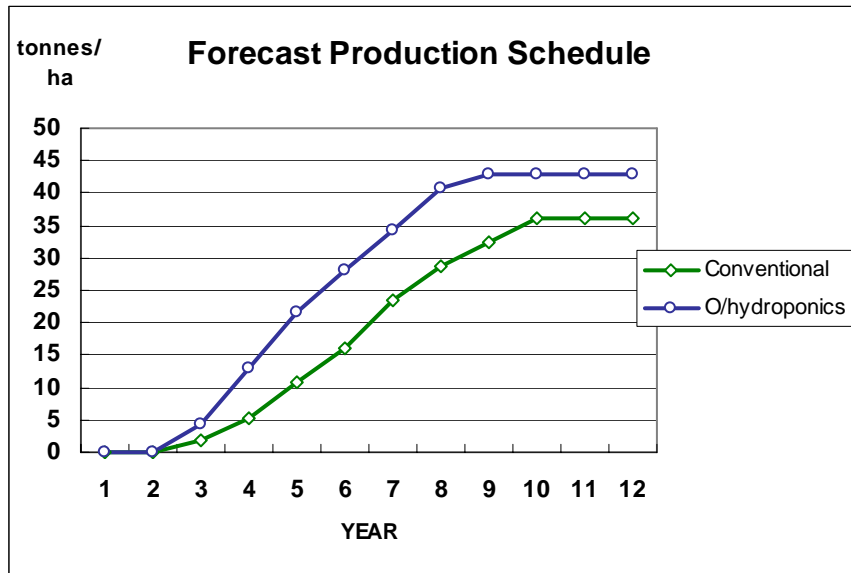


Figure 2 shows the estimated cumulative cash flow (including interest before tax). This graph shows the level of peak debt, ie the minimum cumulative cash flow level, which is approximately \$1.3 million for conventional fertigation and \$1.2 million for open hydroponics. The break-even times for conventional fertigation and open hydroponics are 25 and 16 years respectively.

Figure 2

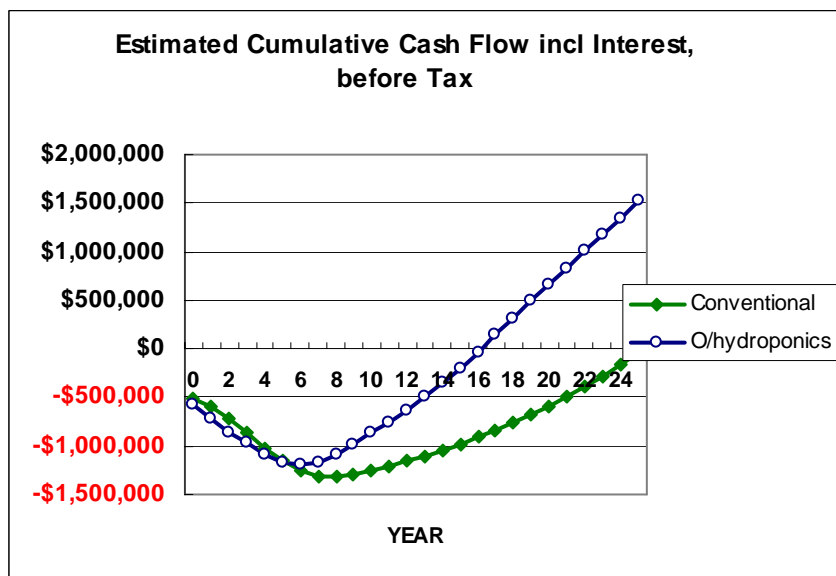
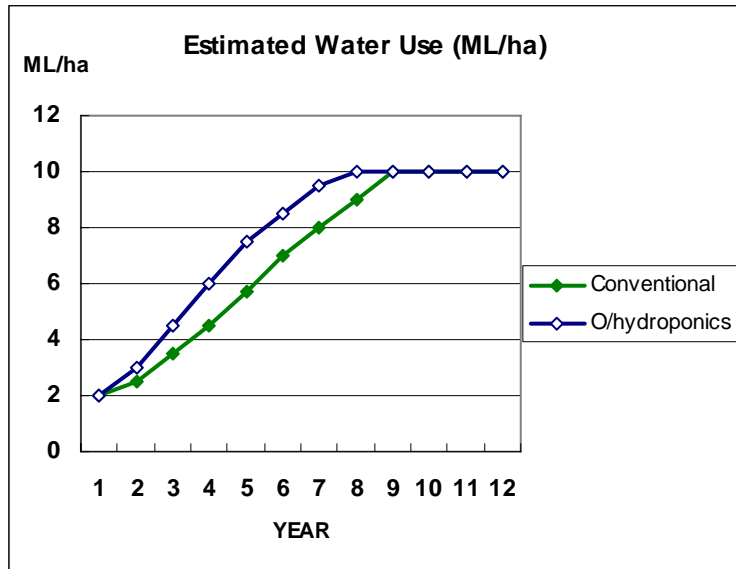


Figure 3 shows estimated water use (scroll right to view graph). This is a graphical presentation of the percentage change in water use by young trees, and the total season water use.

Figure 3



A special feature of the model is a built-in sensitivity analysis, which shows the IRR for a range of investment levels and estimated yield increases based on the particular set of inputs used (Table 1).

Table 1

**Sensitivity of IRR on extra Investment for Open Hydroponic equipment over conventional fertigation**

Extra Investment (\$/ha)	Estimated Yield Increase (Tonnes/ha)			
	2.50	5.00	7.50	10.00
\$1,500	26.9%	33.6%	38.5%	42.5%
\$2,000	21.9%	28.7%	33.5%	37.4%
\$2,500	17.9%	24.9%	29.7%	33.4%
\$3,000	14.5%	21.9%	26.6%	30.3%

The Marginal Investment IRR for this example of 30.0%, was for an extra investment of \$90,000 or \$3,000/ha and a yield increase of 36 to 43 or 7t/ha, according to the assumptions above. This fits into the lower right section of the table, and will change with different investment and yield. Different ranges of investment and yield can be entered into this table by the user.

Other comparisons can be made from this table. For example with a low level of investment in open hydroponics of only \$1500/ha, which would probably include mostly manually operated equipment, only 2.5 t/ha of extra yield is needed for an IRR of 26.9% 'ha. However for a fully automated system the investment may be closer to \$3000/ha, and a yield increase of about 7.5 t/ha is needed to obtain a similar IRR.

It also interesting to compare this table with the equivalent table in scenario 2, for an existing planting (Table 2).

**Table 2**

**Sensitivity of IRR on extra Investment for Open Hydroponic equipment over conventional fertigation**

Extra Investment (\$/ha)	Estimated Yield Increase (Tonnes/ha)			
	2.00	4.00	6.00	8.00
\$1,500	Negative	4.7%	10.8%	15.4%
\$2,000	Negative	3.6%	9.7%	14.2%
\$2,500	Negative	2.7%	8.7%	13.1%
\$3,000	Negative	1.8%	7.9%	12.2%

In this situation the IRR figures are all lower or negative. In Scenario 1 where trees are being replanted part of the benefit of adopting open hydroponics is the assumption that under this system trees start yielding fruit earlier than trees on conventional fertigation. In Scenario 2 this benefit of open hydroponics does not exist because at 10 years the conventional fertigation trees are already at full production. In this example if you were to spend \$3000 per ha converting to open hydroponics you would need a yield increase of nearly 10t per ha to achieve an IRR of 15%

c) Additional tables and data

Tables of income and costs over 25 years are presented for conventional fertigation and open hydroponics.

The costs include set-up costs in the initial years, and then operational costs for the remainder of the period. A total of \$4000/ha has been assumed for crop management each year, which would include all fertiliser, weed and pest control, and equipment operating costs.

These tables are used to calculate cumulative cash flow, and they are the base data for the estimated cumulative cash flow (including interest before tax) graph described above. A Net Present Value (NPV) figure is also calculated, in this case \$344,864 for open hydroponics. This the value of the final cumulative cash flow amount at year 25, expressed in today's dollars. To express a future \$ value in today's \$ this value must be discounted back each year to the present time. The discount rate (in this case 7%) is not

the same as the cost of borrowed money, but a figure which represents an estimate of likely future returns.

Additional tables are presented that are the base data for the other graphs described above, and the IRR sensitivity table.

An example using scenario 2 is also given on the attached CD. This follows a similar format to scenario 1, but is simplified because a 10 year old orchard is assumed.

#### d) Discussion

Because the IRR on the extra capital required for an open hydroponics system is estimated at 30% this does not necessarily mean that replanting utilising open hydroponics is a good investment. The whole investment has to be profitable, not just the return from the extra investment in converting from conventional fertigation to open hydroponics. The IRR on the overall investment in replanting and incorporating an open hydroponics irrigation/fertilisation system was estimated to be 10.1%. If this level of return is not acceptable then you shouldn't go ahead with replanting regardless of the return from the extra capital required to install the hydroponics system.

If you assume replanting using conventional fertigation was profitable and that the IRR on the extra investment to convert to open hydroponics was still 30% it still doesn't mean you should automatically go ahead with it. You have to ask the question whether there are alternative investments that you could undertake that are easier to implement, cost less money or provide better returns than investing in an open hydroponics system. For instance it may be possible to adopt alternative management systems that either improve fruit quality or increase yield, which will improve profitability without the extra expense of investing in open hydroponics. In the end which investment is best for you will depend on your personal circumstances, how much you are prepared to invest, ease of management and your perception of the likely risks and returns from alternative investments.

#### **Using the economic model**

Making changes to the assumptions such as yield and fresh fruit % will change the IRR and hence returns from the investment. The sensitivity of the estimated IRR to changes in some key assumptions is shown in Table 3.

A six tonne increase in average yield (36t to 42t/ha) increased the estimated IRR for Washington navels grown under conventional fertigation from 6.9% to 9.9%. Almost the same increase in IRR can be achieved by increasing the percentage of fruit packed for the fresh fruit market from 70% to 80%. Similarly a seven tonne increase in average yield increased the estimated IRR for the open hydroponics system from 10.1% to 13.2%. Increasing the fresh fruit percentage to 80% increased the IRR to 13.1%. A \$60 per tonne increase in the fresh fruit price (\$480 to \$540) would produce a similar effect on the IRR.

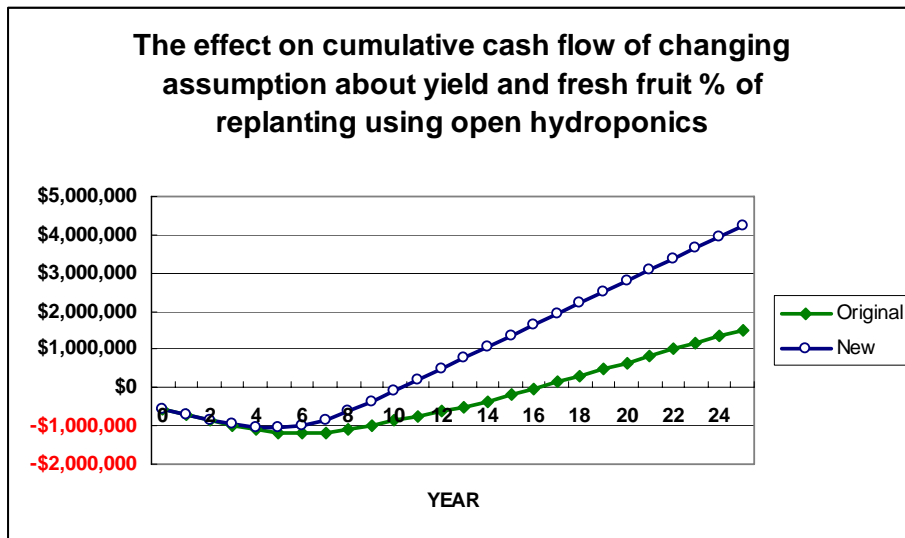
Table 3

**Scenario 1: Replanting Washington Navel Oranges**  
**The sensitivity of the Internal Rate of Return (IRR) to changes in some key assumptions**

Assumptions	Conventional Fertigation		Open Hydroponics	
		IRR		IRR
<b>Base assumptions</b>				
Yield t/ha	36	6.90%	43	10.10%
Fresh Fruit %	70%		70%	
Fresh Fruit Price \$/tonne	\$480		\$480	
Operating Cost \$/ha (excl water, harvest & levies)	\$4,000		\$4,380	
<b>Changed Yield</b>	30t	3.10%	36t	6.40%
	42t	9.90%	50t	13.20%
<b>Changed Fresh Fruit %</b>	60%	3.30%	60%	6.50%
	80%	9.80%	80%	13.10%
<b>Changed Fresh Fruit Price</b>	\$440	4.60%	440	7.80%
	\$520	8.90%	520	12.20%
<b>Changed Operating Costs</b>	\$5,000	4.10%	\$5,380	7.90%
<b>Changed Yield</b>	40t	10.40%	50t	14.70%
<b>Fresh fruit %</b>	75%		75%	
<b>Operating Costs</b>	\$5,000	8.10%	\$5,380	12.90%

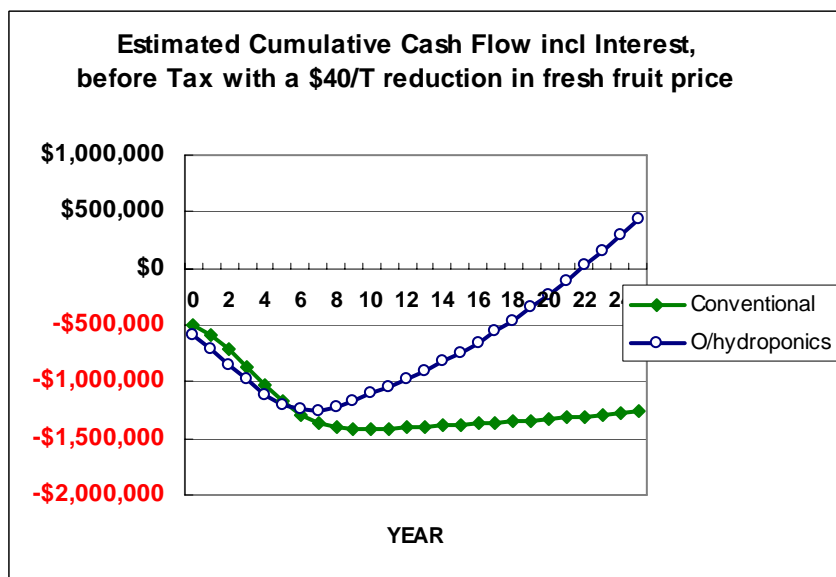
Of course altering the assumptions about yield, price and fresh fruit percentage alter the projected cash flow from the replanting exercise, the peak debt and the number of years before the investment breaks even. The change in the cumulative cash flow of replanting using open hydroponics and increasing the average yield to 50t/ha and increasing the fresh fruit percentage from 70 to 80% is shown in Figure 4. Peak debt is reduced from approximately \$1.2 million to \$1 million, and break-even time is reduced from 16 to 10 years.

Figure 4



Alternatively we could consider the effect of a reduced fresh fruit price. The effect on IRR of reducing the price of fresh fruit has been shown previously Table 3. The change in the cumulative cash flow of reducing the fresh fruit price is shown in Figure 5. Peak debt for the open hydroponics system increases slightly, but the break-even time is extended out from 16 to 22 years. For conventional fertigation, debt peaks around \$1.42 million but only improves very slowly. The investment in replanting does not break even over the life of the planting.

Figure 5



An alternative way of using the model is to ask yourself what IRR would you need to go ahead with replanting a citrus orchard. If for example you decide you want a minimum IRR of 20% what assumptions do you have to change and by how much to obtain the desired result. If you didn't want to rely on an increase in the fresh fruit price you would need an average yield of 60t per ha and a fresh fruit pack out of 80% to give an IRR of 19.7%. The next question is, is this level of performance feasible, year in year out, without increasing cash operating costs? Given an average yield of 60t per ha and a fresh fruit pack out of 75% you would need a fresh fruit price of \$520 per tonne for the estimated IRR to reach 20%.

### **Potential losses and risks with open hydroponics systems**

With frequent application of water and nutrients under open hydroponics there is an increased risk of excess water and nutrients draining below the root-zone. High nitrate levels may lead to increased acidity (decreased soil pH), and a change in soil nutrient availability. Increased nitrate levels draining below the root-zone and reaching the ground-water may also contribute to a public health risk, if this water is used for domestic supplies, or adds to water sources from which domestic supplies are drawn.

So apart from the dollar losses if water and nutrients drain below the root-zone, there are also potential off-site environmental impacts. No losses have been incorporated into the economic analysis above because they are very difficult to quantify, however they need to be considered.

Preliminary field observations have recently been made at the Dareton Agricultural Advisory Station in the Sunraysia district, on a red, sandy to sandy loam topsoil overlaying a heavier sub soil (Figure 6). Tensiometers and ceramic cup soil water samplers were placed at two different depths below the root-zone of a 2 year old citrus planting to directly measure water and nutrient losses.

Figure 6. Field observation site at Dareton Agricultural Advisory Station.



Season water use in 2007/08 was 5.9 ML/ha, and between September 2007 and June 2008, drainage of 18.5% was measured. With modern conventional drip irrigation systems drainage of 5-10% is commonly achieved. During this same period 16% or 23 kg/ha of the nitrogen fertiliser applied was lost as nitrate nitrogen. Some acidification was observed in the surface soil down to a depth of 0.4m, directly below the dripper and into the tree row.

Nitrate nitrogen concentration and salinity of the soil water was measured throughout the season, by extracting samples from the suction cups (Figure 7). At a depth of 1.5m, well below the root-zone, it was found to regularly exceed 10 mg/l, which is an accepted threshold for nitrate nitrogen in drinking water. Average root-zone soil water salinity was found to be below an accepted plant threshold for citrus, however it was higher at 1.5m, and appeared to be correlated with the higher nitrate levels.

Figure 7. Using suction cups to extract soil water and measure soil salinity.



These preliminary figures suggest it is important for careful, on-going measurements to be part of any open hydroponics system, to ensure that losses are not occurring.

### **Practical considerations for growers**

The cumulative cash flow analysis above suggests that good returns can be obtained from open hydroponics, especially with higher yields and fresh fruit %. However in achieving this there are some additional factors not considered in the analysis.

- Because of the reduced root-zone volume, the “root ball” under each tree is smaller, and plant roots are often not developed enough to seek additional soil water if the normal water supply is restricted for any reason, or under drought conditions. This makes trees vulnerable to reduced water supplies, and may result in significant production loss or even tree death.

- The preliminary observations at Dareton noted that salt build-up occurred at the edge of the wetted zone around each dripper. This is not uncommon even in conventional drip systems where irrigation water salinity increases. However with a smaller root volume adjacent to the dripper, salt redistribution back into the root-zone after rainfall may have a greater root-zone salinity impact .
- With the adoption of any new technology it may take several seasons for an irrigator to properly adjust to the new management practices, and so desired yields may not always be achieved immediately. This could well be the case with open hydroponics in an established orchard, and in fact for the first few seasons yield reductions may occur.
- The initial examples used in the cash flow analysis assume similar water use for both conventional fertigation and open hydroponics. This assumption has not been properly assessed in the field, and may need modification. In considering any future climate change effects, any management practice that uses less water is likely to be advantageous unless it results in a yield loss..
- In improving the productivity of any orchard, there is no substitute for good general management. It may well be possible to achieve an extra 10-15 t/ha from a “poorly run” orchard simply by improving general crop management rather than just improving fertigation techniques alone.
- Further research through the project, “Knowledge and tools to manage fertigation technologies in citrus orchards”, is being carried out by the NSW Department of Primary Industries at Dareton, with support from SARDI. This project will look more closely at plant responses under open hydroponics, and a range of extension tools to assist in adoption of this technology.

## Summary

Open Hydroponics is an advanced fertigation management system that has the potential to significantly increase productivity and returns from citrus plantings.

An economic model, that calculates a cumulative cash flow and an associated IRR, has been prepared to estimate returns from a wide range of input levels. Under a conservative set of inputs the IRR is increased from 6.9 to 10.1% by making the change from conventional fertigation to open hydroponics. The marginal IRR on this extra investment is 30.0%. Under an optimistic set of inputs, where yield is increased to 50t/ha and fresh fruit pack out is increased from 70 to 80%, the IRR increases to 16.1% with open hydroponics, and the marginal IRR is 47.7%.As would be expected returns fall significantly with a drop in fruit prices.

The potentially higher returns must be balanced against the higher level of management expertise required, and reliance on sophisticated equipment. Open hydroponics systems may be more vulnerable than conventional systems to reduced water supplies or drought

conditions. There is some potential for environmental impacts, such as groundwater contamination by excess nitrate levels, or increased soil acidity.

Research is being carried out by NSW Department of Primary Industries, with support from SARDI, to better identify knowledge and tools to manage fertigation in citrus orchards.

**Important contacts**

SARDI Water Resources and Irrigated Crops, GPO Box 397, Adelaide SA 5001.  
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