Increasing Adoption of Irrigation and Water Recycling Technologies in Australian Nurseries

FINAL Report for Project PA 57134

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The aim of this project was to identify and evaluate irrigation scheduling tools and techniques appropriate for use within container production nurseries and quantify water savings that can be achieved by utilising these. This would then be used to retrofit production nurseries to achieve and accurately measure the resultant water use efficiencies. An Economic Model would then be developed for use by Industry in discussions with growers to upgrade their irrigation systems to both save water and increase production.

All key objectives have been achieved and the data will be considerable benefit to all industries looking to improve their irrigation systems.

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Queensland **the Smart State**

Increasing Adoption of Innovative Irrigation Technologies in Australian Nurseries

Final Report – 2008.

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Australian Government
Department of Agriculture, Fisheries and Forestry
National Landcare Programme

Queensland Government
Department of Primary Industries and Fisheries

Project Introduction

In today's climate of water restrictions, water recycling and the dams debate, the focus on water use efficiencies has become more stringent. There is a call for all industries to be accountable for their water use, but the finger has definitely been pointed to the irrigation industries. It is well documented that the irrigation industries use approximately 70% of all freshwater resources and primary producers have been pressured to improve irrigation and water efficiencies (Rolfe 2006). In the past, the nursery industry has been seen as a minor player in the commercial world, but now the industry is under greater focus due to an increased interest in lifestyle horticulture, water efficiency and environmental impacts (Rolfe et al 2000).

In 2003 the Nursery & Garden Industry Association (NGIA) conducted a survey to determine the number of nurseries throughout Australia, the average size of a nursery, the volume of water used per nursery and whether water recycling or water saving technologies are being used. The results were surprising as very little quantitative data could be obtained. The findings where compared to figures from the Australian Bureau of Statistics (ABS), which estimated the number of production nurseries in Australia at 3,046 with a total area of 4,250 hectares, compared to the NGIA estimate of around 10,000 nurseries. According to NGIA, the annual water consumption for a production nursery is 17 to 25 million litres per hectare, and studies have suggested as much as 50 to 70 per cent of this water is wasted because of poor irrigation systems and scheduling practices (Per Com 2006 3, RMCG 2006, Cresswell & Huett 1996, Whalley 1991, Neal 2002, Rolfe et al 2000)

On the basis of the ABS and NGIQ figures, an average-sized nursery is around 1.1 hectares, which means the average annual water consumption is 23.1 ML. If 50% of this water can be saved at a current average cost of $1.60 per kilolitre, this represents a saving of $18,480 per annum for the nursery and a saving of 11.55 ML of water per year per nursery. For 3,046 nurseries, this represents a national saving of 35.18 GL per year and for 10,000 nurseries, 115.5 GL could be saved.

The data suggests that many industries are not embracing new technologies to assist in improving water efficiency. Currently many nursery managers use the traditional subjective methods learnt through years of experience in the industry. Although a number of innovative products (e.g. wastewater and irrigation tools utilising high-end IT technology) are currently available, they are yet to be incorporated widely into the industry despite their potential to substantially increase productivity and profitability by reducing input costs in areas such as water and fertilisers. This is due to a lack of specific cost/benefit data and a lack of independent verification of claims made by equipment suppliers. To date, the evidence of product efficacy is anecdotal or is based on insufficient scientific analysis, which has usually been commissioned by the manufacturer or marketer of the product, which further adds to the reluctance of producers to invest in them (Jozwik 2000).

This project was developed as a result of the findings of the NGIA 2003 survey, a 2003 audit and gap analysis of nursery wastewater research and communication (Lane 2003), and the industry's reluctance to adopt new technologies. The project aims to identify and quantify new technologies, which can increase productivity through more efficient water use, reductions in associated costs and evaluation of alternative irrigation scheduling practices. To achieve this, the project was separated into two parts. Part 1 focused on identifying and evaluating soil moisture sensors for adaptation to a containerised production nursery environment, and discussing the issues identified in implementing such technologies and the benefits (i.e. water savings) achieved in relation to current practices. Part 2 focused on retrofitting the irrigation systems of two production nurseries with more efficient technologies to quantify the potential savings and provide data on the financial feasibility of retrofitting. Furthermore, the project aimed to provide specific cost/benefit data on upgrading or retrofitting a nursery according to best management practices and to develop a generic predictive model to help nursery managers to determine returns on investment.

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"Present methods of determining the water needs of plants through the use of instruments are still not far enough advanced as to be counted on for consistent, economical, and accurate analysis. Proper water application depends mostly upon the grower exercising careful judgement accumulated through experience." Jozwik, 2000, The Greenhouse and Nursery Handbook, p. 239.

Acknowledgments

I would like to thank several people whose assistance has made this trial possible. Firstly, I must thank the NGIQ industry development officers who provided continual support throughout the trials, and particularly Steve Hart for his general industry knowledge and assistance in plant assessment.

Also I must thank DPI&F technicians Anthony Troughton, Lin O'Brien and Ola Bors, who carried out much of the early morning data collection. Specific thanks go to Lin for the hours of data entry she provided, and to Anthony who put up with tedious plant assessment and hours of sweating in a poly-tunnel. Finally I would like to thank Janelle Dahler from GrowSearch Australia for her help with the project research and information collation.

Summary

Nursery managers use a variety of methods to control and schedule irrigation, such as analysis of rainfall and evaporation data or physical assessment of the growing media to determine container moisture content. The knowledge required to determine optimal irrigation applications and irrigation scheduling is acquired through many years of experience. However, some of these methods can be inefficient due to the time required to monitor all areas of a nursery. In recent years new innovative technologies have become available to nursery managers to assist in irrigation scheduling, such as soil moisture sensors and computerised irrigation controllers. These technologies are not widely adopted within the industry despite their potential to increase productivity and profitability.

This project was commissioned to identify these new technologies and determine whether they can be adapted for use within containerised production nurseries, and also to quantify the potential benefits that these technologies could deliver. To achieve this, a two stage trial was developed to evaluate the ability of soil moisture sensors to automate irrigation in a containerised nursery and then to compare the benefit of adapting these technologies to current methods.

The trials found that certain types of soil moisture sensor can be used in containers to control irrigation scheduling. They can be used as either an automation tool or a diagnostic monitoring tool and have the potential to reduce water use, improve water use efficiencies and reduce labour time required in determining container moisture levels. However, several issues have been identified that could limit the uptake of soil moisture sensors by the industry, such as interfacing new and old technology and calibrating the sensors to reliably operate in organic media. Also, the small sphere of influence a single sensor has cannot represent an entire nursery due to the variety of plant species grown in a single area and inefficiencies in irrigation uniformity.

Despite the technical issues encountered, soil moisture sensors were proven to work within a container environment. When compared to standard timed and deficit irrigation scheduling practices they showed that substantial water savings can be made without sacrificing plant quality.

Terms used

In this report the terms ‘soil’ and ‘growing media’ or ‘growing medium’ all refer to the mix in which a plant is grown. The term ‘soil’ is also used to identify the equipment used (e.g. soil moisture sensors). Therefore, the word ‘soil’ can be substituted with ‘growing media’ or ‘growing medium’ unless specifically stated that a mineral soil is being discussed.

The term ‘deficit irrigation’ is used as a substitute for ‘evaporation’ and ‘evapotranspiration’ irrigation to reduce confusion associated with these terms. The terms ‘evaporation’ and ‘evapotranspiration’ refer to specific processes:

- ‘Evaporation’ generally refers to the water lost due to moisture evaporation from the growing medium surface and surrounding environment.
- ‘Evapotranspiration’ refers to the loss of water from the growing media through evaporation and water transpired by the plant through biological processes.

For ‘evapotranspiration’ to be accurately determined, a crop factor or crop co-efficient specifically relating to the focus plant used is required to accurately calculate water lost from a container. Unfortunately there is no specific crop factor or crop co-efficient available for the species of plant used in this trial. Instead, the generic or standardised crop factor for turf was programmed into the electronic weather station to calculate the combined loss of water through surface evaporation and plant transpiration from the containers. Therefore, for this report, the term ‘deficit irrigation’ is used in place of ‘evaporation’ or ‘evapotranspiration’ and can be considered interchangeable with these terms unless specifically identified that evaporation or evapotranspiration is being discussed.

Introduction

Nursery managers currently use several methods to control and schedule irrigation in a production nursery. These methods include the use of rainfall and evaporation data, visual subjective assessment of the plants' appearance (e.g. degree of wilting or vigour) and assessment of the growing media moisture content. Moisture content is usually assessed by physically feeling the medium to determine wetness, and/or inverting the plant and removing the container from the root ball to inspect root growth and medium cohesion. However, these methods can be inefficient due to the time required to monitor all areas of a nursery. Furthermore, visual assessment techniques are learnt through years of experience in the industry and require considerable knowledge of plant water requirements.

There are a number of innovative products currently available to assist with irrigation scheduling, such as soil moisture sensors and computerised irrigation controllers. These technologies are not widely used within the industry despite their potential to increase productivity and profitability. This is due in part to the number of new products entering the market each year, a lack of specific cost/benefit data and a lack of independent verification of claims made by equipment suppliers (Handreck & Black 2005).

Overseas research has shown that significant water reductions can be achieved with automated irrigation scheduling. French researchers state that water reductions from 25 to 40% are achievable with the use of a computerised irrigation controller and soil moisture sensors (Lachurie & Lahaye 2001), while American researchers document water reductions as high as 95% (Gonzales et al. 1992). Other studies suggest that further benefits are achievable without reducing plant quality, such as reductions in leachate and fertiliser input (Lieth et al. 1991; Newman et al. 1991; Oki & Lieth 1997).

In Australia, most available sensors have been developed for in-field production systems with mineral soils. Until recently, limited research has been undertaken to examine the adaptability of soil moisture sensors for containerised production or the effectiveness of these sensors for operation in organic media. This is mainly due to the call for these technologies being from broad-acre production industries (Connellan 2003). Now, with an increasing call for these technologies from the nursery industry, equipment manufacturers are developing sensors more suited to the specific needs of the industry (Pers Comm 2006 1, 2).

Part 1 of the project aimed to identify whether soil moisture sensors are appropriate for use in a containerised production environment and to evaluate the effectiveness of soil moisture sensors for irrigation scheduling within organic media. More specifically, Part 1 aimed to determine:

1) Whether soil moisture sensors can be adapted for use in an above-ground container growing environment;
2) Whether soil moisture sensors have the potential to increase water use efficiency by automating irrigation frequency and duration;
3) The potential benefits of soil moisture sensors compared to standard timed and deficit irrigation scheduling practices.

To achieve this, a two-stage trial was set up, with the first stage evaluating the adaptability of soil moisture sensors for use in a containerised nursery. Stage 2 replicated the trial with the soil moisture sensors automating irrigation scheduling. The results from soil moisture irrigation scheduling were then compared to standard timed and deficit irrigation scheduling.

Stage 1: Identification of effective irrigation scheduling tools and techniques for use in a containerised production nursery environment

Scheduling techniques

Although there are several methods for irrigation scheduling available to producers, it was found that timed calendar irrigation and deficit irrigation are commonly used in container production nurseries. Therefore in this trial, timed calendar irrigation and deficit irrigation scheduling were used to compare and evaluate the different scheduling tools chosen.

Initially, five irrigation scheduling options were to be trailed in each medium type:

a) AquaSpy soil moisture sensor connected to a proprietary data logger
b) Senviro soil moisture sensor and controller (wired or wireless)
c) Teven logic irrigation controller with Echo II soil moisture probes
d) Teven logic irrigation controller using evaporation irrigation technique
e) Teven logic irrigation controller set to timers/calendar irrigation.

Media types:

1. Media A consists of 90% composted pine bark and 10% washed river sand
2. Media B consists of 75% composted pine bark and 15% coir chips and fines.

The Senviro soil moisture sensor was removed from the trial due to the product being under ongoing development and the developer not being able to supply the quantity of upgraded units required within the project time frame. (This sensor was trialed and evaluated in a separate project, the final report on the upgraded sensors was completed in December 2007.)

Scheduling Tools – Soil Moisture Sensors

There is a wide range of commercially available soil moisture sensors that can be used for irrigation scheduling. However, most of these products have been designed for broadacre or in-ground production and many are not suitable for use within a container production environment due to their physical size or sensor type.

Firstly, to determine which products were potentially suitable for use within a container production nursery, a review of the written material relating to the equipment (i.e. guidelines/instructions of use, review articles and research articles) was carried out and a preliminary list developed.

Secondly, through discussions with industry development officers, nursery managers, product suppliers and industry consultants, several criteria were identified to narrow the list of available products appropriate for use in irrigation scheduling in a container production environment.

These criteria are:

- *Size of sensor* - the sensor needs to fit into growing containers as shallow as 100 mm.
- *Type of sensor* - Due to the limited growing medium volume, the sensor's sphere of influence must be appropriate for the container, be robust and provide reliable data without being influenced by varying environmental conditions to which above-ground containers can be subjected (i.e. increased movement and disturbance from wind gusts, increased diurnal temperatures and variation in the electroconductivity of the growing medium).
- *Cost* - The sensor must be financially viable for smaller nursery operators.

- *Availability* - The product must be readily available on the local market, with after-sales technical support available if required.
- *Simplicity/ease of use* - The product must be able to be installed and maintained by nursery staff, without requiring extensive calibration by specialized personnel or equipment, and also needs to be moveable (i.e. easily extracted from one container and inserted into another).
- *Interface/connection* - the product should be able to be connected to existing irrigation controllers or have accessories to allow for retrofitting to existing controllers.

Initially a range of products was identified as potentially appropriate for use as irrigation scheduling tools. However, after further investigation, several on the list were removed. For example, the Hortau Inc Hortimetre is a soil moisture sensor that was developed for the Canadian nursery industry and has potential as an irrigation scheduling tool. However, the product is not available in Australia and the cost of purchasing and importing several sensors would have negated the potential benefits of including the product in these trials.

Soil Moisture Sensor Description

Following the criteria identified above, two soil moisture sensors (SMS) were chosen for this trial and are described below.

Agrilink AquaSpy Soil Moisture Sensor

The AquaSpy SMS is a wired capacitance sensor sealed within a durable plastic shell. It measures 163 mm long (sensor length), 72 mm wide at the widest point and is 20 mm thick at the spine tapering down to 5 mm at the edge of the sensor paddle. It comes hard wired with a cable 5 metres in length that can be extended with a proprietary extension cable. Several sensors can be daisy-chained to provide a single run of cable of up to 1000 metres. The AquaSpy sensor can be connected to a data node for continuous data logging or an AquaBlu solenoid controller for direct solenoid control (Agrilink website 2007).

Figure 1: Agrilink AquaSpy soil moisture sensor

The software provided with the data node allows for the output to be represented in graphical form showing daily, weekly, fortnightly and monthly trends, or can be converted into MS Excel for further analysis. The SMS has a built-in temperature sensor that monitors the sensor temperature, which the control software uses to adjust for the effects of hysteresis and also provides the nursery manager with a way of monitoring container temperatures.

There are two primary issues that limit the installation of this device into an existing, older timed irrigation controller. Firstly, the output signal used is a digital signal (RS 485) and is not commonly recognised by irrigation controllers used in many containerised nurseries today. An upgrade of older irrigation controllers would be needed if actual soil moisture values were required. Secondly, a computer is required to program the sensors and display the data in graphical form.

Agrilink have developed an independent interface that will negate the use of a computer, the AquaBlu solenoid controller. These solenoid interfaces, with a built-in percentage control knob, is designed to link the soil moisture sensor directly to an irrigation solenoid or to an irrigation controller through a digital (on/off) rain switch input. The AquaBlu does not interact with the irrigation controller or require a change to the original irrigation programming when connected directly to the irrigation solenoid but will turn off the irrigation solenoid once the soil moisture has reached the preset level or percentage. The irrigation manager can adjust the percentage at the growing bed, but unfortunately this method will only control one solenoid and a separate AquaBlu and sensor would be required for each irrigation zone/solenoid. When the AquaBlu is connected to an irrigation controller via a digital rain switch, the sensor can effectively control several solenoids at once, but again does not provide any actual soil moisture values.

Although the AquaBlu would be an appropriate option for growers that wish to control 1 or 2 growing beds separately from the main controller it will not provide any data for monitoring purposes or provide actual container moisture figures. The nursery manager would be required to physically assess container moisture in a traditional manner to determine set points (the percentage knob position) until the optimum positions are found.

Figure 2: Agrilink AquaBlu regulator

Decagon Ech2o EC-20 Soil Moisture Sensor (pronounced 'Eco 2')

The Ech2o soil moisture sensor is a slim capacitance sensor measuring 254 mm in length, 31.7 mm wide and 1.5mm thick, and comes wired with a 5 metre cable. The cable length can be extended to a maximum length of 75 metres before the output signal starts to degrade. A wireless option is available but a propriety data logger (Em50R) or other is needed (Decagon 2006). The sensor is a fibreglass construction with a durable resin coating and is easily inserted due to its slimline design.

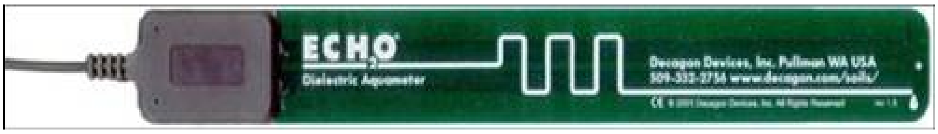

Figure 3: Decagon Ech2o EC-20 Soil Moisture Sensor

The output signal of this sensor is a common 250 to 1000 millivolts that can be connected directly to many older timed and new two-wire irrigation controllers. If a 4 to 20 milliampere input signal is required for connection to an irrigation controller or data logger, the signal is easily converted by incorporating a resistor inline at the interface. However this means that the data received is in a raw form and must be converted via a software program to provide soil moisture in a percentage form.

The sensors themselves are not supplied with any software but will be recognised by various data loggers or monitoring programs. Proprietary software is available for use with a data logger if required or a single sensor can be connected to a hand-held reader for spot checks. One to five sensors can be wired into a hub for connection to a data logger.

Method Summary

To simulate a containerised nursery environment and determine the adaptability of soil moisture sensors, trials were set up in a poly-tunnel at the Department of Primary Industries and Fisheries, Redlands Research Station, fitted with an environmental controller to maintain a relatively consistent growing environment and to minimise excess water inputs. The trials consisted of forty separate irrigation zones representing the five scheduling options and two media types (media A and media B). Each zone/group consisted of four containers (internal replicates) to account for variation within a treatment group. One container within each group was designated as the primary container and housed an 'I-Button' temperature data logger to log the diurnal temperature fluctuations of each primary container. A leachate collection tray was placed under each primary container to capture all leachate for water use efficiency calculation. In two treatments the primary container also housed the soil moisture sensors under evaluation. The treatment groups were randomly placed on a bench and surrounded by a row of guard plants to limit the influence of edge effects associated with containerised production. Each bench was then replicated three times.

A Teven Logic (TL) irrigation control unit (the Nursery Logic 2 wire network/encoder system) was used to control irrigation scheduling for this project. This controller is programmable to operate each irrigation zone independently according to the required irrigation trigger or scheduling practice. The TL controller is also capable of data logging and was used to log soil moisture readings from the Ech2o SMS, while a separate Agrilink data node was used to record the AquaSpy SMS readings. Unfortunately, the AquaSpy sensors could not be connected to the Teven Logic system due to the unique signal type they employ (the use of a separate data logger for the AquaSpy sensor is discussed later).

Due to the reduced size of this trial in relation to a nursery and the small volume of irrigation required, a drip irrigation system was chosen to allow for a more precise control of the applied water volume and for a better evaluation of the soil moisture sensors' responses. An overhead sprinkler system would not have accommodated the small scale of the irrigation zones.

After the initial set-up and calibration phase, which included a water audit of the irrigation system, the system was run for two weeks with bare media (no plants) to obtain baseline data. Following this 2-week period, each pot was planted with the representative plant variety and the trial run for a further three months to identify any technological issues with using soil moisture sensors.

Other considerations

1. Fertilization - Osmocote slow release fertilizer prills were spread over the surface of the pots/containers and mixed into the top two centimeters of the growing media.
2. Growing container/pots - a common black growing container of 200 mm in diameter was used.
3. Container spacing - container placement and spacing relative to plant variety to be trialed was observed as used in a typical production nursery.

Results and Discussion

Soil Moisture Sensors

Soil moisture sensors (SMS) have proven their worth in broadacre and in-ground farming for irrigation control and are, theoretically, adaptable for use in container growing environments (Charlesworth 2005, Stirzaker 2006). These trials have suggested that the use of soil moisture sensors is a viable method of irrigation scheduling; however, the project has identified several issues associated with implementing a soil moisture sensor controlled irrigation system within containerised nurseries.

Interfacing soil moisture sensors with older or low-cost irrigation controllers that either have no external input ports or only on/off rain switch input ports will limit the SMS that can be used. The decision to use a SMS for irrigation scheduling, whether it be as a monitoring tool or an automation tool, starts with an assessment of the irrigation system, the irrigation controller, container size, growing medium type and variety of plants grown.

The irrigation system's uniformity will have a major bearing on the effectiveness of using soil moisture sensors. If the irrigation system's uniformity is poor, a SMS will not improve irrigation scheduling or plant quality, as the same inherent problems will exist. That is, a growing area that has either over- or under-watered sections will continue to have over- or under-watered sections. The placement of the SMS will determine irrigation scheduling according to the pre-set soil moisture range for the container in which it is placed. Therefore, if the SMS is placed in an area of over-watering, the drier areas will still suffer from under-watering due to the uneven uniformity.

A soil moisture sensor installed in a container can realistically only monitor or represent that container and, due to the small sphere of influence or response area a single sensor can measure, (i.e. a portion of one container) one sensor cannot represent the whole growing area unless the irrigation system and media mix are uniform. Several sensors may be needed throughout an irrigation zone to average soil moisture across the zone.

The positioning of the sensors within an irrigation zone must also be considered to avoid the potential influence of edge effects and temperature fluctuations. Studies have shown that increased temperatures and wind activity affect containers on the outer rows of a growing area. An increase in wind can trigger a plant to increase evapotranspiration, drawing more moisture from the growing media and requiring increased irrigation frequency (Rolfe et al.2000). If an irrigation event was triggered to compensate for the outer row's moisture use, containers and plants located in the inner rows maybe over-watered (Connellan 2003). With a uniform irrigation system and media mix, these effects could be reduced.

Another issue identified during this project was that containerised nurseries prefer to use organic growing media, while SMS were developed originally for use in mineral soils. This raises the issue of calibration of the SMS for organic media. Although a SMS will operate and provide soil moisture readings in organic media, the physical water retention properties of organic media vary greatly from those of mineral soils. If a nursery manager wanted to monitor the actual moisture content of a medium (e.g. 20%, 30% etc.), a medium-specific calibration of the SMS would be required to give an accurate quantitative value of moisture within that specific medium type/mix (Decagon 2006).

However, if the nursery manager simply wanted to graphically monitor the soil moisture trends over a day, week or month, or connect the sensor to a rain switch, a sensor could be used without calibration. This scenario would involve the nursery manager comparing the soil moisture sensor readings to the traditional method of assessing container moisture content and developing an understanding of the relationship between SMS readings and container moisture content. Once a comparative relationship is known, trigger points based on observations could be identified. Unfortunately, this method would require ongoing observations for the different seasons or growing periods, and would be somewhat time consuming.

Soil Moisture Sensors and Plant Placement within a Growing Area

One of the main concerns identified during this project is that containerised production nurseries will have multiple plant species and varieties with varying water requirements within the same growing area. Although a SMS could be programmed or calibrated to schedule irrigation, it would be difficult to identify the trigger points (refill and stop points) to accommodate plant varieties with varying water requirements.

To achieve the best water efficiencies from using a SMS, groupings of plants with approximately the same water requirements should be established. If plants with the same water requirements are grouped into the same growing area or irrigation zone, a SMS could be fine-tuned to more accurately represent the water requirements of each grouping.

The nursery manager would need to become familiar with the readings, and over time and seasons, an understanding of the soil moisture fluctuations would be developed. The identification of trigger points would be needed for each irrigation group (i.e. plants with low, medium or high water requirements). Also the nursery manager would need to undertake calibration trials to have an understanding of the sensor reading in relation to the crop or plants grown within an area.

If a weather system was incorporated with the SMS, the system could be set up for the different growing areas and to water on demand. Such a system could reduce not only water wastage but also labour and maintenance costs, once key trigger points were identified.

Installing a Soil Moisture Sensor into a Container

Installing a SMS into a container is relatively easy. The Ech2o soil moisture sensor’s slimline design allows for easy insertion with an appropriate tool, after the container has been filled with media. The AquaSpy SMS is larger, bulkier and less uniform in shape. Therefore, this sensor needs to be installed while filling the container with media.

Soil moisture sensors rely on good contact between the sensor and the growing media for an even transmission of the signal into the surrounding media. As most of these sensors have a limited sphere of influence, approximately 80% of the signal strength or reading accuracy is within a radial distance of 2 cm from the sensor surface. After this 2 cm radial distance the signal degrades and accuracy is reduced. If air gaps exist between the sensor body and media, the sensor’s signal cannot accurately identify moisture content (Decagon 2006, Charlesworth 2005).

Manufacturer’s installation procedures state that if the sensor-media contact is insufficient then erroneous readings will occur. Therefore, manufacturers suggest packing the soil firmly against the sensor’s surface to ensure a good contact (Decagon 2006, Charlesworth 2005 & Connellan 2003). Tests following the manufacturer’s installation recommendations were conducted and it was found that this method resulted in an air-filled porosity of 16 to 18 per cent. This could prove to be a concern if nurseries use media mixes with a higher air-filled porosity. Connellan (2003) also voices this concern and states that production nurseries wishing to use media mixes with high air-filled porosities could effectively reduce the accuracy of the SMS.

Some sensors are less affected, but in general if the growing media does not have a good contact with the sensor’s surface and air pockets exist around the sensor, the sensor will give erroneous readings. However, these affects could be lessoned by a media specific calibration to account for the sensor-media contact, but the actual sensor readings will vary from those achieved using the manufacturer's procedures.

Interfacing the Soil Moisture Sensor with Irrigation Controllers

Some old or low-cost irrigation controllers have a simple rain switch input, but may not have the ability to accept a SMS directly or display the moisture readings graphically or numerically. Therefore it is vitally important that a SMS that will connect to the nursery's existing irrigation controller is chosen. If a new multi-input irrigation controller or a 2-wire encoder system is installed, there is a wider choice of soil moisture sensors that could be used. However, the correct signal type (i.e. the language which the sensor and controller use to communicate) must be compatible.

Soil moisture sensors can use one of several input signal types (e.g. 0 to 5 volts or 4 to 20 milliamperes, etc). Many irrigation controllers will accommodate one or two input signal types, but the SMS must be compatible with the type the irrigation controller uses. This constraint alone will be a deciding factor regarding whether to incorporate a SMS for irrigation scheduling, as a low-cost sensor may not communicate with the irrigation controller and an upgrade to the irrigation controller would be required.

During this project it was found that the Agrilink AquaSpy SMS communicates using a digital RS485 signal, which most data loggers will recognise, but currently, to the author's knowledge, no irrigation controller uses. Therefore, a separate Agrilink data node may be needed to log the data from the AquaSpy sensors. However, the AquaSpy sensor can be connected to an irrigation controller rain switch via an AquaBlu solenoid controller/regulator. Unfortunately this method does not allow for actual soil moisture values to be read. The Ech2o sensors use a low-voltage signal that was recognised by the Teven Logic irrigation controller and allowed for real-time display of soil moisture readings on the computer.

Once the nursery manager has identified the most appropriate sensor suitable for use with the irrigation controller, connecting the sensor to the irrigation controller is a simple matter of identifying the input channel and allocating the appropriate program steps.

Conclusion

Although there have been several technical and operational issues associated with setting up and conducting this trial, these issues have exposed many hurdles that would be faced by nursery managers wishing to implement a SMS controlled irrigation system. A simple step-by-step evaluation process has been identified from these issues that will assist the industry in the decision process when upgrading irrigation tools or techniques.

This trial also highlighted the importance of improving the efficiency of an irrigation system from a technological point of view. Substantial amounts of money could be spent on purchasing new technologies or scheduling software to improve growing conditions, but unless the irrigation system's uniformity and efficiency is first addressed, the addition of advanced technology will not improve plant growth and quality to the theoretical optimum. That is, a modern 2-wire encoder irrigation controller installed into a nursery could improve irrigation scheduling practices but will not address the issues of uneven water application of an irrigation system or a poor water distribution system.

This trial has also identified that a nursery's water use efficiency would benefit from further research into irrigation grouping of plants according to the plants' water requirements. There is little information available on ornamental plant crop factors or water requirements and the practice of growing various plant species with varying water requirements within the same irrigation zone complicates the process of fine-tuning SMS irrigation scheduling. The use of soil moisture sensors for irrigation scheduling requires an understanding of plant water use or crop factors to fine-tune trigger points. Without this information, trigger points would need to be identified through a process of comparing soil moisture readings to traditional assessment methods, which could be a laborious process that negates the expected savings associated with implementing innovative scheduling technologies.

Stage 2: Quantifying and comparing the potential water use efficiencies of soil moisture sensors to standard timed and deficit irrigation scheduling practices

Method Summary

Stage 2 replicated the procedures carried out in Stage 1, but focused on determining whether the soil moisture sensors could effectively and efficiently automate irrigation scheduling. The SMS irrigation zones were controlled independently from each other and from the timed and deficit irrigation scheduling zones. The irrigation trigger points (refill and stop point) to control the soil moisture sensors were identified from stage one and used to automate irrigation scheduling for each zone (irrigation on demand). The sensors were installed with minimal packing of the media, with air-filled porosity targets of 22% to 25% as suggested by Rolfe et al (2000).

The AquaSpy sensor was interfaced with the TL irrigation controller via a digital (on/off) rain switch input. Data collected during this stage was the same as stage one to maintain uniformity of data, and included container moisture content, container temperature, leachate volume, leachate quality (i.e. pH, EC, K, P, NO_2 & NO_3) and a plant quality assessment. Unfortunately only the irrigation durations for the AquaBlu solenoid regulator could be recorded because of the signal type and method of connection.

Timed irrigation simulated standard nursery scheduling practices as identified by NGIQ industry development officers, while deficit irrigation replaced only the portion of moisture evaporated and transpired from the containers in the previous 24-hour period. Timed and deficit scheduling techniques were used to compare and quantify water use efficiencies and irrigation scheduling control capability of the soil moisture sensors. After the initial set-up and calibration phase, which included a water audit of the irrigation system, the system was run for two weeks with bare media (no plants) to obtain baseline data. Then each container was planted with a petunia seedling and the trial run for a further four months under automation.

Results and Discussion:

One of the initial questions asked during this project was: “Do soil moisture sensors have the potential to increase water use efficiency by automating irrigation frequency and duration?” In short, the answer is yes. The results have shown that the use of a SMS to automate irrigation scheduling can reduce water use in a container production environment more so than timed or deficit irrigation scheduling. Soil moisture sensors can also allow irrigation applications to be adjusted to suit container moisture content and the absorption rate of the media mix being used.

With further observation and an understanding of specific plant water use, SMS would allow irrigation scheduling to be tailored for different plant species or irrigation groups. As a diagnostic or monitoring tool, a SMS could identify problems or faults with the irrigation system. For example, line blow-outs or problem solenoids causing either no irrigation or excessive irrigation would be reflected in the SMS readings as reduced or increased moisture content in a container.

Results from this trial are separated into two periods, ‘All data’ and ‘Focus data’. ‘All data’ identifies the full period of Stage two from 6/08/2007 to 16/11/2007 and refers to all water applied to the containers during the trial period, including manually triggered irrigation events and any extra irrigation due to equipment faults or prolonged irrigation. ‘Focus data’ refers to the period from 17/10/2007 to 16/11/2007, which represents complete automation of the irrigation system. During this period the only operator adjustments to the irrigation controller were the entry of the previous

24 hour evapotranspiration (ET) value obtained from the electronic weather station and the adjustment of the AquaBlu percentage knob according to weather conditions. Unless stated, the results of the 'Focus data' period will mainly be presented and discussed here as they represent the actual water use during automation.

Water Use Efficiency

There was a significant difference in the volume of water used between each of the four irrigation treatments (P<0.05). Timed irrigation used the greatest volume of water followed by deficit irrigation (22% saving), and then Echo2 SMS triggered irrigation (44% saving) with AquaSpy SMS triggered irrigation using the least (53% saving). Figure 4 shows the volume of water used by each irrigation treatment for both 'All data' and 'Focus data' periods, as well as the variation between the two media types.

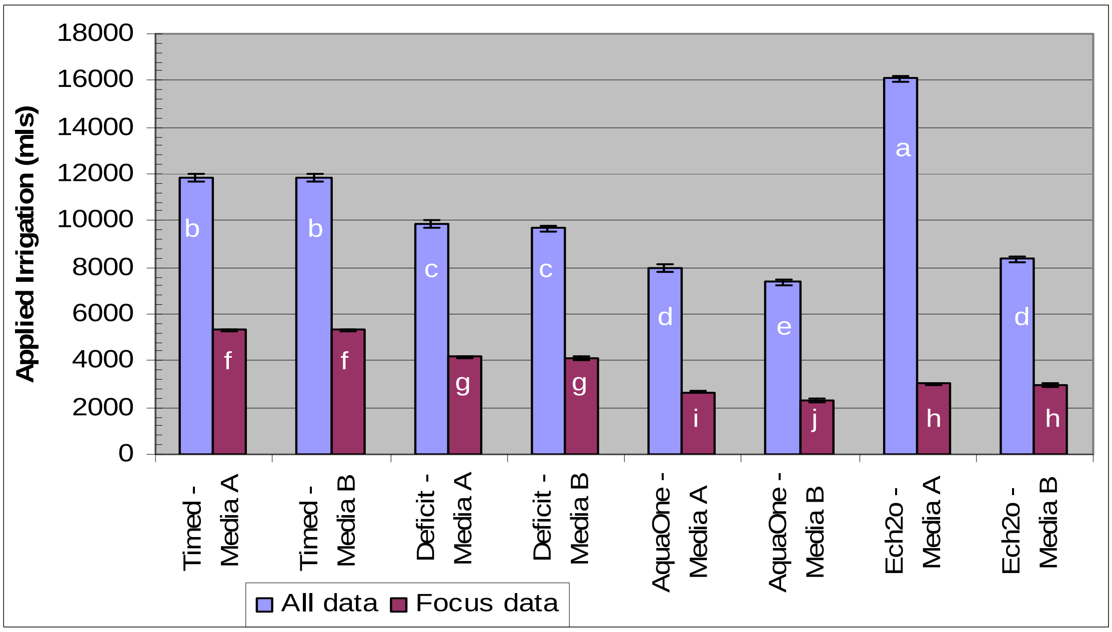

Figure 4: Total volume of applied water by irrigation trigger and media type.
NB: The increased application of Ech2o media A indicates a breakdown in communication between soil moisture sensor and irrigation controller, once corrected water use dropped to expected levels. Columns with different letters indicate a significant difference (P<0.05).

The results show that soil moisture sensors and computerised irrigation controllers can be used for automating irrigation scheduling and can reduce water use substantially. The water savings achieved during this trial support overseas research that suggested water reductions of 25 to 40 per cent were achievable with the use of a computerised irrigation controller and soil moisture sensors (Lachurie & Lahaye 2001). The extent of water savings will be dependent upon the method of irrigation; for example, this trial used a drip irrigation system that had been designed to match the infiltration rate of the media types used and all water applied during this trial was accounted for. Nurseries that use overhead irrigation must be aware that some irrigation systems can waste between 25 and 60 per cent of water due to poor application uniformity, canopy interception, wind effects and container spacing (Whalley 1991, Neal 2002). Therefore, implementing a soil moisture sensor based irrigation scheduling system will not improve an inefficient irrigation system unless irrigation uniformity is addressed first.

The composition of the growing media used will also affect how well a soil moisture sensor can detect the moisture content in a container. Sensors installed in media with high air-filled porosity or high in organic matter will need a specific calibration to ensure a true reading is obtained from the sensor (Decagon 2006).

The main issue in using a soil moisture sensor as an automation tool, and to a lesser degree a monitoring tool, is that current nursery practices do not group their plants into water requirement categories. If a sensor is used as a monitoring tool where a reference plant or container is placed within the irrigation zone, over time the irrigation manager will develop an understanding of the water use relationship between the reference plant and the other plants within that zone. Furthermore, using plant water use irrigation groupings would allow for a finer adjustment to the application rate, effectively further reducing water use.

As a diagnostic monitoring tool, a SMS could identify issues or faults with the irrigation system. For example, when fine-tuning the sensor automation, the Ech2o SMS treatment showed a four-fold increase in daily irrigation application and excessive leaching. On investigation it was discovered that the sensor cable had been dislodged from the interface encoder, a simple fault that could have led to continual over-watering. However, because the irrigation controller logged all irrigation data and graphically represented daily water use, this fault was quickly identified and rectified.

This example shows that soil moisture sensors can be useful diagnostic tools to identify issues such as excessive or prolonged irrigation. The sensor can also indicate other issues, such as under-watering, leaking pipes or blockages. Routine monitoring of the soil moisture readings would allow a manager to see when an irrigation zone was activated and whether the volume of water applied is adequate. If the soil moisture sensor is only used for monitoring purposes, a manager will develop an understanding of how the irrigation system is working and will be able to determine if the irrigation scheduling is sufficient for plant growth for each irrigation zone.

The results also support the benefits of deficit irrigation as an alternative scheduling practice to standard timed irrigation scheduling. The water reductions achieved through implementing a deficit irrigation scheduling practice could provide considerable water savings without incurring the costs associated with installing a SMS scheduling practice.

Irrigation duration and frequency

The irrigation duration required to irrigate the same number of containers under soil moisture sensor irrigation was almost halved compared to timed irrigation. Soil moisture triggered irrigation duration was 44 to 58 per cent lower than timed irrigation duration, while deficit irrigations were reduced by 24 per cent in comparison to timed irrigation durations.

Deficit irrigation was triggered at the same time of day as timed irrigation but had a reduces water use due to the irrigation only being active for the amount of time it took to replace the volume of water evaporated and transpired from the container. This was usually less than that of timed irrigation, which had standard 10 minute morning and afternoon irrigation events. The TL controller has the facility to calculate irrigation durations from the ET value obtained from the weather station.

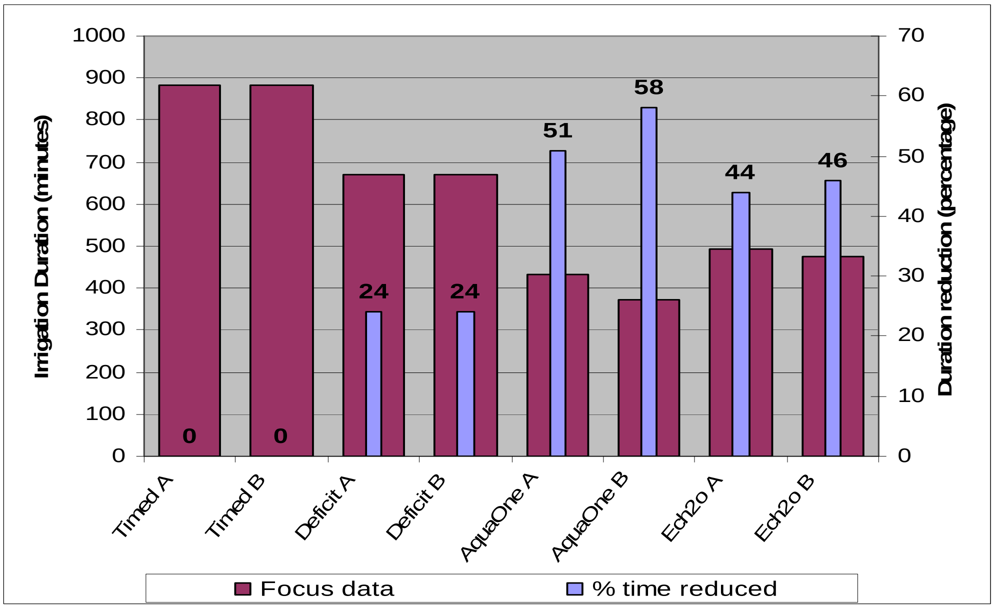

Figure 5: Total irrigation duration for each treatment and media type for the Focus data period and the reduction of time per treatment as a percentage of timed irrigation.

The soil moisture sensor controlled irrigation had an irregular frequency of irrigation, with durations varying according to the moisture content of the media. SMS controlled irrigations were programmed with a minimum moisture content percentage. Once the sensor detected that the moisture content was below this minimum threshold, it would trigger an irrigation event and would continue to irrigate until the moisture content reached the upper threshold value or until the maximum duration (time in minutes) was reached.

Growing Media

For total applied water, in general, the interaction between irrigation practice and media type was significant ($P<0.05$), with media A using more water than media B. However, for the Focus data, deficit irrigation and AquaSpy SMS controlled irrigation had a statistically different water use between media types, while timed and Ech2o SMS controlled scheduling had similar was use for the different media (Table 1). In the All data set, media A under Ech2o SMS irrigation showed a considerable increase in applied water (Figure 4). This represents a period early in the trial where the interface between the soil moisture sensor and the irrigation controller failed, causing a continuous irrigation event. This increased water use for media A, but once the fault was corrected water use returned to expected levels.

Table 1: Statistical results of water use per media

Irrigation Practice		All Data		Focus Data	
Timed	A	11830	b	5304	a
Timed	B	11830	b	5304	a
Evapotranspiration	A	10015	c	4250	b
Evapotranspiration	B	9533	d	4045	c
AquaOne SMS	A	7983	e	2668	e
AquaOne SMS	B	7377	f	2292	f
Ech2o SMS	A	16074	a	3023	d
Ech2o SMS	B	8351	e	2953	d
SEM		133.7		47.4	

NB: treatments with different letters next to the means indicate a significant difference.

Under timed irrigation there was no difference between media A and B, as both had the same timed irrigation scheduling. Therefore a percentage of water used for the three other irrigation treatments was calculated against the timed irrigation to represent the water savings obtained from using more efficient irrigation scheduling practices. Averaged water savings showed that soil moisture sensor triggered irrigation can reduce water use considerably, but the volume saved is dependent on the type of sensor, the scheduling program used, medium type and a medium-specific sensor calibration. Figure 6 shows the percentage of water saved for each medium type by using deficit irrigation and soil moisture sensor controlled irrigation in comparison to timed irrigation.

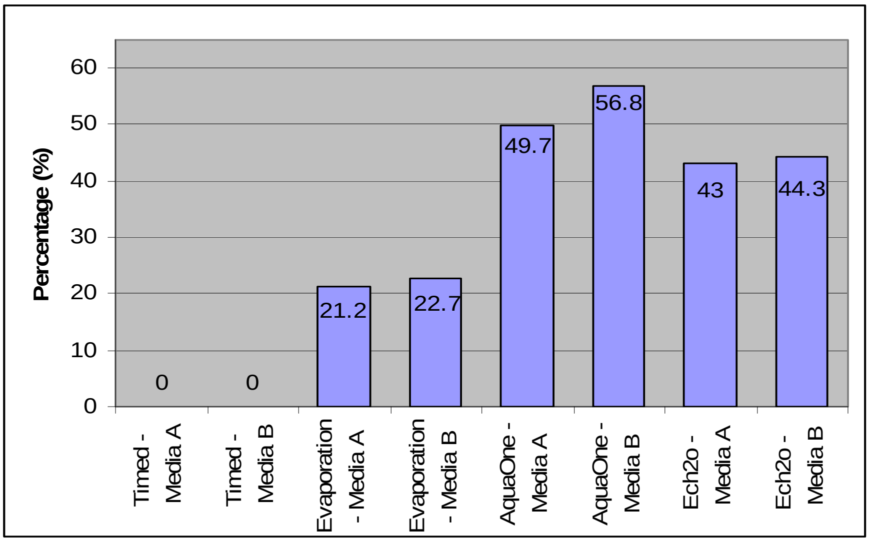

Figure 6: Percentage of water reduction with deficit and soil moisture sensor controlled irrigation compared to timed irrigation.

Plant Quality Rankings

The analysis of plant quality rankings found that, statistically, the impact of irrigation scheduling practices and media type on plant quality was not significant for the total trial period. Despite this, observations and graphical representations of plant assessments suggested that seedlings under AquaSpy sensor scheduling in media B had an increased rate of growth in the first two weeks. In general, all seedlings under deficit and soil moisture sensor scheduling had an increased rate of growth in the first 6 weeks after planting and appeared to reach saleable condition approximately three weeks before that of the timed irrigated plants (Figure 7). Ten weeks after planting, the graphical representation suggested that time scheduled seedling growth had matched that of all other scheduling practices.

However, statistically, the only significance difference in interactions between plant growth and irrigation scheduling practice was at two weeks and six weeks after planting (Table 2). Plant ranking at the end of the trial did not reflect this variation in plant growth and no significant difference in plant quality for either media type or scheduling practice was identified.

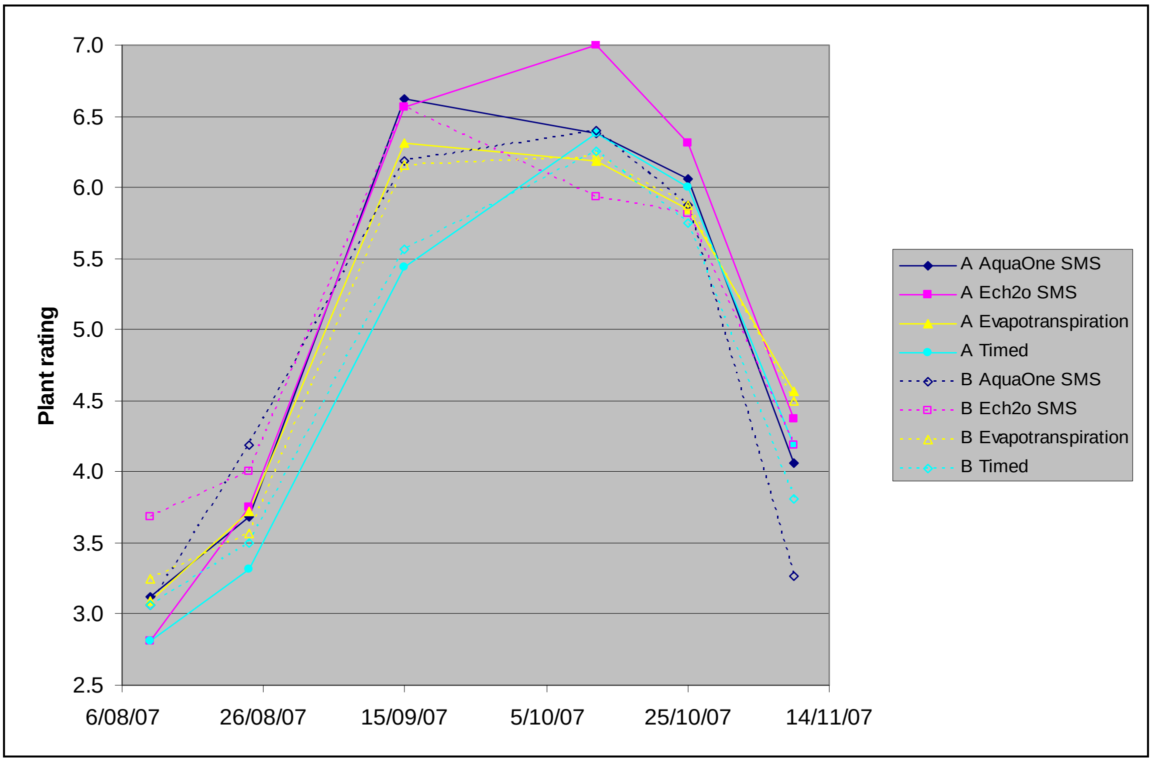

Figure 7: Plant rankings for each scheduling practice and media type

Table 2: Statistical results for plant rankings on 24/08/07 and15/09/07

Treatment	24/08/2007		15/09/2007	
Timed	3.4	b	5.5	b
Evapotranspiration	3.6	ab	6.2	a
AquaOne SMS	3.9	a	6.4	a
Ech2o SMS	3.9	a	6.6	a
SEM (ET)	0.10		0.15	
SEM (other)	0.14		0.21	

NB: treatments with different letters indicate a significant difference.

Plant ranking data also indicate the time of sensor disconnection at around week ten with the plant rankings diverging from the expected result due to the continuous irrigation. Media A under Ech2o SMS irrigation had an increase in plant quality ranking, while media B had a reduced plant quality ranking. A study by Poulter et al. (2007) showed that media with a blend of coir and media B had a higher water holding capacity. Therefore, media B would become water logged sooner, while media A has a faster draining characteristic that would limit the water logging effect, which may explain the divergence.

A study by De Graaf-van der Zande (1990) looked at the effects of watering strategies on petunias and found that high moisture levels increased plant height, leaf density and flower production, but caused an unacceptable longevity and a reduced marketability due to poor visual quality and plant shape. Plants grown under reduced moisture levels were smaller and had fewer flowers at marketing stage, but developed faster with excellent flower growth after planting. It was also found that plants grown under a varying watering strategy had a good visual shape and an excellent marketability.

Although increased water levels will increase plant development, it is a fine line between sufficient water and over-watering. Over-watering a plant can be more detrimental to growth due to water logging (Whalley 1991). Rolfe et al. (2000) and Cresswell & Huett (1996) support maintaining a high air-filled porosity to improve drainage and to limit water logging. Closed media mixes and excessive watering reduces oxygen availability and can cause the media to become anaerobic. An anaerobic medium retards plant growth, reduces root strength and causes root rot (Rolfe et al. 2000, Cresswell & Huett 1996, Neal 2002).

These studies suggest that plants subjected to high levels of watering (timed irrigation) would be expected to have reduced growth rates. In contrast, plants watered with a method that maintains a balance between oxygen and moisture levels (deficit and SMS irrigation scheduling) would be expected to develop faster and provide a higher plant ranking. This may explain the observed variation in plant rankings in the early weeks of this trial, but further tests are needed to determine the extent of influence of media type and irrigation scheduling practices on plant quality rankings.

Leachate

The captured leachate was tested to determine if any of the irrigation scheduling practices and media type had an effect on the volume of leachate captured. The results showed that for leachate, the interaction between irrigation scheduling practices and media type was not significant ($P>0.05$). That is, the difference in volume of leachate recorded for media A and media B under all irrigation scheduling practices was not statistically significant. However, there was a significant difference in the amount of leachate captured for the different irrigation scheduling types.

Timed irrigation had the largest volume of leachate (35.4%), followed by deficit irrigation (24%), followed by AquaSpy soil moisture sensor controlled irrigation (13.6%), with the Ech2o soil moisture sensor controlled irrigation having the least (4.9%). Figure 8 represents the amount of leachate captured in comparison to total water applied during the Focus data period. This also shows the leaching fraction of each irrigation scheduling practice. Table 3 lists the statistical results for combined averaged leaching fractions for each irrigation treatment.

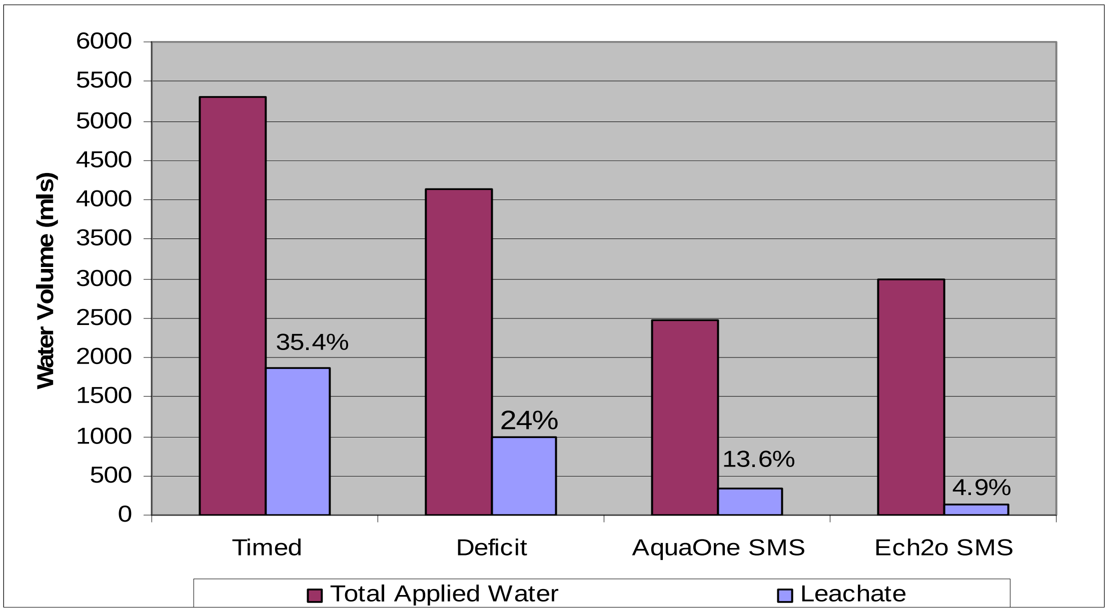

Figure 8: Volume of leachate captured for each irrigation scheduling practice in comparison to the total applied water during the Focus period. Percentages refer to the leaching fraction per scheduling practice.

Table 3: Leaching fraction for the different irrigation scheduling types

Irrigation Type	All data		Focus data	
Timed	43.8	a	35.4	d
Deficit	32.1	b	24.0	e
AquaSpy SMS	27.3	b	13.6	f
Ech2o SMS	8.2	c	4.9	f
Standard Error Mean (ET)	2.36		2.65	
Standard Error Mean (other)	3.33		3.75	

NB: Different letters beside means indicate a significant difference between irrigation scheduling types ($P<0.05$).

The significant difference identified for timed irrigation was expected, as it is well documented that incorrectly timed irrigation causes high leaching fractions. In some cases the leaching fraction can be as high as 50 to 80 per cent under overhead irrigation (Cresswell & Huett 1996). Although these figures are substantially higher than values recorded during this trial, the leaching fractions of 24% for deficit and 35.4% for timed irrigation recorded are still greater than the 12% leaching fraction suggested by the NGIA best management practices. This suggests that irrigation applications were too high and water use could have been further reduced.

Conversely, the leaching fraction for Ech2o SMS scheduling (4.9%) is considerably lower than the 12% target, suggesting the programmed trigger points were too low. When comparing the total applied water, Ech2o SMS scheduling had a higher water application than the AquaSpy SMS scheduling but a lower leaching fraction. This also suggests that the Ech2o SMS scheduling trigger points were incorrect, although a medium-specific calibration had been conducted.

Leachate Nutrient Analysis

To determine if fertiliser leaching due to scheduling practices had an influence on the available nutrients for plant growth, analyses of nutrient concentrations within the leachate were conducted. Although there was some variation in the nutrient concentration in the leachate between irrigation scheduling practices and media types, none were statistically significant and no identifiable trends were determined.

The EC of the leachate remained relatively constant for all irrigation scheduling practices throughout the trial period, with minor fluctuations between the media types. However, the interaction of irrigation scheduling practice and pH was significant, with a greater increase in pH (becoming more alkaline) under timed scheduling than under deficit scheduling or both soil moisture sensor controlled irrigation treatments.

An analysis of concentrations of nitrate (NO_3), nitrite (NO_2), potassium (K) and phosphate (PO_4) in the leachate was also conducted to determine whether the different scheduling practices had an effect on fertiliser retention. Again, variations in concentrations were observed (Figure 9), but no statistically significant trends between nutrient concentrations in the leachate and irrigation scheduling practices were found. However, there was a significant difference in NO_3 concentrations for the Echo2 soil moisture sensor controlled irrigation around week nine after planting. This coincides with the period of sensor connection failure that caused a continuous irrigation event, thus leaching more nutrients from the container.

Table 4: Statistical results of nitrate concentrations in container leachate.

Nitrate NO_3 - 5/11/07		
Ech2o SMS	1.69	a
AquaOne SMS	0.68	b
Evapotranspiration	0.67	b
Timed	0.49	b

Fine-tuning the irrigation application to the infiltration rate of the media mix has the potential not only to reduce water use but also to allow fertiliser to remain in the container longer, and therefore make more nutrients available for plant use (Rolfe et al. 2000, Lieth et al. 1991, Newman et al. 1991, Oki & Lieth 1997). The associated effect of reduced fertiliser leaching has a two-fold effect. Firstly, fertiliser applications are fewer, leading to reduced fertiliser costs and less labour time to apply the fertiliser (Cresswell & Huett 1996).

Secondly, with reduced fertiliser leaching from the containers there is a reduction in nutrient being washed down the drains and accumulating within water storage facilities (i.e. dams, local creeks, rivers or wetlands) which reduces the environmental impact of nursery production. Oele (1996) also found that correct irrigation scheduling and the use of organic matter in growing media can help to reduce nutrient leaching to environmentally acceptable levels. Another study found that media type had a definite influence on phosphate leaching and media with higher organic content can reduce fertiliser leaching due to the buffering affect between organic matter and water (Marconi & Nelsen 1984).

Although the statistical analysis of this trial did not find any significant interaction between nutrient leaching and irrigation scheduling practices, other studies suggest that using organic media and an appropriate irrigation scheduling technique can reduce nutrient leaching. Furthermore, monitoring nutrient levels in leachate may provide another method of determining appropriate irrigation application while reducing the environmental impact of a nursery.

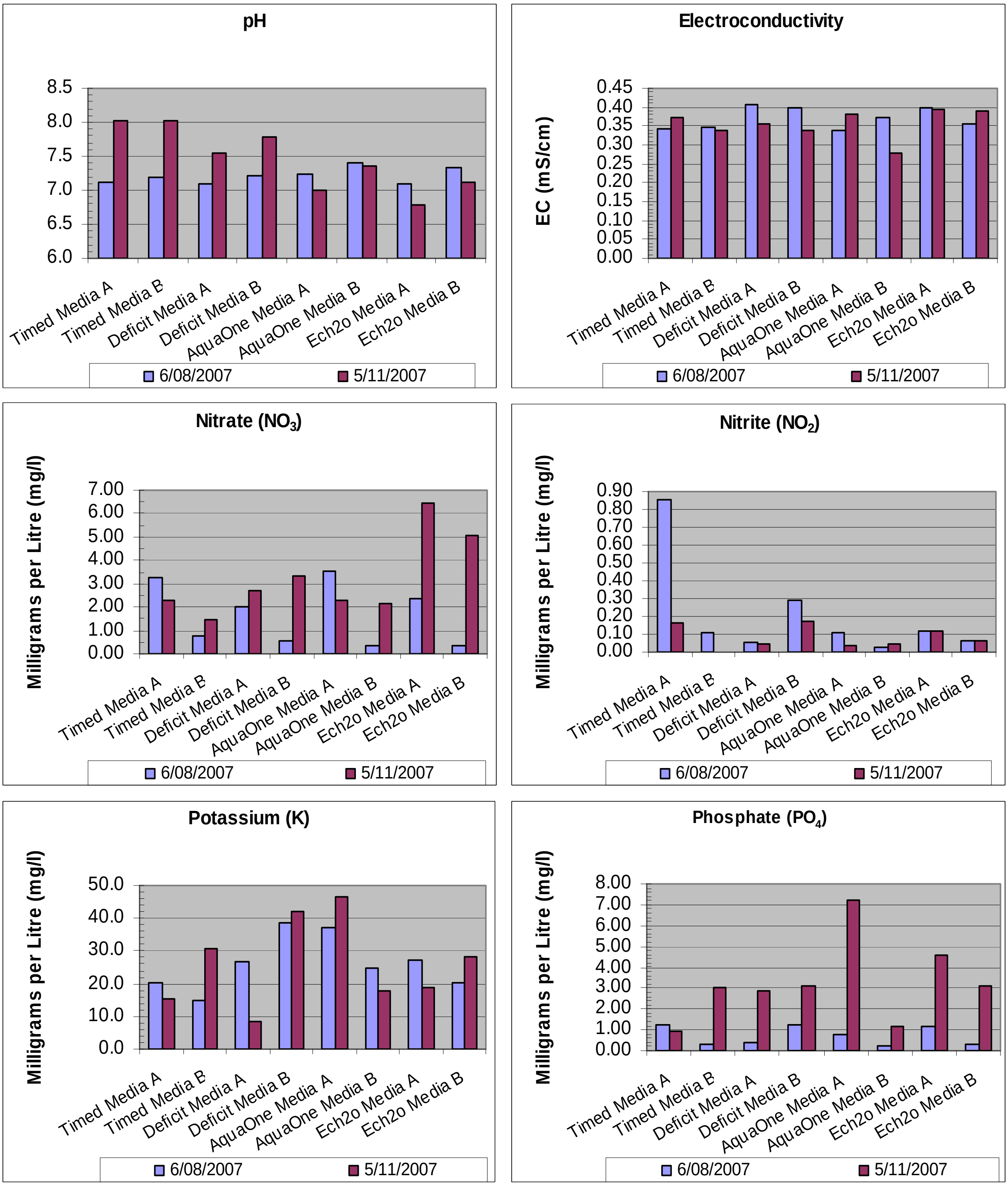

Figure 9: Representation of the nutrient concentrations in the captured leachate.

Container temperature

The temperature data collected from primary containers was analysed to determine whether container placement, media type and the different scheduling practices had an effect on container temperature, or whether the soil moisture sensors influenced container temperature. There was no identifiable effect on temperature relating to container placement, and no identifiable continuous trend over the course of the trial relating to irrigation scheduling practice or media type. However, there were several isolated effects on temperature due to scheduling practice.

At nine weeks after planting, media B showed a slightly higher maximum temperature than media A, but this difference was not present in the previous or following weeks. During this period weather conditions at Redlands Research Station were varied, with isolated daily storms occurring irregularly. Although the trials were conducted in a poly-tunnel fitted with an environmental controller, the rapid changes in climatic conditions were too great for the environmental controller to accommodate. Diurnal fluctuations in atmospheric temperature and solar radiation level during this irregular storm period are suspected to have influenced this result, as no other statistical difference in temperature between media types was found.

Apart from the expected temperature changes due to seasonal changes, the soil moisture sensor controlled treatments had a lower minimum and medium temperature in weeks 6, 8 and 16 after planting (Table 5). Week 16 also had varying higher temperatures under the soil moisture sensor controlled irrigation than under the deficit or timed scheduling (Figure 10). However, statistical analysis did not identify any temperature trend that could be specifically contributed to either an irrigation scheduling practice or media type. Therefore temperature was not considered to be an influencing factor during this trial.

Table 5: Statistical results of temperature analysis.

	Minimum		Median				Maximum	
	Week 16		Week 6		Week 8		Week 16	
Deficit	16.7	a	23.5	a	24.6	a	30.2	b
Timed	16.7	a	23.5	a	24.5	ab	30.7	ab
AquaOne	16.4	b	23.3	ab	24.1	bc	31.7	a
Echo	16.4	b	23.1	b	24.1	c	31.2	a
SEM (ET)	0.06		0.08		0.10		0.28	
SEM (other)	0.09		0.12		0.15		0.39	

NB: Different letters indicate a significant difference between irrigation scheduling types (P<0.05).

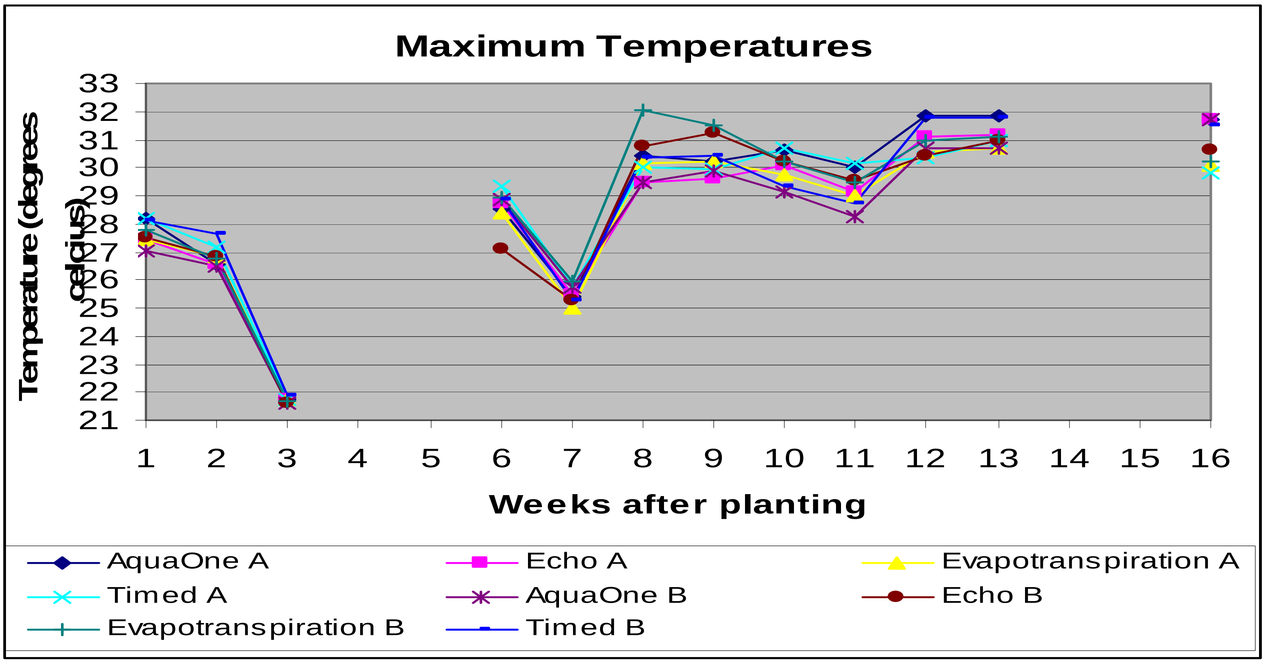

Figure 10: Maximum primary container temperatures for the different irrigation scheduling practices.

Deficit Irrigation or Evapotranspiration (ET) Irrigation Scheduling

An electronic weather station was installed in the poly-tunnel to monitor temperature variations and identify ET losses over the course of a day. This value was entered into the Teven Logic irrigation controller deficit irrigation program to control irrigation for the deficit treatments. The program allows the operator to input a value in millimetres of lost water from the container which can be tailored for different container volumes, or it can be set up to control several groups of growing areas simultaneously. Once the TL program parameters have been set, it is a simple process of entering the ET value from the previous 24-hour period.

However, after monitoring water loss from the containers due to plant water use, observations suggested that the actual water loss from the container was greater than the ET value calculated from the internal weather station. This variation could be contributed to the weather station using a turf reference in the Penmen-Monteith equation to calculate ET and not a plant-specific crop factor. If a plant-specific crop factor was known for this trial, the deficit irrigation scheduling treatment could have been fine-tuned and potentially would further reduce water use. The Penmen–Monteith equation is a recognised method for calculating ET. However, studies have shown that using a modelling equation rather than physical data affects the accuracy of the results (Kirnak et al. 2002). Many other studies have been conducted exploring the intricacies of this equation and are far too detailed for a simple description here. (For a greater discussion of the Penmen–Monteith equation and how ET values are calculated, refer to the discussion papers by Meyer (1999) and Allen et al. (1998)). For general nursery use this method of calculating ET is sufficient due to the diversity of plants grown within most nurseries. It is recommended that nursery managers using electronic weather stations to calculate ET are aware that a generic ET value does not represent all plant varieties and due to water requirements some plants could still be under- or over-watered.

Conclusion:

One of the initial questions posed at the beginning of this project was: “Do soil moisture sensors have the potential to increase water use efficiency by automating irrigation frequency and duration?” In short, the results of the trials suggest that the answer is yes. The results have shown that the use of a SMS to automate irrigation scheduling can improve water use efficiencies and reduce container leaching more so than can timed or deficit irrigation scheduling. In these trials, plant growth was not affected by the reduced water application of the different irrigation scheduling practices, and media type only showed small or limited significance in interaction with all scheduling practices.

Soil moisture sensors can also be used to adjusted irrigation applications to suit container moisture content, daily climatic conditions, and match the absorption rate of the media mixes. With further observations and an understanding of specific plant water use, SMS would allow irrigation scheduling to be tailored for different plant species or irrigation groups. However, setting the correct trigger points for automation is necessary to ensure appropriate irrigation. This requires a medium-specific calibration to be conducted, but depending on the type of sensor, the connection type and the media characteristic, this would need to be conducted on a regular basis to ensure the correct trigger points are determined.

As a diagnostic or monitoring tool, a SMS can identify problems or faults with the irrigation system. For example, line blow-outs or problem solenoids causing either no irrigation or excessive irrigation would be reflected in the SMS readings as reduced or increased moisture content in a container.

Although SMS can be used for irrigation scheduling, there are other issues that need to be addressed when considering implementing a soil moisture sensor-based irrigation scheduling practice. Irrigation uniformity will have a major bearing on the effectiveness of sensor-based irrigation. Considerable money could be spent installing and implementing these new technologies but if the irrigation system’s uniformity and efficiency are poor, new scheduling technologies will not improve production and profitability.

Unfortunately, the issues identified with installing and implementing an SMS-based scheduling practice could limit the use and uptake of these technologies. A greater focus on implementing a deficit irrigation scheduling practice while upgrading to new technologies will improve water use efficiency, and has the potential to reduce operating costs through reductions in water, fertiliser leaching and labour time.

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Part 2
Retrofit of Nurseries to Industry Standard – Water Use Efficiencies and Economic Assessment

David Hunt, Scientist, Department of Primary Industries and Fisheries, Qld

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Many thanks go to Rod Strahan, Senior Agricultural Economist from DPI&F Toowoomba for sorting through all the financial data and conducting the cost benefit analysis. Also for developing the 'Nursery Production Economic Model' that will allow the nursery industry to conduct independent cost benefit analyses.

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Summary

Irrigation uniformity and water use efficiency have become major drivers in the future of many production nurseries throughout Australia. How to maintain production while reducing water use and without increasing operating costs is the question being asked by many nursery managers.

This project focused on retrofitting irrigation systems with an aim to improve water use efficiencies and to identify the costs involved. The project has delivered water use savings of between 28 to 55 per cent in commercial nurseries, with those reliant on potable town water achieving water and associated cost savings in excess of $16,000 a year. One nursery has reduced its town water use from 70 to 13 per cent, with town water cost savings of approximately $19,000 per year.

Retrofitting nursery irrigation systems and conducting cost/benefit analyses has revealed a number of potential benefits:

- The efficiencies gained by the new irrigation systems has allowed greater use of alternative water sources and much less use of town water.
- The significant water savings gained from the new irrigation systems dramatically reduced the pressure on dam supplies to provide the required water, which was especially significant in recent dry climatic conditions.
- The new irrigation systems provided an even distribution of water, resulting in increased growth uniformity, a decrease in the number of plant throw-outs and savings in variable costs and labour inputs.
- The new irrigation systems required less water pressure, thus reducing wear on pumps and pipes and providing significant savings in electricity costs.
- The drainage systems channel excess water back to the dam for reuse.
- The efficiencies gained by the new irrigation systems have resulted in a much drier plant area, which is likely to reduce conditions for disease.
- The drier plant area creates a safer, more efficient working area, including paths and roads.

However, the extent of savings achievable is dependent on a nursery’s water source and the inefficiency of the old irrigation system. The positive results achieved from the installation of more efficient nursery irrigation systems provide a robust business case to encourage nursery owners to invest in more sustainable production technologies. Prior to the retrofits, the future of the businesses was questionable, but now the owners have effectively 'future proofed' their nurseries for many years to come.

Introduction

Water use efficiency and managing water resources is of increasing concern for many industries. Governments are now looking to water as an economic resource that can be bought and sold just as any other commercial product and are moving towards a full 'user pays' system (Rolfe et al. 2000, Yeager 1992, Irmak et al. 2003). The implementation of regulations and monitoring programs such as the Water Efficiency Management Plan (WEMP) or the Business Water Efficiency Management Plan (BWEMP) to ensure water use and users are accountable is putting more pressure on irrigation industries to responsibly use and manage water (Anon 2006). As water resource management bodies try to balance the allocation of water resources for domestic and industry use, those businesses that rely totally on town water supplies will feel the greatest impact.

Many nurseries are faced with using alternative water sources or investing in new technologies and implementing management programs to improve water use to remain open. This may appear to be a bigger burden on a nursery than the business can support, however improving water use efficiencies through a properly designed irrigation system and collecting runoff can have added benefits (Rolfe 2000). These benefits can be in the form of financial savings directly related to water use, electricity pumping costs, fertiliser costs and chemical costs. Or there may be benefits in the form of more efficient use of labour by reducing the time needed for crop and nursery maintenance, such as reduced chemical applications and order picking times.

Furthermore, poor irrigation efficiencies and uneven application can affect plant quality and uniformity of growth, leading to lost production. Inefficient irrigation affects crop production and plant quality by limiting the amount of water available for plant use, for example, through evapotranspiration (Dodds et al.2005). If irrigation uniformity is poor and some areas have insufficient irrigation while the plant's evapotranspiration is constant across the area, then the plant's transpiration threshold in areas of low irrigation application will be reached sooner and hence water stress will occur sooner, causing reduced in plant quality. Conversely, over-watering a crop can cause more damage to the plant due to water logging (Whalley 1991).

Whalley (1991) suggests 60 to 90 per cent of the water applied from overhead sprinklers is lost and does not make it to the container due to inefficient systems, wind effects, variations in crop canopy and growing bed slope. Neal (2002) states that overhead sprinkler efficiencies can be 75 per cent or lower for field nurseries due to wind effects and evaporation, while at least 25 per cent of applied water is lost in container nurseries due to container spacing and foliage interception. This highlights not only how important it is to operate an efficient irrigation system, but also how inefficient many old systems are. Therefore, addressing the inefficiencies of an irrigation system is of paramount importance.

An efficient irrigation system must apply sufficient water to a plant within the allotted time to maintain optimum growth without wasting water. This is dependent on several design parameters such as sprinkler type, the spacing between sprinklers, the shape of the area to be irrigated, operating pressure and height of the sprinkler above the crop (Rolfe et al. 2000, Rolfe 2000). Other factors that can effect the efficiency and uniformity of a system include pipe friction losses, elevation changes, wind drift and evaporation losses. These physical and climatic influences cannot be controlled by an irrigation system but can be lessened by a well-designed and efficient system (Christen et al. 2006, Haman and Pitts 2005, Rolfe et al. 2000).

This project was commissioned to carry out nursery retrofits, quantify achievable water savings and provide cost/benefit analyses to determine the extent of the influence a well-designed and efficient irrigation system can have on water use and operating costs.

Two production nurseries were identified which were working towards Nursery Industry Accreditation Scheme Australia (NIASA) accreditation. They required an irrigation system upgrade and had the potential to collect runoff for reuse. Both nurseries were assessed to determine the efficiency of the existing irrigation system and runoff collection capability. An irrigation specialist was hired to design and install the new irrigation system, according to the Nursery and Garden Industry Association's (NGIA) best management practices for irrigation design.

When the two nursery retrofits were completed, the water use efficiency and operating cost data were collected and compared to two other nurseries that had undertaken a private retrofit. A cost/benefit analyses of the four case study nursery irrigation retrofits was carried out in order to determine the economic implications to each nursery business. The economic and financial impacts of the retrofits were compared with the base case scenarios before changes were implemented. The results of the water saving and cost saving assessments from these case studies will enable the nursery industry to quantify the benefits of adopting water saving technologies.

This report presents the water savings achieved and the economic results obtained from the retrofits, and explains some of the compromises required when retrofitting an older nursery. Furthermore, the project has led to the development of a generic economic decision model for the nursery industry to assess proposed changes to a business, specifically in regards to water saving technologies, before investment is made. This model will allow growers to plan and implement water use efficient technologies based on a return of investment.

Case Study Nursery 1 - *Landscape plant nursery*

Nursery description and old irrigation system

Nursery 1 has approximately 0.8 of a hectare under production on a large flat block, with an 8 megalitre dam positioned behind the owner's house and adjacent to the production area. Irrigation was a combination of potable town and dam water supply using a direct-on-line or constant pressure system set at 85 psi (586 kPa). The dam water is extracted by two Lowarra pumps fitted with Hydrovar controllers via two slow sand filters. A town water supply was connected to the mainline after the sand filters. The irrigation system was driven by the town water pressure, with the pumps providing back up. A gate valve on the town water supply line was used to regulate the volume of town water needed, depending on the level of water remaining in the dam.

Combined daily water use (kilolitres per day) was not monitored and actual daily water use figures were not known prior to fitting a water metre to the pump line three months before the retrofit.

The two slow sand filters represented the only disinfestation system in place. Disease control was achieved purely by chemical spraying of the plants on the growing beds, usually once every two weeks for weed and fungus control, and on an adhoc basis for other pathogens as they were identified.

The outside growing areas were comprised of three large rectangle areas, each with four or five irregular irrigation zones and two smaller areas divided into three irrigation zones. There were two propagation igloos, a small propagation shadehouse and a larger shadehouse, as well as a large tunnel-house. The propagation igloos and small shadehouse were not included in this retrofit, as they were operated separately from the main nursery areas and only irrigated with town water (Figure 13).

The sprinkler system had been installed and later extended to accommodate the growth of the nursery over a 15-year period and to address dry patches throughout the growing areas. A two-inch poly pipe main line ran across the growing beds and fed the PVC sub-mains and laterals. Various sprinkler types were used throughout the nursery, with some areas having two or three sprinkler types within the same irrigation zone. Riser heights also varied within the same irrigation zone, from 1.2 metres to 2 metres. Lateral spacing, on average, was 6 metres by 8 metres, but in places extended to 10 metres.

The nursery had the potential to collect and return all excess irrigation runoff and rain to the on-site dam; however, the collection drains had suffered from limited maintenance and the efficiency of the drainage was poor. The growing beds had been compacted and much of the surfaces had sunken, causing the runoff to pool either on the growing beds themselves or in the walkways. Therefore the majority of the irrigation runoff was not returned to the dam.

This excessive water pooling throughout the growing beds also led to increased fungal and algal growth. Many of the walkways and growing beds had a waterway plant (*Azolla* sp.) permanently growing across some areas. The sunken beds, excessive water pooling and accumulation of potting media within the gravel provided an ideal growing environment for weeds, algae and pathogens. To combat the growth of weeds, fungi and algae, regular spraying of herbicides and fungicides was required. During rainfall or prolonged irrigation, these chemicals and leached fertiliser were being washed into the dam, causing algal blooms and a distinctly unpleasant smell associated with the first stages of eutrophication.

Although the nursery was profitable and was an on-going concern, staff morale at times was low due to the conditions in which they worked. On several occasions, staff commented on the need to work in mud-ridden areas that hampered their work progress and the need to weed individual containers before dispatch. During high rainfall events, areas of the nursery became “a river of water”, further hampering staff duties and consequently levels of productivity.

After a walk-through survey it was determined that improving the efficiency and uniformity of the irrigation system would address several issues affecting the day-to-day working of this nursery (the walk-through survey and recommendations for both nurseries are presented in the Appendix).

It was determined that an upgrading of the growing beds would considerably improve runoff capture and drainage of the beds. Unfortunately the upgrading of the growing beds was not included in the retrofit project. However, the nursery owner has started to upgrade the growing beds by levelling, re-grading and re-gravelling to allow more efficient drainage into the collection drains. The collection drains are to be cleaned and re-shaped with ‘trash traps’ installed to capture any debris washed from the growing areas. Once the upgrade of the nursery’s drainage is complete, a greater return of irrigation runoff to the dam will be achieved and the true potential water savings for this nursery will be realised.

New irrigation system

The equipment choices and design of the new system were determined by the irrigation specialist and approved after discussions with the nursery owner, the Nursery & Garden Industry Queensland (NGIQ) industry development officers and an independent irrigation consultant.

The brand of sprinklers and solenoids used was at the discretion of the irrigation specialist and was chosen for:

- the efficiency ratings, which needed to be equal to or better than NIASA standards;
- the mean application rates required;
- the ease of installation;
- cost, including associated costs such as parts replacement and lateral connectivity; and
- the simplicity of design, allowing for quick and simple maintenance by nursery staff.

This project did not involve altering the original pumps or sand filters, as both units had been recently serviced and were operating to the level required for the new system. Unfortunately, due to the condition and limited capacity of the original mainline, all piping needed to be replaced back to the slow sand filtration system. A manual water metre with pulse output was installed at this point to monitor water use and flow rates for the disinfestation system. The original irrigation controller was retained and reprogrammed to suit the new irrigation system (Table 6).

Table 6: Case Study Nursery 1 - Irrigation system specifications

Irrigation system specifications	
Pumps	Original 2 Lowarra 2.2 kW variable frequency drive with Hydrovar controllers Irrigation zones operating pressure 200 kPa (2 bar or 29 psi)
Control solenoids	Irritrol 2 inch solenoids used for all outside growing beds and a Toro 1.5 inch pressure regulating solenoid for the shadehouse and tunnel-house
Lateral spacing	Outside growing areas = 5 m x 5 m; shadehouse = 4 m x 4 m; tunnel-house = 3 m x 3.6 m
Risers	Riser heights set at 1.5 m; riser supports were 10 mm galvanised rod held in place by 1.2 m star pickets; riser pipe was a 12 mm flexible poly pipe connected to the laterals line via a press-fit connector
Upright sprinklers	Plastro Rondo XL 360^{o} sprinklers with a Brown jet used for all outside growing areas (modelling specifications: CU 85%, SC 1.1, MAR 8.4 mm/hour)
Inverted sprinklers	Plastro Rondo inverts with white jets used in tunnel-house (modelling specifications: CU = 98, SC 1.02, MAR 12.8 mm/hr); Plastro inverts 360^{o} with red jets used in shadehouse 4 (modelling specifications: CU 97, SC 1.1, MAR 5.7 mm/hour).

Pressure-regulating solenoids were installed on the shadehouse and tunnel-house due to the pressure fluctuation within the main line. The small number of sprinklers used within the shadehouse and tunnel-house were affected by the drop in pressure during the response times of the hydrovar. Pressures fluctuated in some cases by 100 kPa, which affected the application uniformity. Prior to installing the pressure-regulating solenoids, application uniformity was irregular and below standards, with a CU of 80.6, a SC of 1.71 and MAR varying between 4.3 mm/hr and 5.1 mm/hr.

Theoretically, the hydrovar pump controllers should have been able to adjust the main line pressure to maintain the required operating pressure. However, the lag time associated with pressure reductions in the main line and response timing of the pump controllers was too great for the pumps to overcome the small flow rates needed for the shadehouse and tunnel-house. This issue did not affect the outside growing beds due to the larger number of sprinklers per irrigation zone and the higher application and flow rates.

Disinfestation

The old irrigation system did not include any form of disinfestation other than the two slow sand filters. No infrastructure was in place to accommodate the Aldos chlorine dioxide EcoOxi disinfestation unit chosen for installation. Although the disinfestation unit itself was small and easy to install, the main issue that confounded the installation was how to provide the required contact time for disinfestation. Initially a ring main was to be run around the boundary of the property to provide the three to four minute contact time. Unfortunately due to existing structures and costs involved, this was not practical, and space limitations restricted the installation of a holding tank.

Instead, the innovative method of burying two joined rolls of 75 mm poly pipe behind the dam was chosen. This added an extra 200 metres of pipe to the main line and offered an added benefit of keeping the water cool while it was being treated. The benefit of this method was that no added expense was incurred to install a holding tank or ring main and labour costs were reduced. Furthermore, the area in which the coils were buried was an unused area that was too unstable for a holding tank and is subject to high levels of rainfall runoff during wet periods. This resulting arrangement has proven to be unobtrusive and easily accessed for maintenance if required.

Sprinklers and spacing

A lateral spacing of 5 metres by 5 metres was chosen for all outside growing areas. This spacing has been identified by NGIQ officers to offer an efficient application uniformity and provides growing beds of a manageable size. The spacing allows the irrigation system's operation pressure to be reduced, which in turn reduces pumping time and pumping expense. Also, the irregular shape of the existing growing beds better accommodated a smaller spacing and allowed for a greater number of smaller irrigation zones per bed. The smaller irrigation zones provided the manager with the ability to switch off particular zones when empty without altering the operation of the broader irrigation system. The system also allows for further reductions in water use.

Lateral spacing varied for the protected structures, shadehouse and tunnel-house. The spacing was chosen to provide the best uniformity of application according to the structure. For example, lateral and sprinkler spacing for Shadehouse 4 was 4 metres by 4 metres, compared to the 3 metre by 3 metre spacing that was initially chosen. This change was due to the position of the structure's support posts. The 3 metre spacing would have caused the inverted sprinklers to fall directly next to the support posts which were positioned at 6 metre intervals. This would have blocked the path of the water and caused a shadow effect, reducing the uniformity and leading to the creation of dry patches.

The tunnel-house spacing was initially 5 metres by 5.2 metres, but preliminary tests showed that application uniformity at this spacing was poor. The spacing was changed to 3 metres by 3.6 metres to accommodate the shape of the domed roof and to avoid minor application shadow effects due to the support posts.

Water use and irrigation efficiency

The water use figures used to calculate daily and yearly water use were an estimate calculated from town water use records and an in-line mechanical water metre fitted to the dam water supply line two months prior to retrofit work being carried out. These figures were used to calculate the yearly water use by means of extrapolation from irrigation scheduling times and seasonal adjustment. Unfortunately no other daily water use records were available for this nursery, hence minimum and maximum calculations are presented to account for possible variations. The nursery manager agreed with the estimated daily water use values and has now implemented a water use monitoring schedule.

Under the old irrigation system, the maximum daily water use varied from 48 kilolitres per day during winter to 72 kilolitres per day during summer, with town water making up 69 to 72 per cent of the daily irrigation. This equated to a combined water use ranging from 20 megalitres to 23.5 megalitres per year.

Under the new irrigation system, maximum daily water use ranged from 25 kilolitres per day during winter to 50 kilolitres per day during summer, with town water making up 8 to 12 per cent of daily irrigation. Yearly water use under the new system is estimated to be between 11 megalitres to 14 megalitres, a saving of 8.9 megalitres to 9.5 megalitres. This equates to a reduction in yearly water use of 40 to 44 per cent compared to the old irrigation system.

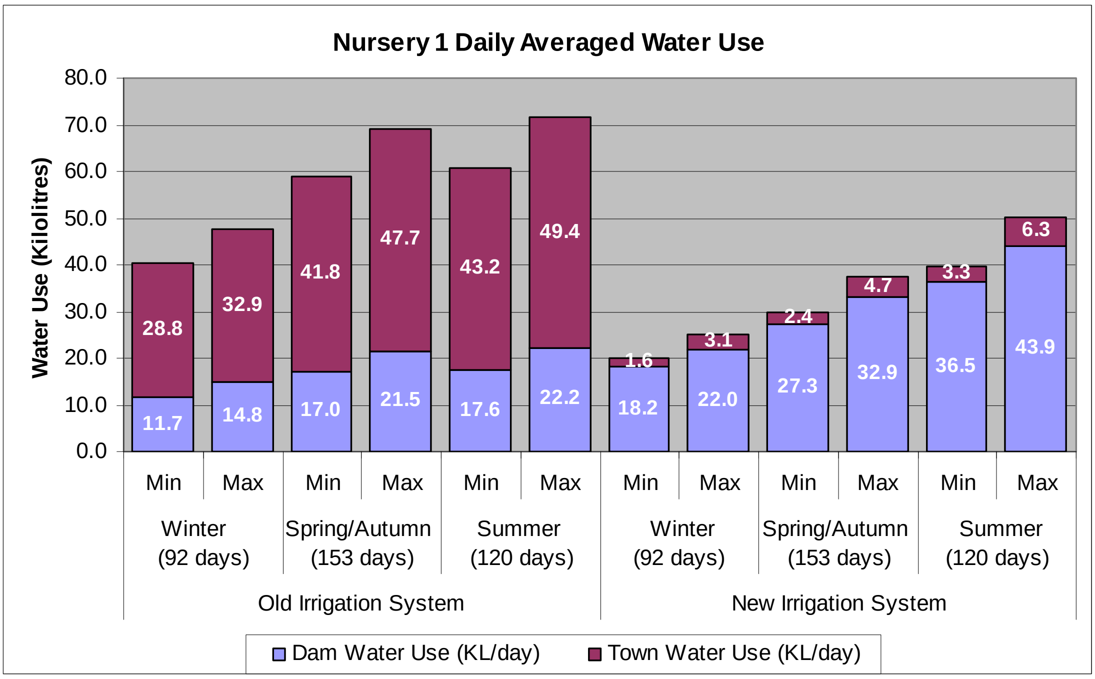

Figure 11: Comparison of average daily use of town and dam water per season under old and new irrigation systems

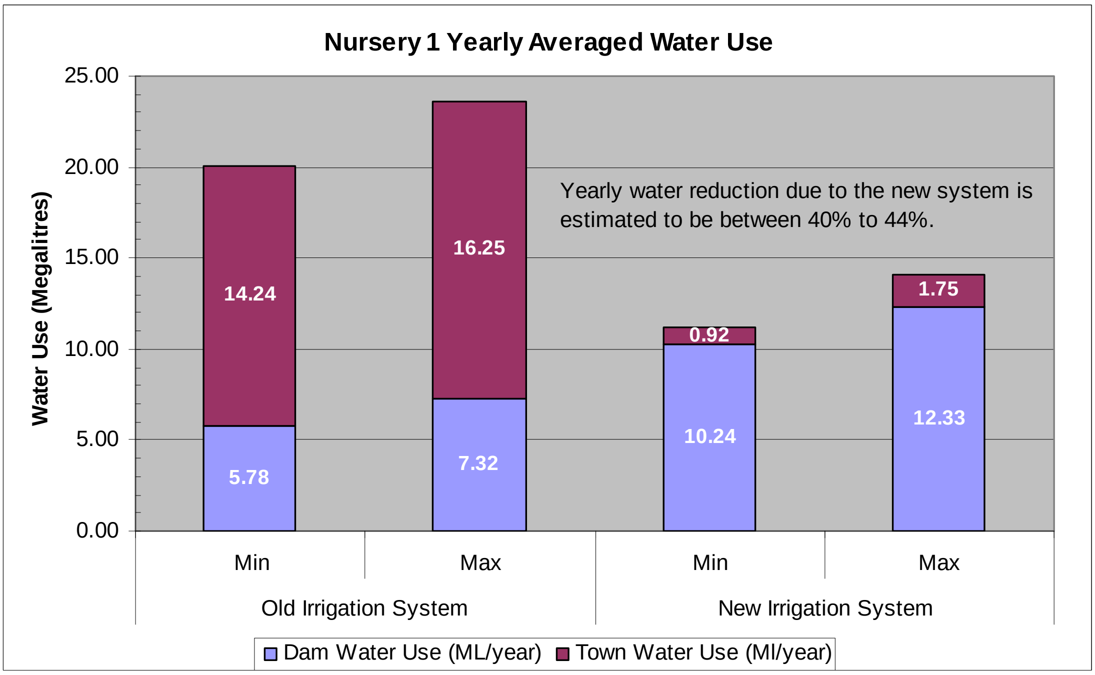

Figure 12: Comparison of average yearly water use under old and new irrigation systems

Water use calculation assumptions:
1) Water metre readings used for calculations represent actual water use for the seasonal period in which they were recorded.
2) Percentage increase or decrease in irrigation timing is not altered during the season.
3) Variation between seasonal irrigation periods is consistent, e.g. irrigation controller timers are changed on the same day each year.
4) Calculations do not take into account any reduction or pausing of the irrigation system for rain days.
5) Calculations do not take into account turning off irrigation for one or more zones when growing bed is empty.
6) Water use calculations include all water used on-site including that not directly used in crop irrigation, e.g. equipment cleaning.

The irrigation efficiency of the outside growing areas under the old system varied dramatically, with the co-efficient of uniformity (CU) ranging from of 47% through to 82% and scheduling co-efficient (SC) ranging from 2 to 7. Shadehouse 4 and the tunnel-house had CU values of 54.5% and 60.4% and SCs of 3.63 and 5 respectively. While the mean application rate (MAR) for all areas was within the industry parameters, they varied considerably between irrigation zones (6 mm/hr to 13.1 mm/hr).

The new irrigation system has improved irrigation efficiency significantly and all irrigation zones now fall within NIASA standards. The outside growing beds now have a CU of 86.5 to 95.9% and a SC of 1.11 through to 1.41. MAR still vary between growing beds but are relatively constant between 8.6 mm/hour and 10.7 mm/hour. MAR for Shadehouse 4 and the tunnel-house varied from these rates, as the system was tailored to suit the purpose of each area.

Shadehouse 4 is a well-protected propagation transitional area that required a reduced MAR and a pulse watering schedule to suit the infiltration rate of the plug and seedling trays. A smaller jet delivering a finer droplet size was chosen to reduce the application rate to 5.1 mm/hour. The tunnel-house contains plants with higher water use rates and required a higher application rate (12.9 mm/hour). A map of the nursery with the new and old water use efficiency values for the different irrigation zones is shown in Figure 13.

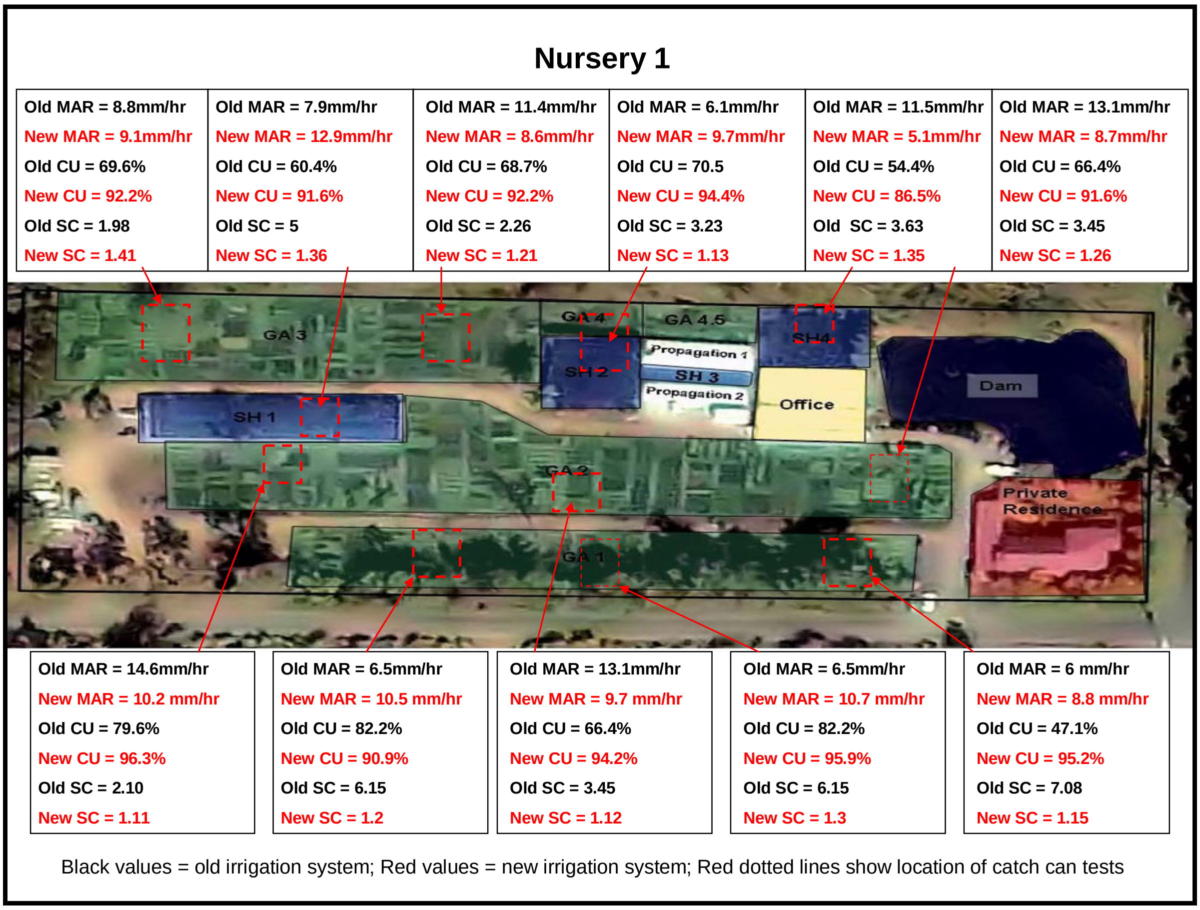

Figure 13: Irrigation efficiency values for different irrigation zones under old and new irrigation systems

Irrigation scheduling

Although irrigation uniformities and mean application rates varied under the old system, irrigation scheduling for all areas was a standard timed 10 minutes. This standardised approach left areas of poor uniformity and low MAR under-watered. The nursery manager would inspect the growing areas daily and determine which areas needed supplemental irrigation. The extra irrigation events were triggered manually and had to be timed around daily staff duties. At times this required the manager to alter the scheduled staff duties or wait until staff had signed off before an irrigation event could be triggered.

The improved uniformities and more consistent MAR of the new irrigation system not only negated the need for extra irrigation events but also allowed the duration of the irrigation events to be reduced. Providing a higher application rate for the tunnel-house meant that the standard timed schedule (10 minutes) could be maintained without any disruption to daily staff duties. Also, by tailoring the MAR for Shadehouse 4 and implementing more frequent lower applications (pulse watering), media moisture levels were consistent without excess leaching of the fertiliser. Furthermore, the propagation supervisor has commented that with the new tailored system, management of this shadehouse has become more efficient, media loss due to droplet impact has been reduced, and daily supplemental hand watering is lower.

Table 7: Irrigation scheduling times for old and new irrigation systems

Nursery 1	Old system		New system	
	Morning	Afternoon	Morning	Afternoon
Winter	15	0	10	0
Spring/Autumn	10	10	10	5
Summer	15	10	10	10

NB: These times do not reflect irrigation scheduling for Shadehouse 4, which has a pulse watering schedule that is being fine-tuned.

Cost of retrofit

The costs listed in Table 8 are directly related to the irrigation system retrofit and do not include the cost of upgrading the growing beds or collection drains. The upgrade to the growing beds and collection drains are included in the economic analysis to represent the actual cost of the whole of nursery retrofit.

Table 8: Cost breakdown of Nursery 1 retrofit by growing area

		Irrigation zones		Cost of retrofit		Total
Growing Area	**Size**	**Old system**	**New system**	**Equipment $**	**Labour $**	**$**
Tunnel-house	517m^2	2	2	2630.4	1331	3961.4
Shadehouse 2	369m2	Removed and converted to outside growing pad; extension of GA4				2206
Shadehouse 3	58.9m2	Not retrofitted; propagation house using town water; managed separately from the rest of the nursery				350
Shadehouse 4	248m^2	1	1	1036.13	625.00	1661.13
Growing area 1	1524m^2	5	4	4449.00	3048.00	7497.00
Growing area 2	3059m^2	6	4	4677.20	2796.85	7474.05
Growing area 3	1980m^2	5	4	3527.99	1717.22	5245.21
Growing area 4	541.8m^2	1	1	970.56	472.42	1442.98
Growing area 4.5	198.7m^2	1	1	354.25	172.43	526.68
Mainline installation (includes 2 x 100 m coils of pipe for disinfestation contact time)				5875.00	1650.00	7525.00
Trenching for main line - subcontractor					700.00	700.00
			Irrigation system retrofit = $	23520.53	12512.92	36033.45
					Chlorine dioxide disinfestation system ECOOXI, Type A = $	8561.00
					Total cost of retrofit Ex-GST + $	**44594.45**

NB: Shadehouses 2 & 3 were initially included in the quote but were not refit during this project. These costs are not included in the final costing.

Economic assessment

The economic assessment figures vary slightly from the water use calculations stated previously. The previous figures were based on the daily seasonal change in water use associated directly with the irrigation retrofit. The figures used for the economic analysis are averaged annual figures that incorporate all nursery water use, including the propagation areas and residential water use.

Prior to the retrofit, the nursery's water use was 70% town water and 30% dam water. The changed irrigation system allowed a substantial reduction in town water use and a greater use of the available dam water. Table 9 indicates the changes in water use.

Table 9: Annual water use results for Case Study Nursery 1

Annual water usage	Old system	New system	Change
	(Klitres water/year)	(Klitres water/year)	(Klitres water/year)
Town water	15,221	1,314	-13,907
Dam water	6,534	10,996	4,462
Total water usage	**21,755**	**12,310**	**-9,445**

The retrofit has provided annual water savings of 9.4 ML, a reduction of 43% from the previous system. The new system uses 87% dam water and only 13% town water. The significant reduction in town water use represents combined water and associated cost savings of around $24,000 per year after an adjustment for depreciation. Plant throw-outs have been reduced from 10% of annual plant production to 6%.

Table 10: Associated cost savings achieved due to the retrofit, before adjustment for depreciation

New System Benefits	$ Savings
Town Water Cost Saving	$24,058
Pumping Costs Savings	$1,500
Throw Out Labour Savings	$3,000
Throw Out Savings	$3,271
Total Benefit	$31,829

The benefits of the system changes are:

- The efficiencies gained by the new irrigation system allowed greater use of alternative water sources and much less use of town water.
- The significant water savings gained from the new irrigation system dramatically reduced the pressure on dam supplies to provide the required water, which was especially significant during the recent dry climatic conditions.
- The new irrigation system provided an even distribution of water, resulting in increased growth uniformity, a decrease in the number of plant throw-outs and savings in variable costs and labour inputs.
- The new irrigation system required less water pressure, thus reducing wear on pumps and pipes and providing significant savings in electricity costs.
- The drainage system channels excess water back to the dam for reuse.
- The efficiencies gained by the new irrigation system have resulted in a much drier plant area, which is likely to reduce conditions for disease.
- The drier plant area creates a safer, more efficient working area, including paths and roads.

Conclusion

This nursery has benefited more from the retrofit than just a substantial reduction in water use. The increased profitability as a result of money saved through reducing the reliance on town water has proven to be significant and substantially more than initially anticipated. Improving irrigation uniformity and reducing water use has resulted in a reduction in a variety of other operational costs, including those related to fertiliser and chemical use. Uniformity of plant growth has been improved, leading to a reduction in throw-outs and a reduction in labour time relating to crop maintenance. A reduction in pumping times and operating pressure has reduced pump duty and wear, and has stopped line blow-outs previously caused by higher operating pressures.

Furthermore, growing beds are drier and disease outbreaks are noticeably lower due to a reduction in excess irrigation. The potential return on investment for this nursery is significant as, coupled with the substantial savings, a corresponding increase in business income is anticipated. Prior to this retrofit, the long-term future of the nursery was questionable, with the owner considering closing down due to water supply concerns and the increasing cost of water. Now, the owner can see a future for the nursery and has plans to upgrade his second nursery to the same standard.

Case Study Nursery 2 - General ornamental nursery

Nursery description and old irrigation system

Nursery 2 is a 5.67 hectare property with 1.22 hectares under production. It has been in operation for generations and has been extended several times. It is positioned on a hill, with a retail nursery and offices at the front of the property and production areas positioned at various locations down the property. One open growing area and two shadehouses are located high on the hill behind the retail nursery. One open growing area is positioned halfway down the hill, while another open area and shadehouse is located in the lower section. The dispatch area and a 13.5 megalitre dam are located at the bottom of the property. The nursery is dependent on the dam for irrigating the production areas and only uses town water for the propagation igloo. The igloo is semi-automated with a fogging and irrigation system that is run separately from the rest of the nursery.

A small pump house situated next to the dam houses the extraction pump, chlorine dosing pump and containers of chlorine. The water is pumped from the dam, injected with chlorine and passed through a large disc filter to 2 holding tanks on top of the hill. Prior to the retrofit, no water metres were fitted and daily water use was estimated from the volume of water left in the holding tanks at the end of the day and the frequency and duration of operation of the extraction pump.

Two Lowarra multi-stage pumps stationed next to the tanks maintained the direct-on-line or constant pressure irrigation system for both the retail and production areas at 345 kPa (3.45 bar or 50 psi). Two-inch rural poly pipe was used for all supply lines, with 20 mm PVC class 12 pipes used for all open growing area laterals and 25 mm PVC class 12 pipes for the shadehouses. Sprinkler risers were PVC supported by star pickets. Due to the age of the irrigation system and the constant movement of the PVC risers on the star pickets from sprinkler vibration, riser and supply line blow-outs were common.

The outside growing beds were well maintained and raised with a combination of weed matting and gravel that sloped to the concrete collection drains edging the beds. Sealed roadways and collection drains directed the irrigation runoff via a series of channels and underground pipes to the dam. Drainage ditches run along the property boundaries, allowing all rainfall to be channelled to the dam. Rocks and boulders were used to slow drainage flows, reduce erosion and collect any trash or sediment washed from the beds. The dam was surrounded with vegetation, which stabilised the banks and acted as a secondary trash and sediment filter.

Although the nursery was well maintained, the irrigation system reflected the age of the nursery. Moss and pope rotoframe sprinklers were used for most outside areas, except the small upper growing area that used a combination of Lego and impact sprinklers of unknown manufacture. Riser heights of approximately 1.2 metres were consistent throughout the nursery.

Sprinkler and lateral spacing, although consistent within each irrigation zone, varied between zones. Several outside growing areas, using the same sprinkler, had spacings varying between 5 metres by 5 metres and 5 metres by 8 metres, while another area had laterals tapering down from 6 metres to 2 metres to accommodate the shape of the bed. Rarely were sprinklers positioned at the edge of the beds. In general, sprinklers stopped one metre from the edge and nursery staff had identified dry patches within each irrigation zone where only selected plants were placed.

Two of the three shadehouses used inverted moss sprinklers at a different spacing, one at 2.5 metres by 3.2 metres, and the other at 8 metres by 5.6 metres with MAR of 50.6 mm per hour and 29.2 mm per hour respectively. The third shadehouse used inverted Nelsen S10 sprinklers at a 2.6 metre by 5.6 metre spacing. All shadehouses had thick patches of moss growing throughout. These application rates were taken into consideration when scheduling the irrigation; however, the three old timed-irrigation controllers were positioned at three different locations around the nursery. Each controller had to be re-programmed separately, was limited in its versatility and was time-consuming to adjust.

After the initial walk-through survey, it was determined that the growing beds and shadehouses required little or no work. However, an upgrade to the irrigation system would considerably improve water use efficiency and prolong the use of the available water. Also, streamlining the pipe work for the upper pump house and installing a variable frequency drive (VFD) pump controller to monitor and adjust operating pressures would reduce line blow-outs, pump wear and pumping costs.

Furthermore, replacing the three irrigation controllers and relocating the new controller to a central location would reduce the effort required to reprogram or correct the irrigation scheduling, thereby allowing scheduling to be adjusted to daily climatic conditions. The walk-through survey and recommendations for both nurseries are presented in the Appendix.

New irrigation system

The equipment and design of the new system were determined by the irrigation specialist and approved after discussions with the nursery owner, NGIQ industry development officers and an independent irrigation consultant. The brand of sprinklers and solenoids used was at the discretion of the irrigation specialist and was chosen for:

- the efficiency ratings, which needed to be equal to or better than NIASA standards;
- the mean application rates required;
- the ease of installation;
- cost, including associated costs such as parts replacement and lateral connectivity; and
- the simplicity of design, allowing for quick and simple maintenance by nursery staff.

The extraction pump in the lower pump house was not altered during this retrofit and all main lines were retained. The two original Lowarra pumps in the upper pump station were in excellent condition and had been serviced prior to the retrofit beginning. However, the upper pump shelter was insufficient to house the VFD pump controller and the pipe connections needed replacement. An appropriate pump shed was installed by the nursery staff, while the irrigation installers re-plumbed the pump connections to a more efficient design to remove any workplace safety issues and accommodate the installation of the VFD pump controller.

Table 11: Case Study Nursery 2 - Irrigation system specifications

Irrigation system specifications	
Pumps	Original 2 Lowarra 2.2kW variable frequency drive with a Techsys VFD pump controller Irrigation zones operating pressure 200 kPa (2 bar or 29 psi)
Control solenoids	Irritrol 2-inch solenoids used for all growing areas
Lateral spacing	Outside growing areas = 5 m x 5 m; Shadehouse 1 = 4 m x 4 m; Shadehouses 2 and 3 = 3 m x 3 m
Risers	Riser heights were set at 1.5 m; riser supports were 10 mm galvanised rod held in place by 1.2 m star pickets; riser pipe was a 12 mm flexible poly pipe connected to the laterals line via a press-fit connector
Upright sprinklers	Plastro XL 360^{o} sprinklers with a Brown jet used for all outside growing areas (modelling results: CU 85%, SC 1.1, MAR 8.4 mm/hour)
Inverted sprinklers	Plastro Rondo inverts with violet jets (modelling results: CU 99, SC 1.1, MAR 19.3 mm/hr) used in Shadehouses 1 and 2; Plastro Rondo inverts with white jets (modelling results: CU 98%, SC 1.02, MAR 12.8 mm/hr) used in Shadehouse 3.

Disinfestation

The nursery already had a chlorine dosing system installed, which injects chlorine into the dam-to-tank main line directly after the extraction pump. The two-inch rural poly pipe ran for 400 metres and provided sufficient contact time for disinfestation. No changes to this system were required, although the chlorine dosing pump was replaced by the nursery during the retrofit due to age and failure of the seals.

Sprinklers and spacing

The design for Nursery 2 followed the same principles of those outlined for Nursery 1 except that the existing main lines were used, with only the lateral lines and risers replaced. The lateral lines for all outside growing areas were installed at a 5 metre by 5 metre spacing, with the same sprinkler type and jet size. Unfortunately, some compromises were necessary due to the irregular shape of the lower growing areas. For example, the lower growing area was comprised of two small triangular beds (GA 3 and GA 5, see 14), one at each end of the main section.

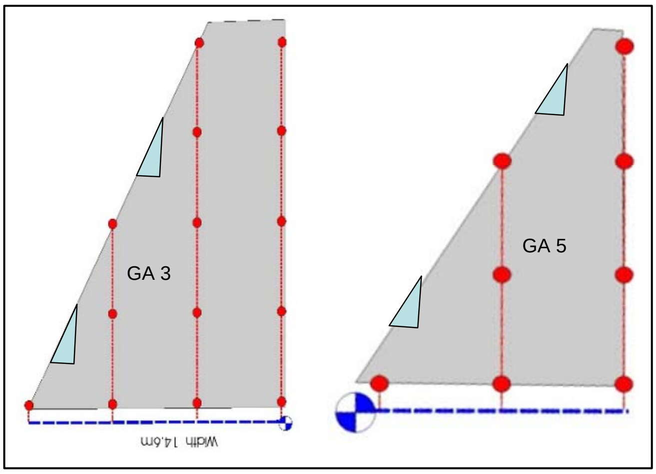

Figure 14: Growing areas 3 and 5 showing sprinkler layouts and areas of reduced MAR (small triangular sections)

Growing areas 3 and 5 were treated as truncated squares, which meant the 5 metre spacing was retained and provided a uniform application across most of the beds. Some sections were expected to have a reduced uniformity and MAR but this was addressed within the nursery's crop management and plant placement layout.

This main section (GA 4 and GA 4.5) tapered from 14 metres wide down to 11.5 metres wide at the north end and stepped in by 1 metre approximately half way along the bed towards the south end (Figure 15). Physically reshaping the growing area to a more rectangular shape was not possible due to the existing roadways and drainage. Instead, the irrigation system was altered to provide the most efficient layout possible for each area.

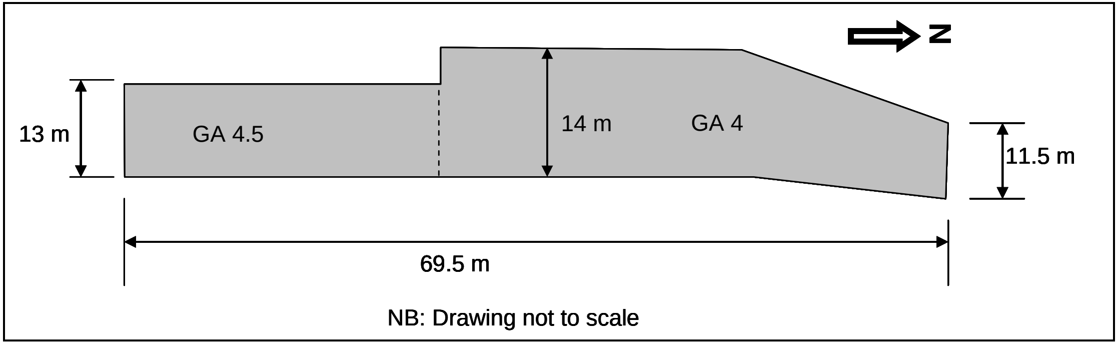

Figure 15: Representation of growing area 4 and 4.5 at Nursery 2
NB: This does not show the actual curved edges of the beds.

To address the irregular shape of GA 4 and GA 4.5, the area was theoretically separated into two growing beds, each with two irrigation zones. The north end (GA 4) required the lateral lines to taper down from 14 metres to 11.5 metres for approximately one-third of the bed. Therefore the sprinkler spacing at the north end was only 3.8 metres. This affected the CU and MAR for the north end of the bed slightly but was not considered significant. The manager has incorporated this into the irrigation and crop management, and will place plants with higher water requirements in this section or reduce the irrigation scheduling to suit.

The southern end (GA 4.5) simply required a narrower lateral spacing to accommodate the narrower bed. Spacing used for this area was 4.3 metres by 4.5 metres. This slight reduction in lateral and sprinkler spacing did not alter the CU or MAR significantly.

Lateral and sprinkler spacing for Shadehouses 2 and 3 was 3 metres by 3 metres. This ensured the inverted sprinklers did not fall next to support posts and avoided potential shadow effects. Spacing for Shadehouse 1 was 4 metres by 4 metres due to the position of the support posts. This did have an effect on the application rate, with initial MAR lower (3.8 mm/hr) than expected (8.6 mm/hr). This was corrected by replacing the jets with a higher flow jet to increase the MAR to an acceptable rate.

Another variable identified as having an effect on sprinkler efficiency was the operating pressure. The VFD pump controller was programmed to provide an operating pressure of 200 kPa at the growing area. Pump response times were adjusted to provide the smoothest and quickest response to varying line pressures without causing excessive line pressure increases or water hammer. Sprinkler pressures were fine-tuned using the control solenoids at each irrigation zone. Several catch can tests conducted with slightly different operating pressures showed that the sprinklers had a limited range in which to operate efficiently. In some areas, a fluctuation of 10 kPa (± 5 kPa) did not affect uniformity or MAR significantly but a fluctuation of 20 kPa (± 10 kPa) had a major effect on the results. However, the influence of pressure fluctuation at each bed was not consistent. Some areas with slightly different sprinkler spacing returned acceptable results at higher or lower pressures, while others were poor when operating under similar pressure fluctuation. The actual or total affect the varying pressures had on sprinkler efficiency was not explored during this project, but the observed effect of varying pressures suggests that this could alter application uniformity and efficiency significantly.

Water use and irrigation efficiency

The water use figures used to calculate daily and yearly water use were an estimate calculated from an in-line mechanical water metre fitted to the dam water supply line two months prior to retrofit work being carried out. These figures were used to calculate the yearly water use using irrigation scheduling times and seasonal adjustment. Unfortunately, no other daily water use records were available for this nursery prior to this project; hence all calculations are presented as a minimum and maximum to account for possible variations. The nursery manager agreed with the estimated daily water use values and has now implemented a water use monitoring schedule.

Under the old irrigation system, the maximum daily water use varied from 48 kilolitres per day during winter to 98 kilolitres per day during summer. This equated to a total water use ranging from 22 megalitres to 26 megalitres per year.

Under the new irrigation system, maximum daily water use ranged from 36 kilolitres per day during winter to 73 kilolitres per day during summer. Yearly water use under the new system is estimated to be between 16 megalitres and 19 megalitres, a saving of 6.3 megalitres to 6.7 megalitres. This equates to a reduction in yearly water use of 24 to 30% compared to the old irrigation system.

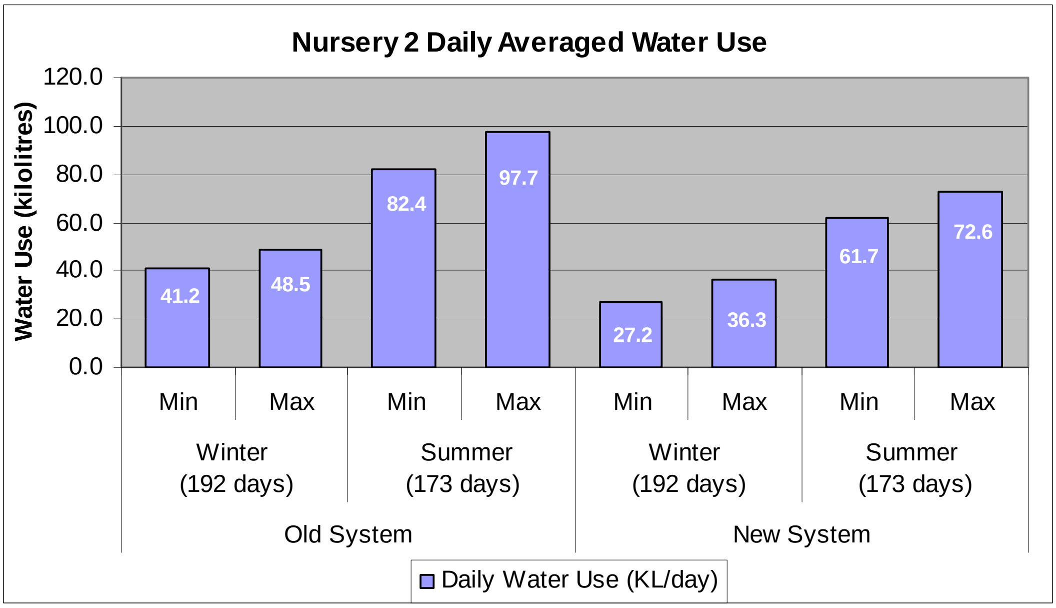

Figure 16: Comparison of average daily dam water use per season under old and new irrigation systems

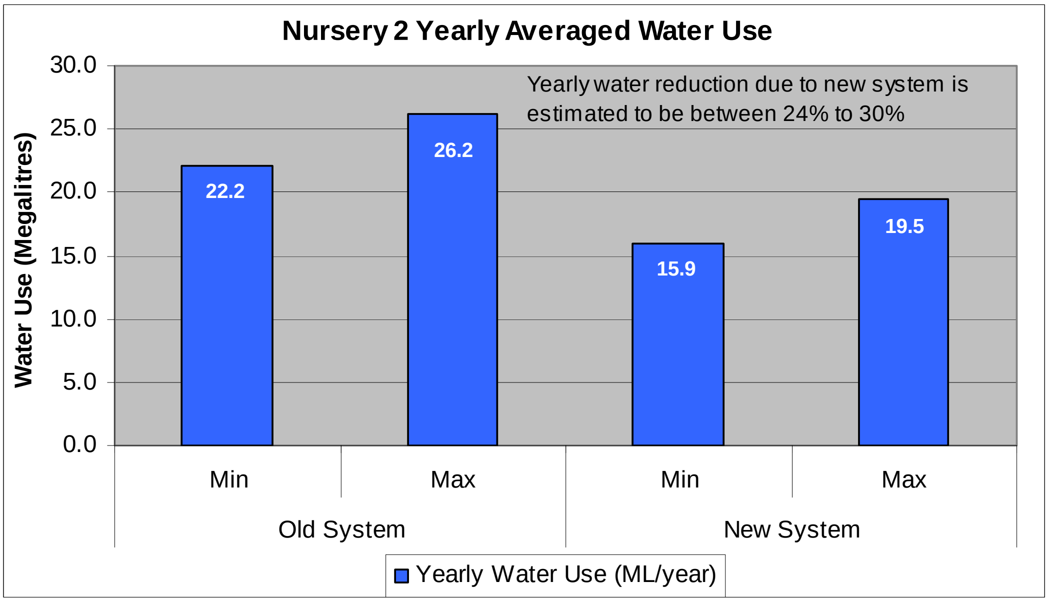

Figure 17: Comparison of average yearly water use under old and new irrigation systems

Water use calculation assumptions:
1) Water metre readings used for calculations represent actual water use for the seasonal period in which they were recorded.
2) Percentage increase or decrease in irrigation timing is not altered during the season.
3) Variation between seasonal irrigation periods is consistent, e.g. irrigation controller timers are changed on the same day each year.
4) Calculations do not take into account any reduction or pausing of the irrigation system for rain days.
5) Calculations do not take into account turning off irrigation for one or more zones when growing bed is empty.
6) Water use calculations include all water used on-site including that not directly used in crop irrigation, e.g. equipment cleaning.

The irrigation efficiency of the outside growing areas under the old system varied considerably, with CU ranging from 66.4 to 90.7% and SC ranging from 1.65 to 3.09. The three shadehouses had CU values of 61.1 and 74.5% and SC of 2.1 and 5.01. Although the uniformities in some growing areas where relatively good, the MAR values were significantly higher than those suggested by NGIA as the benchmark. MAR varied between irrigation zones from 13.6 to 50.6 mm/hr.

The new irrigation system improved irrigation efficiency considerably, and all irrigation zones now fall within NIASA standards. The outside growing beds now have a CU of 86.5 to 92.8% and SC of 1.16 to 1.33, while SC for the shadehouses vary from 1.03 to 1.4. MAR values still vary between outside irrigation zones but are relatively constant between 8.4 and 12.2 mm/hour. The lower rates (8.4 mm/hr) are at the small upper growing area, which tends to be more affected by wind than the other areas. This area may need to have a larger jet installed to counter the wind effect. Currently the manager is monitoring the area and will determine whether a change in jet size is needed.

Efficiencies recorded for Shadehouse 1 and 2 directly after the retrofit were within NIASA standards but less than the modelling results suggested. MAR for the two shadehouses were lower than desired (SH 1 MAR = 3.8 mm/hr; SH 2 MAR = 8.1 mm/hr) and plants were drying out faster than expected. Further observations suggested Shadehouse 2 was being affected by wind; therefore, the jets were changed from the original green jet (modelling MAR = 8.9 mm/hr) to a violet jet (modelling MAR = 19.3 mm/hr) to counter the wind effect. Also, the jets for Shadehouse 1 were changed to violet jets as the MAR (3.8 mm/hr) was too low to meet the water needs of plants grown in this shadehouse. However, the MAR for the two shadehouses varied (SH 1 MAR = 9.6 mm/hr; SH 2 MAR = 17.3 mm/hr), owing to the Shadehouse 1 having a spacing of 4 metres by 4 metres and Shadehouse 2 having a spacing of 3 metres by 3 metres.

Again, the MAR for the two irrigation zones in Shadehouse 3 was less than expected after the retrofit and insufficient to maintain plant growth (Nth = 6.1 mm/hr; Sth = 5.6 mm/hr). As this shadehouse was the transitional area from propagation, any plant loss at this point had significant ramifications. To ensure sufficient irrigation for plant growth and provide a larger droplet size to counter any wind effect, the jets were changed from the green jets (modelling MAR = 8.9 mm/hr) to a white jet (modelling MAR = 14.6 mm/hr), which provided an actual MAR of 10.6 mm/hr. Prior to the retrofit, application efficiencies varied between the two zones, with the north end having a poor uniformity due to its triangular shape. The new system has improved uniformity and application efficiency for the north end and allows this section to be used more often. A map of the nursery with the new and old water use efficiency values for the different irrigation zones is shown in Figure 18.

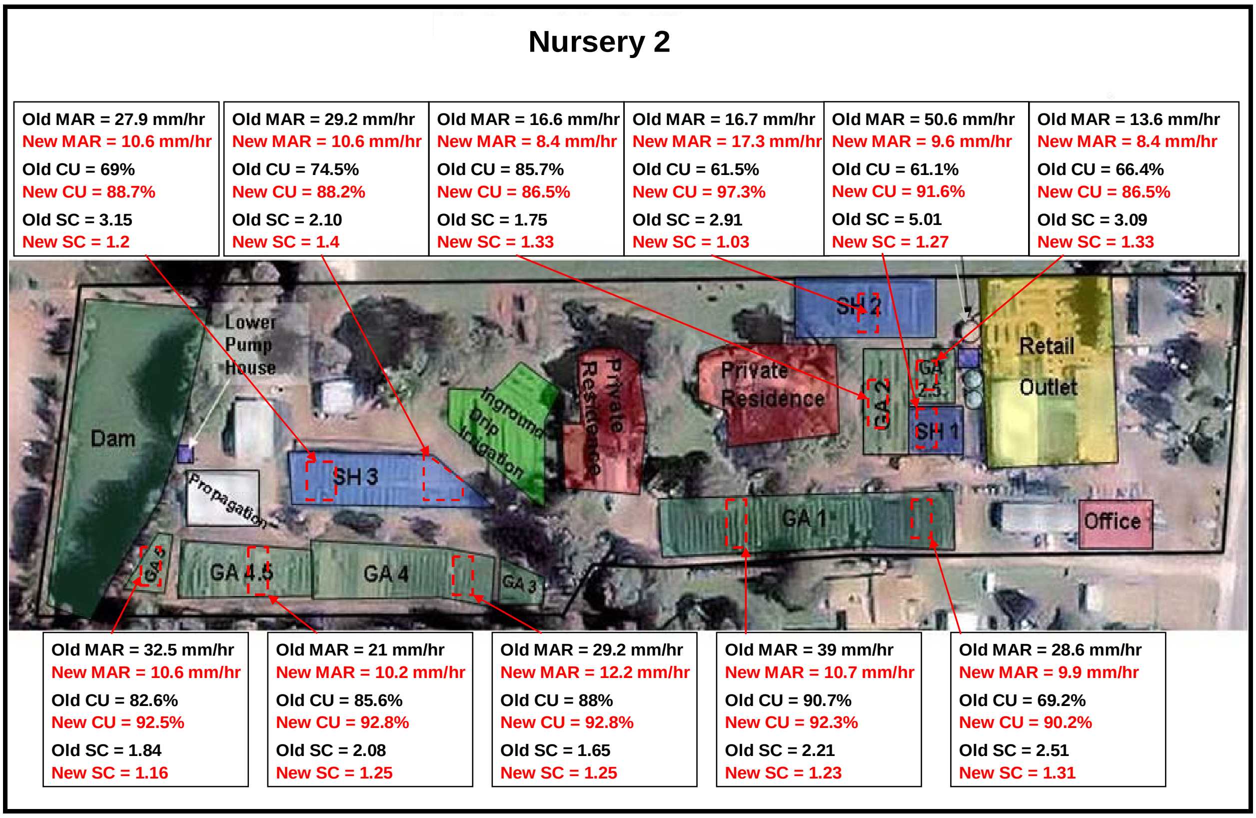

Figure 18: Irrigation efficiencies for the different irrigation zones under old and new irrigation systems

Irrigation scheduling

The nursery management determines the irrigation scheduling for each zone, according to the variety of plants within a zone and daily climatic conditions. Table 12 shows the general change in irrigation scheduling between the old and new systems for the first two months after the retrofit. Under the new system, the irrigation duration increased for most of the growing areas. This was due to the considerable reduction in MAR. As the nursery management is currently adjusting to this new system, it is expected that irrigation scheduling will continue to be fine-tuned over the following months. Unfortunately, the actual changes to the irrigation scheduling in this case will not be known until a full yearly production cycle is completed.

Table 12: Comparison of daily irrigation scheduling times for pre- and post-retrofit

Growing area	Old system			New system		
	Summer	Winter	Total Mins	Summer	Winter	Total Mins
SH 1	17	13	30	42	32	74
SH 2	36	25	61	42	29	71
SH3 Nth	46	25	71	48	26	74
SH3 Sth	46	25	71	51	28	79
GA 1 Nth	40	20	60	37	19	56
GA 1 Sth	40	20	60	34	17	51
GA 2 & 2.5	36	25	61	62	43	105
GA 3	46	18	64	46	18	64
GA 4	46	25	71	53	29	82
GA 4.5	46	25	71	53	29	82
GA 5	46	25	71	54	29	83

Cost of retrofit

Table 13: Cost break-down of Nursery 2 retrofit

		Cost of retrofit		Total
Growing area	Size	Equipment $	Labour $	$
Shadehouse 1	153m^2	546.00	400.00	946.00
Shadehouse 2	600m^2	2154.00	1590.00	3744.00
Shadehouse 3 (trapezoid)	790m^2	2815.00	2000.00	4815.00
Growing area 1	1290m^2	4045.00	2400.00	6445.00
Growing areas 2 & 2.5	717m^2	2435.00	1334.00	3769.00
Growing area 3 (trapezoid)	231m^2	723.00	400.00	1123.00
Growing area 4 (trapezoid)	839m^2	2655.00	1578.00	4233.00
Growing area 4.5	474m^2	1440.00	878.00	2318.00
Growing area 5 (triangular)	70m^2	248.00	120.00	368.00
Cost of retrofit irrigation system = $		17061.00	10700.00	27761.00
Installation of new irrigation control unit & wiring = $			560.00	560.00
Re-siting of pumps (parts & labour) = $			910.00	910.00
Variable speed drive pump controller = $		4648.70	660.00	4648.70
Irrigation system retrofit = $		21709.70	12830.00	33879.70
Total cost of retrofit Ex-GST + $				**34539.70**

Due to this nursery relying only on the on-site dam and runoff for irrigation, the primary benefits returned from this retrofit included water savings from the improved irrigation efficiencies, reduced maintenance and pumping costs, and a small reduction in fertiliser costs.

Economic assessment

The economic assessment figures vary slightly from the water use calculations stated previously. The previous figures were based on the daily seasonal change in water use associated directly with the irrigation retrofit. The figures used for the economic analysis are averaged annual figures.

The water supply for this nursery is totally dam water and no change to the water supply was implemented during the retrofit. However the new irrigation system has allowed a substantial reduction in water use through increasing the irrigation efficiency. Table 14 shows the changes in water use.

Table 14: Annual water use results for Case Study Nursery 2

Water Usage	Old System	New System	Change
Area of Retrofit 0.52 Hectares	(Klitres Water/year)	(Klitres Water/year)	(Klitres Water/year)
Town Water			
Dam Water	24,200	17,700	-6,500
Total Water Usage	**24,200**	**17,700**	**-6,500**

The retrofit has provided annual water savings of 6.5 ML, a reduction of 27% from the previous system. Unfortunately, the cost savings from water use are considerably less than for the other nurseries, with water and operational costs savings of approximately $831 per year, after an adjustment for depreciation, due to no change in the water supply. However, the availability of enough water to meet requirements has been a constant worry for the management of this nursery. The significant water savings gained from the new irrigation system has dramatically reduced pressure on the dam supply to provide the required water, especially under recent dry climatic conditions.

Table 15: Associated cost savings achieved due to the retrofit, before adjustment for depreciation

New System Benefits	$ Savings
Town water cost saving	$2,655
Throw-out labour savings	$2,000
Total benefit	$4,655

The benefits of the system changes are:

- The new central irrigation control system has enabled easier irrigation management and labour savings.
- The new irrigation system requires less water pressure, thus saving wear on pumps and pipes and significant savings to electricity costs.
- The completed drainage system channels excess water back to the dam for reuse.
- The efficiencies gained by the new irrigation system have resulted in a much drier plant area.
- The drier plant area results in reduced plant disease and a decrease in fungicide required and application costs.
- The efficiencies gained by the new irrigation system have resulted in a decline in fertiliser leaching, thus improving plant nutrition resulting in improved plant growth, plant vigour and more even plant growth.
- The drier plant area creates a more efficient working area, including safer paths and roads.

Conclusion

Financial and water savings for Nursery 2 were substantially less than for Nursery 1, due to their reliance on the on-site dam for irrigation rather than using town water. There were, however, some savings in associated costs, such as labour costs incurred during plant maintenance, reduced leaks and line blow-outs, and less time required to correct and adjust irrigation scheduling.

The primary benefit obtained through this retrofit was improved irrigation efficiencies, reducing the pressure on the on-site dam. Prior to the retrofit, the longevity of their water supply was a serious concern for management. During dry periods and with dam levels becoming worryingly low, the constant question was how the crop would be maintained when the dam dried up. Now, with the increase in water use efficiency, dam water availability has been extended, providing the management with greater flexibility and providing a level of 'drought-proofing' that was not present before the retrofit.

Desktop comparison nurseries

A desktop comparison nursery is one that had undertaken a private retrofit of the irrigation and water delivery system prior to this project. The new systems were designed and installed by an irrigation specialist to follow the NGIA best management practices and to achieve NIASA accreditation.

Comparison nurseries were chosen using the following criteria:
1) Had documented water use records for a period of 3 to 6 months before and after an upgrade/retrofit
2) Had system efficiencies data for before and after the upgrade
3) Were willing to provide financial records for the previous financial year.

This information was used to compare water savings, dollar return, and increase in business potential with the retrofitted case study nurseries.

Case Study Nursery 3 *- Seedling propagation nursery*

Nursery description

Nursery 3 is a seedling propagation nursery that has been operating for 18 years. The property is approximately 4 hectares in size with 0.6 of a hectare under production. There is a 2.5 megalitre dam on site that collects all runoff. However, the dam is only used to irrigate a small area of bedding plants, while the rest of the nursery was 100% reliant on town water.

The previous 15-year-old irrigation system used Moss and Pope rotoframe sprinklers at unknown spacing providing application efficiencies of MAR 26.9 to 28.5 mm/hr, CU between 66.4 to 76.1 and SC ranging from 3.04 to 4.51. Daily water use was approximately 26 kilolitres and was only monitored due to the use of town water. The cost of irrigating the nursery and their reliance on town water was becoming a concern. The owners decided to take action to secure the future of the business and commissioned an irrigation specialist to retrofit the nursery's irrigation system to improve efficiency and reduce town water use.

The new irrigation system meets the NIASA standards for accreditation and has reduced daily water use to approximately 14 kilolitres. During the retrofit the old standard timed irrigation controller was replaced with a new 2-wire encoder system, an old bore that was previously decommissioned due to the high levels of manganese was reinstated, and a green sand filter with a chlorine dosing system was fitted. The bore now provides 78% of the nursery's water, with the other 22% being town water. Another two low-flow bores are available for use but currently are not used. If extraction volumes from the active bore are reduced, the owners have considered incorporating filtered dam water for irrigation with the two low-flow bores topping up the dam.

Economic assessment

Prior to the retrofit, town water use was a concern and a limiting factor. The retrofitting of the irrigation system included sinking a bore, installing tanks for treatment and installing a filtration system. This has resulted in a substantial reduction in town water use. Table 16 shows the water use changes achieved.

Table 16: Annual water use results for Case Study Nursery 3

Water Usage	Old System	New System	Change
Area of Retrofit 0.6 Hectares	(Klitres Water/year)	(Klitres Water/year)	(Klitres Water/year)
Town Water	9,490	1,095	-8,395
Bore Water		4,015	4,015
Total Water Usage	**9,490**	**5,110**	**-4,380**

The retrofit has provided annual water savings of 4.4 ML, a reduction of 46% from the previous system. The new system uses 78% bore water and only 22% town water. The significant reduction in town water use represents real savings in the costs of water. Collectively, after adjustment for depreciation, water and associated cost savings of around $16,300 per year were achieved. Plant throw-outs have been reduced from 7% to 4% of annual plant production.

Table 17: Associated cost savings achieved due to retrofit, before adjustment for depreciation

New System Benefits	$ Savings
Water cost saving	$8,340
Throw-out labour saving	$12,000
Throw-out cost savings	$3,855
Total benefit	$24,194

The benefits of the system changes are:

- The inclusion of bore water and the efficiencies gained by the new irrigation system have resulted in a substantial reduction in town water usage.
- The new irrigation system provides an even distribution of water, resulting in a decrease in the number of plant throw-outs and savings to variable costs and labour inputs.
- The new irrigation system requires less water pressure, thus saving wear on pumps and pipes and significant savings to electricity costs.
- The completed drainage system channels excess water back to a dam for reuse.
- The efficiencies gained by the new irrigation system have resulted in a much drier plant area.
- The drier plant area results in reduced plant disease and a decrease in fungicide required and application costs.
- The efficiencies gained by the new irrigation system have resulted in a decline in fertiliser leaching, thus improving plant nutrition and resulting in improved plant growth, plant vigour and more even plant growth.
- The drier plant area creates a more efficient working area, including safer paths and roads.

Case Study Nursery 4 - Tree nursery

Nursery description

Nursery 4 is a tree nursery that has been in production for generations. It is a 10 hectare property with 2.7 hectares currently under production. Prior to the retrofit the nursery was totally reliant on town water, using an overhead sprinkler system with irrigation scheduling controlled solely by manual control. Drainage and runoff collection was poor, relying on the natural slope of the land to drain excess irrigation away from the growing areas. The increasing costs of irrigating with town water and a need to improve production efficiency led to the decision to upgrade the irrigation system.

To achieve NIASA accreditation the owners retrofitted the irrigation and water delivery system over several years. This included recommissioning an old 1.3 megalitre dam and drilling a bore to supplement the irrigation supply. A biological filtration system was installed to filter the dam water and runoff collection drains were built to channel all runoff back to the dam. Irrigation efficiencies prior to the retrofit were not recorded but the owner has stated that the nursery would not be in business today if they were still operating under the old irrigation system. The new sprinkler system was designed to accommodate the production of tree crops and now is a combination of overhead sprinklers (3.5%), drip irrigation (65.5%) and microirrigation (31%).

Economic assessment

The new irrigation system has substantially reduced the nursery's reliance on town water. The installation of runoff collection drains has channelled irrigation runoff away from the growing areas, resulting in drier growing area and a reduction of disease and fungal outbreaks.

Table 18: Annual water use results for Case Study Nursery 4

Water Usage	Old System	New System	Change
Area of Retrofit 2.7 Hectares	(Klitres Water/year)	(Klitres Water/year)	(Klitres Water/year)
Town Water	55,480	6,935	-48,545
Dam Water		24,273	24,273
Bore Water		3,468	3,468
Total Water Usage	**55,480**	**34,675**	**-20,805**

The retrofit has delivered annual water savings of 20.8 ML, a reduction of 37.5% compared to the previous system. The new system uses 70% dam water, 10% bore water and 20% town water. The significant reduction in town water use represents water and associated cost savings of approximately $89,500 per year after adjustment for depreciation.

Table 19: Associated cost savings achieved due to retrofit, before adjustment for depreciation

New System Benefits	$ Savings
Water cost saving	$63,463
Throw-out savings	$43,200
Total benefit	$106,663

The benefits of the system changes are:

- The inclusion of dam and bore water into the system and the efficiencies gained by the new irrigation system have resulted in much less use of town water supply.
- The new irrigation system provides an even distribution of water, resulting in a decrease in the number of plant throw-outs and savings to variable costs and labour inputs.
- The new irrigation system requires less water pressure, thus saving wear on pumps and pipes and significant savings to electricity costs.
- The completed drainage system channels excess water back to the dam for reuse.
- The efficiencies gained by the new irrigation system have resulted in a much drier plant area.
- The drier plant area results in reduced plant disease and a decrease in fungicide required and application costs.
- The efficiencies gained by the new irrigation system have resulted in a decline in fertiliser leaching, thus improving plant nutrition and resulting in improved plant growth, plant vigour and more even plant growth.
- The drier plant area creates a more efficient working area, including safer paths and roads.

Economic Model Development

The data collected from the retrofits was used to develop an economic model for the nursery industry to be able to predict potential water and cost savings achievable from retrofitting an irrigation system. This model has been tested and will allow Industry Development Officers to assist nursery owners to predict a time to return on investment and water savings achievable for individual nurseries. It will also provide estimates on other operational cost savings such as reduced electricity cost, plant throw-outs, and fertiliser and chemical usage.

A copy of the model is included on the attached CD but it is recommended that this model be used by an Industry Development Officer during a nursery assessment to ensure all appropriate data is considered to provide an accurate suggested outcome.

Discussion

The retrofitted nurseries have shown that improving a nursery's irrigation system can have greater benefits than simply improving irrigation efficiency. The retrofit of the irrigation systems for all four nurseries has resulted in substantial reductions in water use. Money saved through reducing a nursery's reliance on town water has proved to be considerable. Improving irrigation uniformity and reducing water use has had further reductions in a variety of other operational costs. A reduction in leachate has reduced fertiliser cost. The cost of chemicals (herbicide, pesticide, fungicide and algaecide), and the number of applications required has been reduced due to a drier, cleaner growing environment. The new irrigation systems operating at a lower pressure reduce wear on pumps and pipes, reducing line blow-outs and resulting in lower electricity costs. All of these benefits can be directly related to upgrading an irrigation system, but will vary from nursery to nursery depending on the efficiency of the old irrigation system being replaced, the source of the water supply and the extent of the retrofit conducted.

Further benefits can be obtained through improving runoff collection drains and the reuse of nursery runoff. The reuse of runoff reduces the reliance on water sources and provides a greater return on the initial investment of purchasing or pumping the water. Also, fertiliser nutrients are already in a usable form for plants and do not require additional energy inputs. A cleaner growing environment reduces the prospect of reintroducing disease and pathogens to the crop as the water has already undergone disinfestation (Ferrini et al. 2005). A nursery that has implemented an environmental monitoring program (e.g. EcoHort) and regularly monitors for any detrimental inputs will limit the impact of outbreaks.

However, there are several issues that need to be considered when planning to undertake a retrofit of an irrigation system. These issues can affect the efficiencies of the new system and should be addressed during the planning stage or before the new system is commissioned. These issues are discussed below.

Design considerations and compromises

Size and shape

As this project was to retrofit production nurseries to best management practices, several compromises to the designs were made to accommodate existing structures and the irregular shape of some growing areas. Many shadehouses are built to the available space and building codes. Unfortunately, this may not provide the optimum size and shape to suit an irrigation system and an alternative design must be considered. For example, Shadehouse 4 at Nursery 1 was originally to have a sprinkler spacing of 3 metres by 3 metres. However, the support posts were placed at 6 metre intervals and every second sprinkler fell next to a post. This created a 'shadow effect' that may have prevented uniform application. To counter this effect, sprinkler spacing was increased to 4 metres by 4 metres, which offset the sprinklers from the support posts. Although the support posts still have a small influence on the efficiency of the sprinkler application, this influence has been reduced simply by tailoring the new system to suit the situation.

However, when altering the original design, consideration must be given to the change in application efficiency this will cause. Changing sprinkler spacing will affect the distribution uniformity and MAR of the sprinklers. Jet size or even sprinkler type should be assessed to ensure application efficiencies are maintained. An example of this is Shadehouses 1 and 2 at Nursery 2. Both shadehouses have the same sprinkler type and jet size, but MAR varies due to Shadehouse 1 having a 4 metre spacing and Shadehouse 2 having a 3 metre spacing.

Operating pressure

Changes in operating pressure will have a marked influence on the application efficiency of a sprinkler. The best quality sprinkler maybe installed but if not operated at the correct pressure, the efficiencies can be reduced dramatically. The pressure for each irrigation zone needs to be adjusted to suit the number of sprinklers within that zone. In many cases a VFD controlled pump will adjust and maintain the line pressure required for the majority of the irrigation zones, but over long distances friction losses may require the pump pressure to be greater than appropriate for smaller areas. In this case a pressure regulator may be needed to counter the fluctuation in the mainline, especially if a small zone or shadehouse with a low flow rate is close to the main pump.

An example of this was Shadehouse 4 at Nursery 1, which had a low flow requirement and was the first lateral off-take in relation to the pump. Mainline pressure fluctuations affected the operation and uniformity of the sprinklers for this shadehouse and a pressure regulator was needed to maintain an optimal operating pressure. After the installation of the pressure regulator application efficiencies improved and remained constant.

Height above crop

Another factor influencing sprinkler efficiencies was sprinkler height above the crop, particularly in some shadehouses. When conducting catch can tests at Nursery 1 and 2, it was discovered that application efficiencies were considerably lower than expected. Through discussion with the sprinkler manufacturer it was identified that the quoted efficiencies for the inverted sprinklers are calculated for either 0.5 m or 2 m height above the crop. For example, Shadehouse 4 at Nursery 1 had seedling trays placed on benches standing 0.9 m off the ground and the inverted sprinklers had a drop of 0.3 m, providing a height above the crop of approximately 1.2 m. Shortening the sprinkler drop to 0.1 m thus increased the height above crop to approximately 1.4 m, improving application efficiency from 79.6% to 86.5% (CU) and reducing the scheduling coefficient from 1.54 to 1.35.

A similar effect was noted in the tunnel-house of Nursery 1, where the tension wires holding the suspended lateral line had drooped between supports. This slight droop in the suspended lateral line effected application efficiency considerably. Prior to re-tensioning, two catch can tests returned CU values of 81.1% and 78.3% and SCs of 1.51 and 1.69, with MAR varying between 10.7 mm/hr and 13.1 mm/hr. After re-tensioning the lateral lines, application efficiencies increased to 91.6% CU, 1.36 SC and 12.9 mm/hr MAR. It is expected that tension wirers will stretch within the first several weeks after installation and should be checked and re-tensioned on a regular basis. Alternatively, when installing a new system, it should be ensured that there are sufficient supports holding the suspended laterals.

Wind effect

Even in protected structures such as a shadehouse, wind can influence the application efficiency of the sprinklers, as discovered with Shadehouse 3 at Nursery 2. This shadehouse is the propagation transitional or hardening-off area for the nursery and the irrigation system was designed to provide an appropriate application rate of 8.6 mm/hr to suit. However, the small droplet size was affected by wind blowing through the shadehouse, disrupting the application uniformity and reducing the MAR to half of what was expected. The nursery manager noted that there was insufficient application and had to increase the irrigation duration to provide enough water to sustain the plants. To correct this issue, the jets were replaced to provide a larger droplet size and greater MAR (15 mm/hr). Although the actual MAR recorded from catch can tests was 10.6 mm/hr, the replacement jets proved to reduce the wind effect and allowed the irrigation duration to be reduced. After running the system for several weeks with the replacement

jets, the nursery manager has commented that application rates are more consistent and plants no longer show signs of water stress.

Observations

On several occasions the nursery owners have commented on the dramatic change in nursery conditions due to the new irrigation system. For example, growing areas that have always been wet are now dry. In some areas of Nursery 1 the ground was so sodden that workers could not safely walk along the rows due to algal and fungal build up. Regular spraying of fungicide and algaecide was needed to retard growth. Furthermore, several of the outside growing areas of Nursery 1 had a covering of *Azolla* spp. growing in the walkways and across the beds. *Azolla* is a waterways plant that usually grows on top of water bodies, indicating that an excessive amount of water was pooling throughout the nursery. Since the retrofit these areas have dried out and no *Azolla* can be found growing on the beds.

Nursery workers have commented that it is easier and more pleasurable to work in the nursery with the new system. They no longer finish their day with layers of mud covering their shoes or clothing. There is less trash and old pots and dying plants lying around the nursery, and areas that were only used as the last resort are now being used regularly.

Other comments included the dramatic improvement in plant uniformity and growth. The improvement in plant quality and uniformity was so great that within the first two months after commissioning the new irrigation system, the improvement was visually perceivable. This improvement was reflected in a reduced number of plant throw-outs. For example, Nursery 1 prior to the retrofit had plant throw-outs as high as 30% and staff spent considerable time sorting through the stock for appropriate plants to fill orders. The uniformity of the new irrigation system has improved plant growth and quality so much that although one growing area was reduced in size by $180m^2$, the productivity of that area has increased to compensate for the reduced bed size.

Conclusion

The results of the analysis have shown that substantial water use savings are achievable, but the extent of the saving is dependant on the nursery's water source and the efficiency of the old irrigation system. Nurseries that had been solely reliant on town water achieved greater water savings than those operating from on-site dams.

The financial results from the cost/benefit analysis varied considerably between nurseries, due to the size of the nurseries, the state of the irrigation system and the extent of the retrofit that was required. Further cost savings were achieved through reductions in fertiliser use (due to reduced leaching), herbicide and pesticide use, and labour associated with crop and nursery maintenance. Nursery managers have also commented on an improvement in crop quality and uniformity, leading to a reduction of plant throw-outs.

The positive results achieved from the installation of more efficient irrigation systems provide a robust business case to encourage nursery owners to invest in more sustainable production technologies. Prior to the retrofits, the future of the businesses was questionable, but now the owners have effectively 'future proofed' their nurseries for many years to come.

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Appendix

Walk through survey report for Nursery 1

Date of Survey: 18/12/2006

Overview

Nursery 1 is located on a flat rectangular corner block with a residential dwelling positioned in the front corner. The collection dam is located diagonally behind the residential dwelling at the back of the property with the business offices along side of the dam. The production area is to the side of the dwelling and in front of the offices and runs the length of the property to the car park and dispatch area at the end. The production area, although accessible and well laid out, requires maintenance and upgrading of the irrigation, runoff collection and water recycling systems. The nursery has the potential to collect and channel all water, irrigation runoff and rain, to the onsite dam. Due to this property being in a flat area and having council drains running along two sides of the property the potential for contaminants and offsite water running into the property are low unless there is a major flood event.

Production area approx = 2.5 acres

Water source: Dam (runoff collection) and town supply

Dam capacity: approximately 8Megalitres

Dam Condition: – Dam structure OK, water quality poor to OK, algae present (green colour)

- Minor erosion on edges and inflow drains.
- Sediment & trash entering dam
- No aerators used

Recommendations:

- Install sediment and trash traps – perhaps primary traps at collection point for each irrigation area.
- Install aerator(s),
- Test water quality- may require some chemical additives to clean up water.

Collection drains – earthen open channels, poor in need of refurbishment

- Water loss due to profile leaching – drains damaged and allow water to spill from drains
- Minor erosion occurring
- Channel damage at walkways due to traffic

Recommendations:

- Re-shape drains and seal with either plastic or concrete, perhaps gradient needs redoing
- Install minor trash/sediment traps at each irrigation area
- Culverts needed over walkways to stop traffic damage

Growing areas – need refurbishment

- No plastic layer under gravel – water loss through profile leaching
- Gravel layer compacted

Recommendations:

- *Ideally, re-surface growing areas and lay down plastic to aid runoff collection*
- Apply new layer of gravel to aid runoff collection and reduce weed growth (NB: without a sealing layer runoff collection will be reduced)

Irrigation system – controller old but OK (will be usable, needs programming)

- 18 – 20 irrigation zones/growing areas in use
- Overhead sprinklers used with a variety of jets – Lego partial circuit impact (red jet), Maestro ND
- Lateral irrigation lines OK and usable depending on new sprinkler spacing
- Sprinkler spacing approx. 10 metres
- Estimate of sprinkler heads currently used – 308 (144 in open areas + 164 in shadehouse)
- No mixing tank used to combine dam and town water
- No flow meter used, therefore no data on water use – flow meter due to be installed when new pump is installed.
- New pumps in use with pressure regulator (approx. 85psi) – Lowarra pump with Hydrovar (1 new pump installed, a 2nd due to be installed)
- Solenoids OK, usable

Recommendations:

- Evaluate current sprinklers and update & standardise.
- Install a ring line, small mixing tank, flow meter, pressure regulator and check valves.
- Growing area irrigation lines will need re-positioning (spacing), some new risers needed
- Current solenoids could be used – wiring may need upgrading in places due to alteration of irrigation lines.

Water filtration – currently 2 sand filters in good condition, usable.

Recommendations:

- Possible re-positioning of connection piping needed to install disinfestation system and mixing tank.

Disinfestation system – None currently

Recommendations:

- Purchase & installation a Chlorine Dioxide disinfestation system

Infrastructure – in good condition and usable, may need some minor alterations depending on disinfestation and ring line installation.

Recommendations:

- None at this stage

Miscellaneous – No water quality monitoring in place

Recommendations:

- Water quality monitoring needs to be implemented – simple testing of runoff to dam to monitor and control fertiliser, herbicide and other chemicals in the system.

Benefits of water quality monitoring

- Water quality monitoring will help to reduce diseases in the system
- Will reduce costs of fertiliser and increases in nutrient loads.
- Will assist in calculating Chlorine Dioxide dossing effectively reducing volume of chemicals used and associated inputs such as pH stabiliser, also assist in reducing scale build up within irrigation pipes.

Walk through survey report for Nursery 2

Date of Survey: 18/12/2006

Overview

This nursery is positioned on a hill with the retail nursery and offices at the front of the property on top of the hill. Production growing areas are positioned at various locations along the property with open growing areas and 2 shade houses high on the hill behind the retail nursery. Other open growing areas are positioned halfway down the hill with 1 open growing area and shade houses in the lower section with the dispatch area and collection dam at the bottom of the property. All areas are well maintained with sealed roadways and appropriate collection drains directing the runoff to the dam at the bottom. There is an open drainage ditch running the length of the property on both side boundaries effectively allowing all water (irrigation runoff and rain) to be channelled to the collection dam.

Production area: approx = 3 acres (property is approximately 14 acres)

Water source: Dam (runoff collection from property and surrounding areas, includes possible pollution or nutrient loads from other properties especially during high rainfall or flood event)

Dam capacity: approximately - 13.5 Megalitres (this is a **rough** estimate of storage capacity)

Dam Condition – Dam structure OK, water quality appears good – testing required

- Minor erosion on edges and inflow drains.
- No aerators in use

Recommendations

- Install aerators
- Repair erosion around inflow drain (reduce sediment inflow to dam)

Collection drains – mainly concreted open channels, some closed pipe from upper growing area to dam.

- Little water loss through profile leaching – minor work required for erosion mitigation around some drains.
- Sediment and trash traps located at confluence of growing area runoff collection drains

Recommendations

- Repair erosion along collection drains to limit washouts and overland flow

Growing areas – surface and runoff collection in good condition, perhaps minor work required during irrigation system upgrade.

Recommendations

- No work required at this time

Irrigation system – 3 separate controllers (Hunter EC) used at 3 different location throughout nursery but system OK and usable; irrigation equipment in good condition.

- Approximately 12 irrigation zones or growing areas in use.
- Overhead sprinklers used, a combination of impact, moss, butterfly & inverted sprinklers
- Lateral irrigation lines and sprinkler spacing vary from area to area and are too large for simple sprinkler replacement.
- Estimate of sprinkler heads currently used – 320 throughout open and protected growing areas.
- 2 pumps in use (Lowarra multistage) 1 in good condition, 1 in OK condition
- Current solenoids in good condition, can be used
- Irrigation controller wiring may need upgrading in places depending on irrigation line replacement.

Recommendations

- Installation of flow meter on main supply line
- Installation of pressure regulator and check valves for each irrigation zone
- Evaluate current sprinklers and/or update & standardise.
- Minor redesign of supply lines to separate production and retail areas
- Major redesign of open growing area irrigation lines, need re-positioning (spacing), some new risers needed,
- Redesign of shade house irrigation lines, reduce spacing & replace moss sprinklers
- Depending on the condition and age of the irrigation controllers perhaps an upgrade is required – further discussion with nursery owner is needed.
- Pump replacement, none at this stage

Ideally an upgrade of the worn pump to a variable speed pump with Hydravar would reduce the stress of water pressure on the irrigation system. Replacing one pump could be sufficient to maintain a constant regulated pressure suitable for new low pressure sprinklers However, further investigation into the infrastructure and method of paralleling an old and new pump is required.

Water filtration – large disk filter used to remove organic matter from dam, in good condition and usable. Small disk filters at top pumping station but no other filtration used.

Recommendations

- No alterations to filters required at this time

Disinfestation system – currently using chlorine dossing pump, working OK, no upgrade required

Recommendations

- Maintenance of dossing pump and maintenance schedule implemented.

Infrastructure – in good condition and usable, no foreseeable alterations required

Recommendations

- None

Miscellaneous – No water quality monitoring in place and chemical store not bunted.

Recommendations

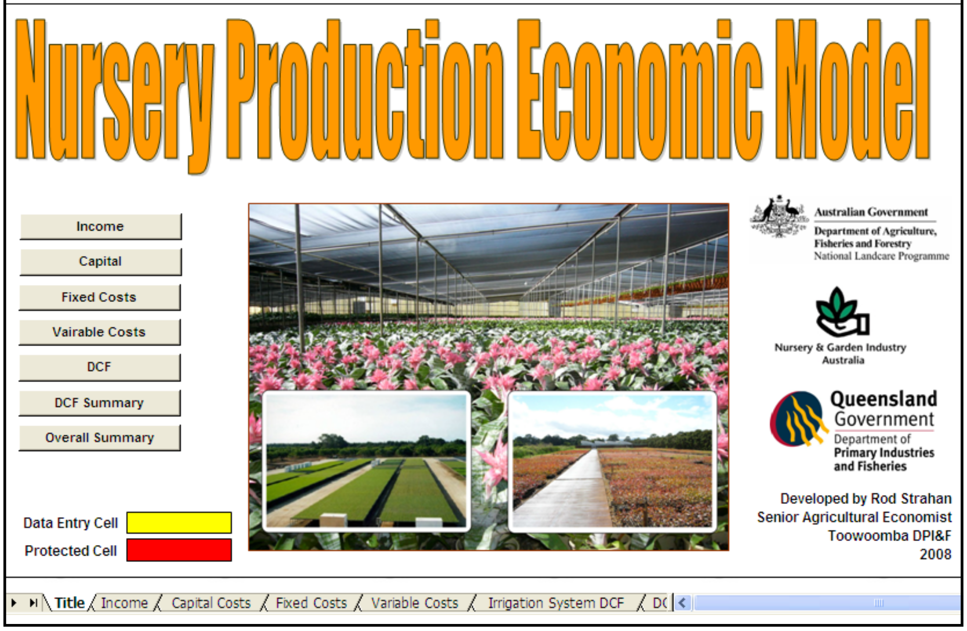
- Isolate chemical store (bunt) to avoid any contamination of dam water.
- Water quality monitoring should be implemented – simple testing of runoff to dam for monitoring fertiliser, herbicide and other chemicals in the system.

As this dam is part of a chain of dams acting as the head waters of the local creek, monitoring of nutrient loads and chemical levels is recommended. There are several other possible inflow sources in the area and during a rain/flood event pollution sources would be hard to identify. Due to the nature of the business on this property questions could be raised as to the potential pollution inputs to the local creek system, especially during flood events. Therefore, water quality monitoring will provide documented proof that the Timbara Mentz Nursery is an environmentally responsible operator and will alleviate possible legal problem if questions are raised in the future.

Benefits of water quality monitoring

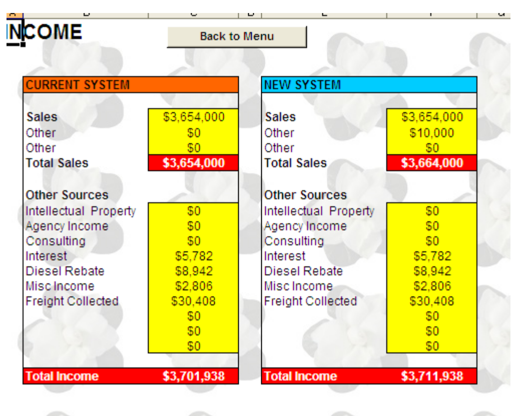
- Provide documented evidence of water quality if questions are raised in the future.
- Water quality monitoring will help to reduce diseases in the system.
- Will reduce costs of fertiliser, if a fertigation system is used.
- Will allow for early warning of nutrient load increases.

Front Screen of Excel Model



Income Screen : requires input of data from company records.

Data is typed into Yellow cells.



INCOME

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CURRENT SYSTEM		NEW SYSTEM	
Sales	$3,654,000	Sales	$3,654,000
Other	$0	Other	$10,000
Other	$0	Other	$0
Total Sales	$3,654,000	Total Sales	$3,664,000
Other Sources		Other Sources	
Intellectual Property	$0	Intellectual Property	$0
Agency Income	$0	Agency Income	$0
Consulting	$0	Consulting	$0
Interest	$5,782	Interest	$5,782
Diesel Rebate	$8,942	Diesel Rebate	$8,942
Misc Income	$2,806	Misc Income	$2,806
Freight Collected	$30,408	Freight Collected	$30,408
	$0		$0
	$0		$0
	$0		$0
Total Income	$3,701,938	Total Income	$3,711,938

Capital Costs: From financial records input existing costs and NEW costs of equipment.

CAPITAL COSTS

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CURRENT SYSTEM

	Cost	Years for Depreciation	Annual Depreciation
CURRENT SYSTEM TOTAL	$2,435,000		$182,214
BUILDINGS & ROADS			
Amenities block	$20,000	20	$1,000
Buildings	$1,200,000	20	$60,000
Dispatch shed	$0	0	$0
Growing shed	$0	0	$0
Landscaping	$0	0	$0
Office	$1,200,000	10	$120,000
Packing shed	$0	0	$0
Roadworks	$0	0	$0
Storage shed	$0	0	$0
	$0	0	$0
	$0	0	$0
OFFICE EQUIPMENT			
2 Way Radio	$0	0	$0
Communication system	$0	0	$0
Computer Software	$0	0	$0
Computers	$5,000	7	$714
Digital camera	$0	0	$0
Drinking water unit	$0	0	$0
Filing cabinent	$0	0	$0
Hot water urn	$0	0	$0
Lighting	$0	0	$0
Office furniture	$0	0	$0
Phone system	$0	0	$0
Photocopier	$0	0	$0

NEW SYSTEM

	Cost	Years for Depreciation	Annual Depreciation
NEW SYSTEM TOTAL	$2,510,000		$189,814
NEW SYSTEM EXTRAS	$75,000		$7,600
IRRIGATION RETROFIT			
Bore	$10,000	20	$500
Control System	$3,000	15	$200
Dam/s	$10,000	20	$500
Drainage	$25,000	20	$1,250
Electricity	$0	0	$0
Labour	$3,000	1	$3,000
Mainlines	$4,000	15	$267
Pipes	$2,000	10	$200
Plant Surfaces	$5,000	15	$333
Pumps	$5,000	10	$500
Sprinklers	$3,000	5	$600
Tanks	$5,000	20	$250
	$0	0	$0
	$0	0	$0
	$0	0	$0
	$0	0	$0
	$0	0	$0
	$0	0	$0
	$0	0	$0
	$0	0	$0
	$0	0	$0
	$0	0	$0

Title / Income / Capital Costs / Fixed Costs / Variable Costs / Irrigation System DCF / DC

Fixed Costs: From financial records input Total Fixed costs and NEW savings are calculated.

FIXED COSTS

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CURRENT SYSTEM		NEW SYSTEM SAVINGS
TOTAL FIXED COSTS	$182,521	$26,146
Accountant	$0	
Advertising	$0	
Bank Charges	$0	
Book Keeping	$0	
Broadband	$156,000	
Cleaning	$0	
Electricity	$0	$183
First Aid	$0	
Hire Plant & Equipment	$0	
Licenses/Fees	$0	
Motor Tolls	$0	
Motor Vehicle Expenses	$0	
Pest Control	$0	
Protective Clothing	$0	
Rates	$0	
Repairs & Maintenance	$0	$800
Security	$0	
Staff Training	$0	
Superannuation	$0	
Suscriptions	$0	
Technical Books & Journals	$0	
Telephone	$0	
Tool Replacement	$26,521	
Town Water Charges	$0	$20,206
Wages	$0	$4,957
Waste Disposal	$0	
Water Testing	$0	
Work Cover	$0	

Title / Income / Capital Costs / Fixed Costs / Variable Costs / Irrigation System DCF / DC

Variable Costs: From financial records input Variable costs and NEW savings are calculated.

VARIABLE COSTS

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	CURRENT SYSTEM	Determining Throw Out Savings — *Variable Costs Associated with Throw Outs*	NEW SYSTEM SAVINGS
Throw Out Costs	$6,830	$4,098	$183
Total Variable Costs	$493,120	$68,295	
Bags	$0	$0	
Blades	$0	$0	
Cartons	$0	$0	
Chemicals	$2,560	$0	← $183
Commissions	$0	$0	
Containers	$30,000	$30,000	
Freight	$458,000	$0	
Fungicide	$0	$0	
Herbicide	$0	$0	
Insecticide	$2,560	$2,560	
Labels	$0	$5,698	
Levies	$0	$0	
Payroll Tax	$0	$0	
Plants	$0	$25,698	
Plastic Trays	$0	$0	
Pots	$0	$256	
Seed	$0	$1,256	
Soil	$0	$258	
Stakes	$0	$0	
Staples	$0	$0	
Tape	$0	$0	
Ties	$0	$0	
Wax Trays	$0	$2,569	
Weed Mat	$0	$0	

Title | Income | Capital Costs | Fixed Costs | **Variable Costs** | Irrigation System DCF | D(

Discounted Cash Flow Analysis: From business records input key data into Yellow cells and other data points are calculated.

DISCOUNTED CASH FLOW ANALYSIS

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Discount Rate: 7%

CURRENT SYSTEM - Scenario Without New System

Average Daily Water Usage		
Water Supply	KL per Day	KL per Year
Town Water	42	15,330
Dam Water	28	10,220
Bore Water	10	3,650
Other	0	0
Total Average Water Usage	80	29,200

Calculate Average Daily Water Usage - Seasonal Variation			
Season		KL per Day	KL per Day
Summer	25%	30	7.5
Autumn / Spring	50%	20	10
Winter	25%	10	2.5
Average Daily Water Usage			20

		Year 1	2	3	4	5	6	7
Town Water Cost	$ / Kilolitre							
Real Annual Increase per Annum	3%	$1.73	$1.78	$1.84	$1.89	$1.95	$2.01	$2.07
Town Water Cost		$26,521	$27,317	$28,136	$28,980	$29,850	$30,745	$31,667
Pumping Costs (Average Daily Costs)	$3.40	$1,241	$1,241	$1,241	$1,241	$1,241	$1,241	$1,241
Treatment Costs (Average Daily Costs)	$2.00	$730	$730	$730	$730	$730	$730	$730
Annual Maintenance (Irrigation System)	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500
Throw outs (% of Assoc. Variable costs)	10%	$6,830	$6,830	$6,830	$6,830	$6,830	$6,830	$6,830
TOTAL COSTS		$36,821	$37,617	$38,437	$39,281	$40,150	$41,045	$41,968

NEW SYSTEM - Scenario With New System

Average Daily Water Usage		
Water Supply	KL per Day	KL per Year
Town Water	10	3,650

Calculate Pumping Costs			
Season	Hrs / Day	Usage KW / Hour	Cost $ / KW

Title | Income | Capital Costs | Fixed Costs | Variable Costs | **Irrigation System DCF** | D(

Cash Flow Summary: This report shows impact of investment on the business Cash Flow. Provides clear evidence of what payback period is required if finance is being sought.

Cash Flow Summary

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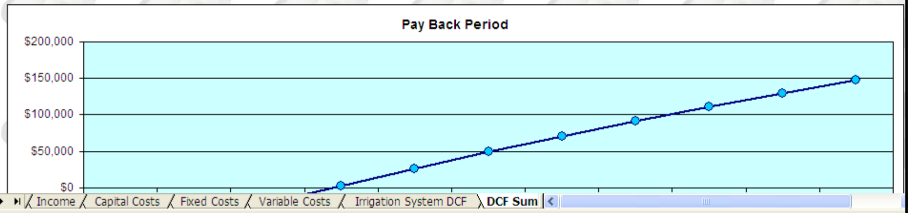
Total Investment Cost	$75,000										
Annual Cash Flow	-$75,000	$29,061	$29,668	$30,294	$30,938	$31,601	$32,285	$32,988	$33,713	$34,460	$35,229
Discounted Cash Flow	-$75,000	$27,160	$25,914	$24,729	$23,602	$22,531	$21,513	$20,543	$19,621	$18,744	$17,908
Years	0	1	2	3	4	5	6	7	8	9	10
Cumulative Discounted Cash Flow	-$75,000	-$47,840	-$21,926	$2,802	$26,405	$48,936	$70,448	$90,992	$110,613	$129,357	$147,265
Net Present Value (NPV)	$147,265										
Benefit / Cost Ratio	3.0										

Net Present Value (NPV)
The net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over the life of the project. If the NPV is positive the project is likely to be profitable.

Benefit – Cost Ratio
The benefit – cost ratio is simply a measure of the total flow of benefits over the life of the project as compared to the flow of costs. If the ratio is greater than one the project is deemed acceptable. In other words, the ratio describes the return per dollar invested; e.g. if the b-c ratio is 1.6 then we can say that for every $1.00 invested in the project or enterprise we get a return of $1.60.



Income / Capital Costs / Fixed Costs / Variable Costs / Irrigation System DCF / DCF Sum

Overall Summary: This report shows the impact of the investment on the business compared to the current business system. Details water savings and profit improvement.

Overall Summary

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CURRENT SYSTEM		NEW SYSTEM	
Assets		**Assets**	
Land Area (Ha)	35	Land Area (Ha)	35
Value ($/Ha)	$75,000	Value ($/Ha)	$75,000
Production Area (Ha)	7.54	Production Area (Ha)	7.54
Land Value	$2,625,000	Land Value	$2,625,000
Plant & Equipment	$2,435,000	Plant & Equipment	$2,510,000
TOTAL ASSETS	**$5,060,000**	**TOTAL ASSETS**	**$5,135,000**
Total Income	**$3,701,938**	**Total Income**	**$3,711,938**
Number of Staff (FTE's)	20.0	Number of Staff (FTE's)	19.0
Expenses		**Expenses**	
Variable Costs	$493,120	Variable Costs	$492,938
Fixed Costs	$182,521	Fixed Costs	$156,375
Depreciation	$182,214	Depreciation	$189,814
Total Expenses	**$857,855**	**Total Expenses**	**$839,127**
Net Profit	$2,844,083	Net Profit	$2,872,811
BENCHMARKS		BENCHMARKS	
Return on Investment	56.2%	Return on Investment	55.9%
Income per Hectare	$490,973	Income per Hectare	$492,300
Income per Square Metre	$49.10	Income per Square Metre	$49.23
Income per FTE	$185,097	Income per FTE	$195,365
Annual Water Usage (ML)	29.2	Annual Water Usage (ML)	17.5

WATER SAVING (ML) 11.7 → 40%

Variable Costs / Irrigation System DCF / DCF Summary / Overall Summary

Increasing Adoption of Innovative Irrigation and Water Recycling Technologies in Australian Nurseries.

Part 1:
Irrigation Scheduling

Conducted by

Queensland Department of Primary Industries & Fisheries
Tropical Lifestyle Horticulture Products & Services Team

For

Nursery & Garden Industry Association

Project aim:-

•Identify and evaluate irrigation scheduling tools and techniques appropriate for use within container production nurseries i.e. soil moisture sensors & computerized irrigation control units

•Quantify water savings that could be achieved by utilising these tools.

More specifically, this project intended to

1) Determine whether soil moisture sensors can be adapted for use in a containerized production nurseries & evaluate their potential for irrigation scheduling control - automation.

2) Compare the soil moisture sensors to standard timed and deficit irrigation scheduling practices to determine the potential water savings.

Part A: - Can Soil Moisture Sensors Work?

•Are soil moisture sensors adaptable to a container growing environment? –

Yes, as a monitoring tool or an automation tool

•Can they save water and improve irrigation scheduling? – Yes

• However, there are several issues that need to be considered before purchase!

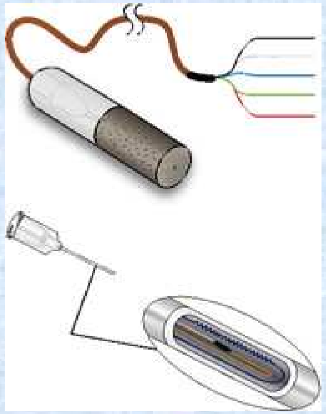
There are a variety of soil moisture sensors available:-

1) Insertion units (monitoring tool) with Moisture, Temperature & EC

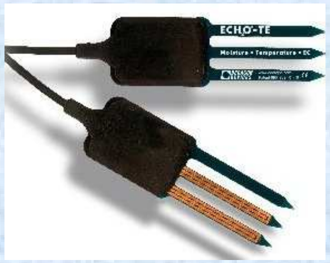
- Simple, quick, requires little technical experience

2) In-situ units (monitoring or automation tool)

- Technical experience needed to install
- Can be connected to irrigation controller
- More expensive





Issues associated with Soil Moisture Sensors to consider

Assess irrigation system before purchasing any new equipment!

- **Irrigation controller capable of sensor connection – Inputs & what type**
- **Interface signal – what communication code/language used for sensor & controller**
- **Connection – wired or wireless (more expensive but easier to install)**
- **Requires media specific calibration for organic media – identify trigger points**
- **Only represents container it is installed in – Container acts as reference for whole growing area, different plant water requirements & container sizes need to be considered**
- **Irrigation uniformity – sensors will NOT improve uniformity**
    - **A sensor will automate irrigation but only for the container it is placed in!**

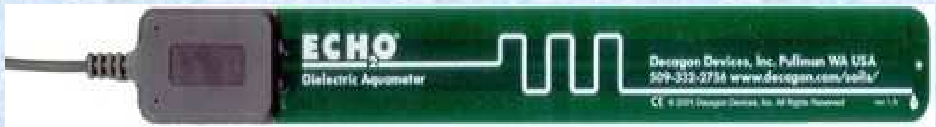
Identifying the right soil moisture sensor to use

Criteria used –

***Size of sensor*: -   the sensor needs to fit into growing containers**
***Type of sensor*: - Volumetric or Soil potential sensor**
- Be robust and provide reliable data
***Cost*: - should be financially viable for smaller nursery operators.**
***Availability*: - should be readily available with after sales technical support**
***Simplicity/ease of use*: - can be installed and maintained by the nursery staff,**
***Interface/connection*: - the product can be connected to existing irrigation controllers**

From this criteria 2 soil moisture sensors were chosen to trial -

The AquaSpy soil moisture sensor and Ech2o soil moisture sensor .
Both are a capacitance sensor, 200mm in length and measure the volumetric moisture content of soil.



A clarification of deficit/evapotranspiration/evaporation

- True deficit or evapotranspiration (ET) irrigation scheduling requires a crop factor or crop coefficient specific to the crop being grown.

- Limited information available on crop factors or crop coefficients for ornamental plants
- Instead a standard 'Turf" reference value is used for electronic weather station.

Evaporation = Class A evaporation pan or electronic weather station without a crop specific coefficient programmed, (standard coefficient = turf)

Evapotranspiration (ET) = plant water use (transpiration) + media evaporation
* Electronic weather station with a specific crop coefficient programmed
* Or use a gravimetric weight measure method.

For simplicity, the term 'Deficit Irrigation' is used to describe the irrigation scheduling practice utilising an electronic weather station to determine ET values.

Irrigation Scheduling Trial

- Conducted in a poly-tunnel at Redlands Research Station
- 4 Treatments – Timed, Deficit & 2 soil moisture sensors controlled scheduling
  * Ech2o sensor connected directly to Teven Logic encoder irrigation controller
  * AquaSpy sensor connected via a regulator to a rain input on irrigation controller
- A drip irrigation system used to match infiltration rate of media
- 2 media types used – A = Pine bark (85%), Sand (15%);

  B = Pine Bark (85%), Coir (15%)
- Petunia *Var.* in 200 mm containers

  Trial run for 4 months with 1 month of automation

  * Only operator input was entering the previous 24 hr ET value for deficit irrigation

  * Adjustment of AquaSpy regulator to suit climatic conditions

Irrigation Scheduling Trial Results

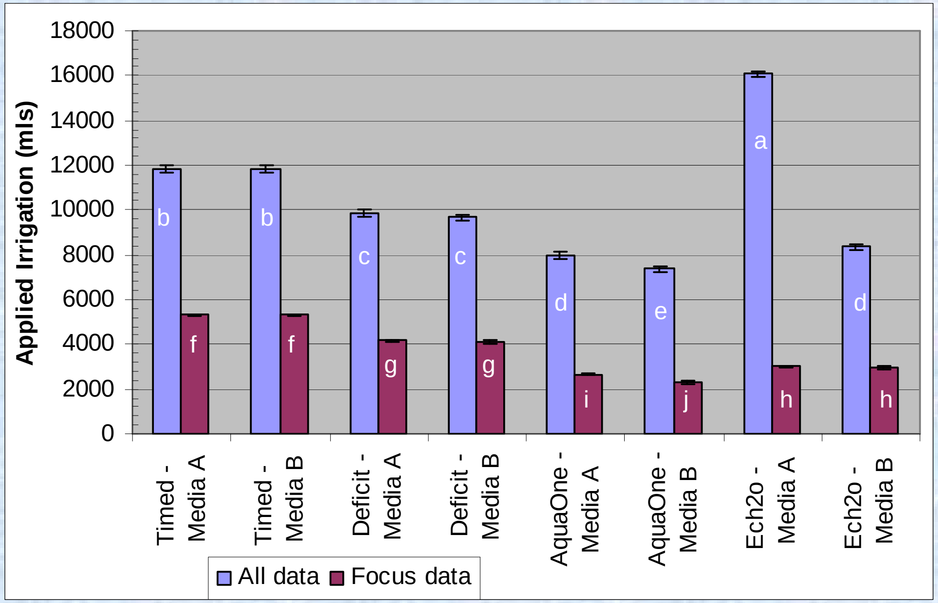
Water Use

Soil Moisture sensors (SMS) showed greater water savings than Deficit and Timed irrigation scheduling

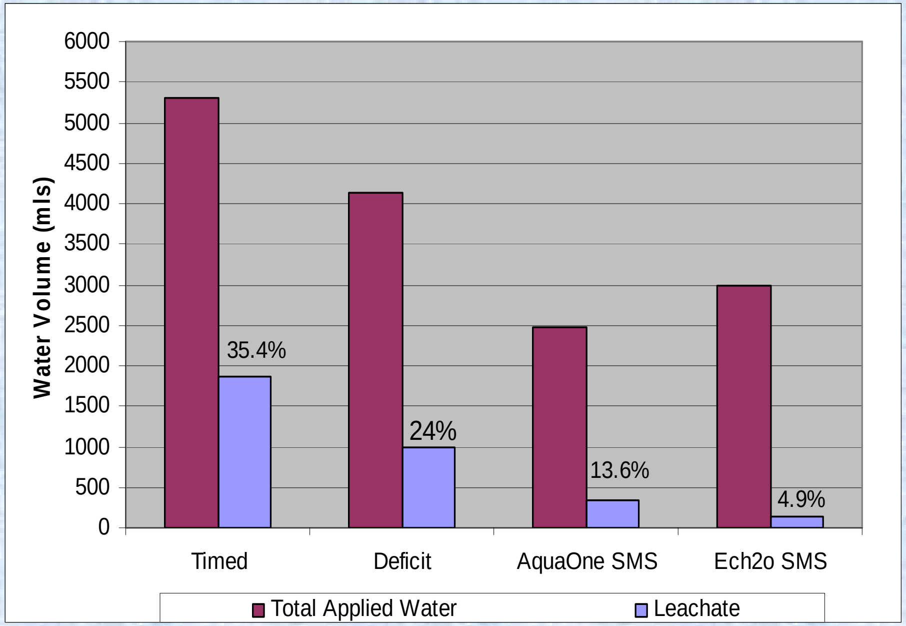
Container leaching fraction similar to application volume, but Ech2o sensor controlled plants used more water than others – possible influence by sensor?

Water use & leaching fraction for 1 month automation period

Irrigation Type	Total Applied Water (L)	Leaching Fraction (%)	Savings compared to Timed
Timed	5.3	35.4	0%
Deficit	4.1	24.0	22%
AquaSpy SMS	2.4	13.6	53%
Ech2o SMS	3	4.9	44%



Water use for each treatment & media type



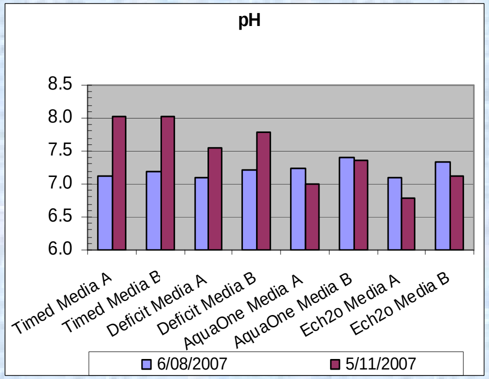
Combined water use per treatment

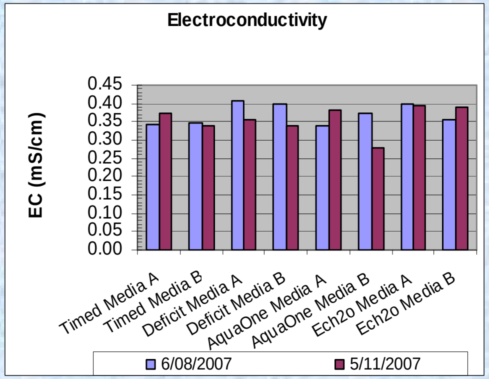
Irrigation Scheduling Trial Results

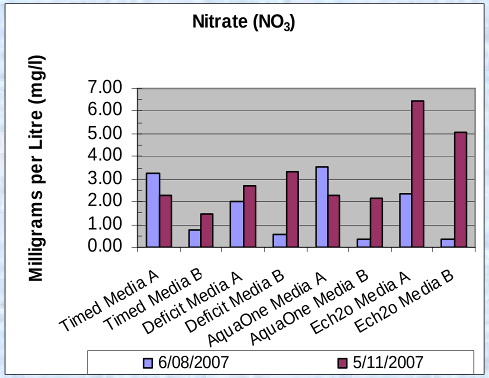
Leachate analysis

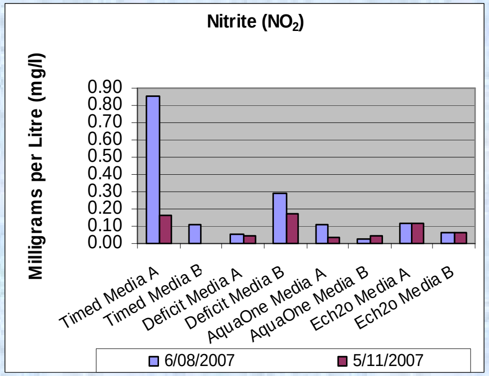
Leachate analysis for EC, P, K, NO3, NO2 showed no statistical significance or trends relating to irrigation or media type.

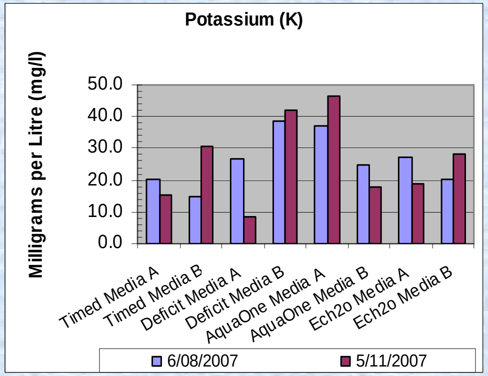
However, pH of the leachate did show a statistical significance – becoming more alkaline under timed irrigation scheduling. Possibly due to larger quantity of water being flushed through the container.

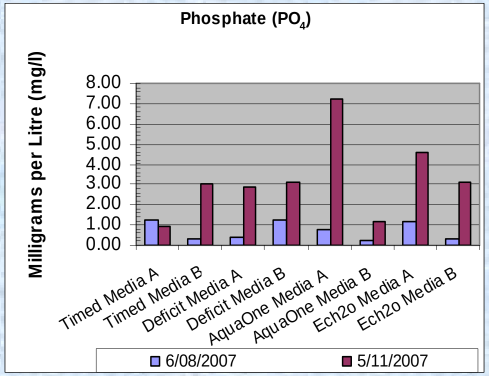








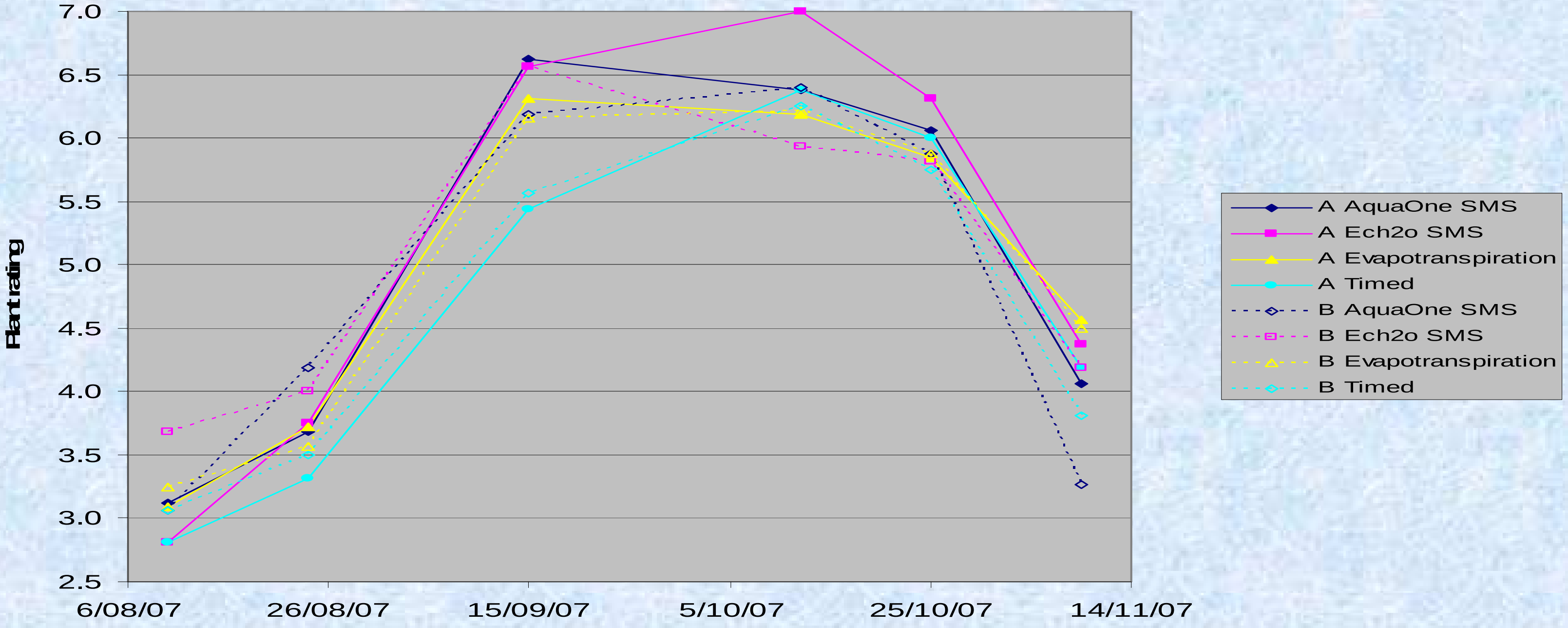


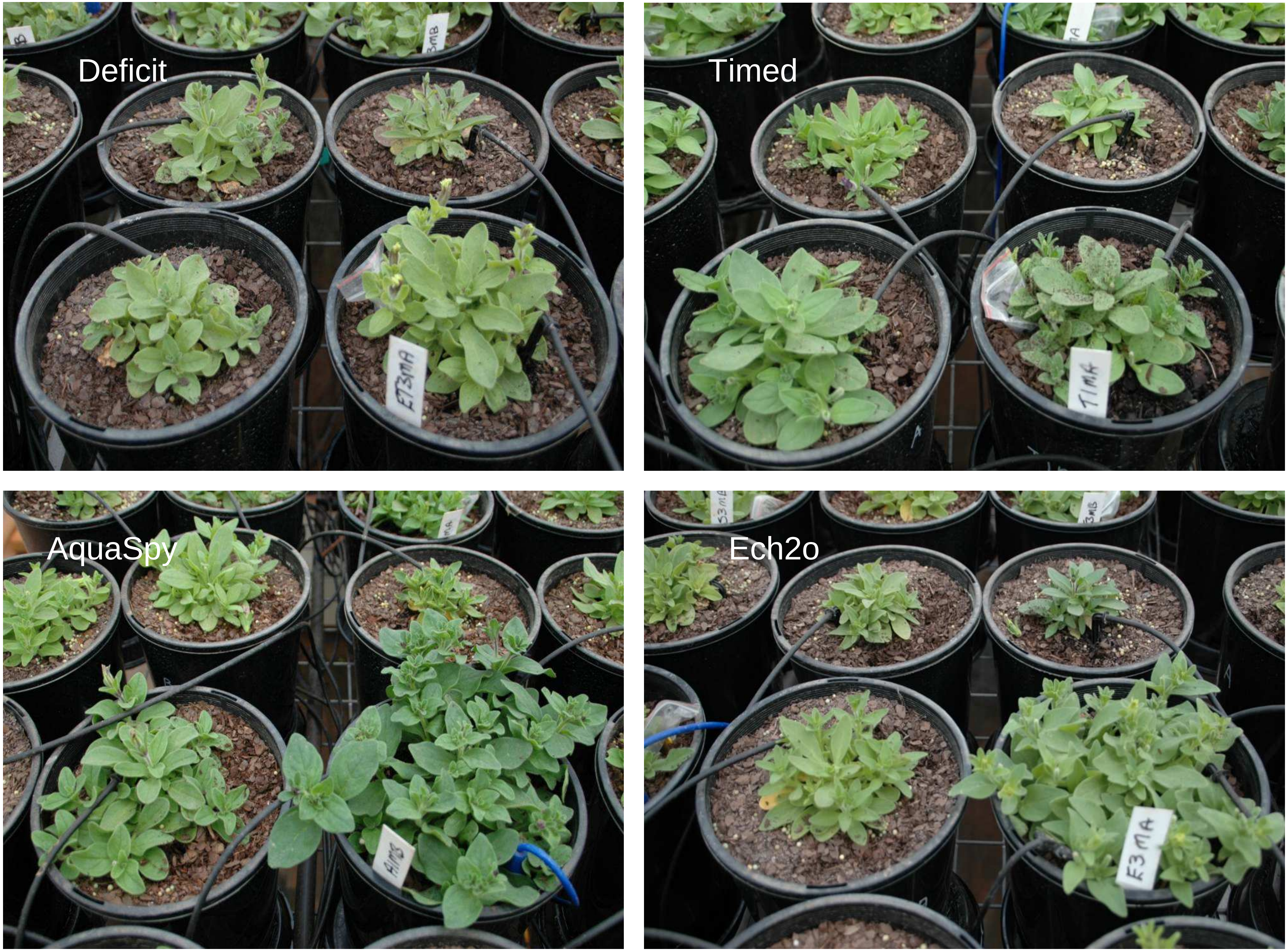


Irrigation Scheduling Trial Results

Plant Quality & Growth

- At the end of the trial, there was no significant difference in plant growth or quality between the irrigation types.
- However, there was minor significant differences in plant growth within the first several weeks after planting.
- Timed irrigation scheduling showed a lower growth rate than all other scheduling methods in the first 2 months after planting.
- Media B (pine bark (85%), Coir (15%) showed a higher ranking in the first 2 months.




Deficit
Timed
AquaSpy
Ech2o

Conclusions

1) Soil moisture sensors are a viable method of irrigation scheduling but several issues must be addressed before implementing irrigation automation.

2) Using soil moisture sensors as a monitoring tool or to automate irrigation can reduce water use and improve scheduling to suit the daily climatic conditions.

3) Deficit irrigation scheduling is a cheaper and effective way of reducing water use while maintaining plant quality.

Recommendation:-

Implement deficit irrigation scheduling while considering irrigation system upgrades

If using an old timed irrigation controller that limits scheduling adjustment an upgrade to a more flexible unit with a percentage control facility will make scheduling adjustments simpler and will save water.

**** Save Water – Save Money ****


THE END
Questions ?

Increasing Adoption of Innovative Irrigation and Water Recycling Technologies in Australian Nurseries.

Part 2 - Retrofitting

Conducted by

Queensland Department of Primary Industries & Fisheries

For

Nursery & Garden Industry Association

Queensland Government
Department of Primary Industries and Fisheries

Project Aims:

1) Identified 2 wholesale production nurseries working towards NIASA accreditation that had an old inefficient irrigation system.

Retrofit these nurseries to meet NIASA standards to -

1) Reduce water use for WEMP – (quantify possible water savings achievable with a retrofit)

2) Improve water use efficiencies – [irrigation uniformity & application rates (CU, SC, MAR)]

3) Reduce production costs OR identify what other associate cost are reduced by improving irrigation efficiency

4) Conduct a cost-benefit analysis to determine financial feasibility of a retrofit

5) Development of an economic model that can be used by nursery managers to predict the benefit and returns prior to outlaying any money

2) Compared 2 privately retrofitted nurseries with the case study nurseries.

1) Support findings obtained from case study nurseries (retrofits not unique)

2) Provide a benchmark for achievable water use reductions

3) Compare water and associated cost savings with case study nurseries (cost-benefit analysis).

4) Test economic model with real nursery data.

Nursery 1

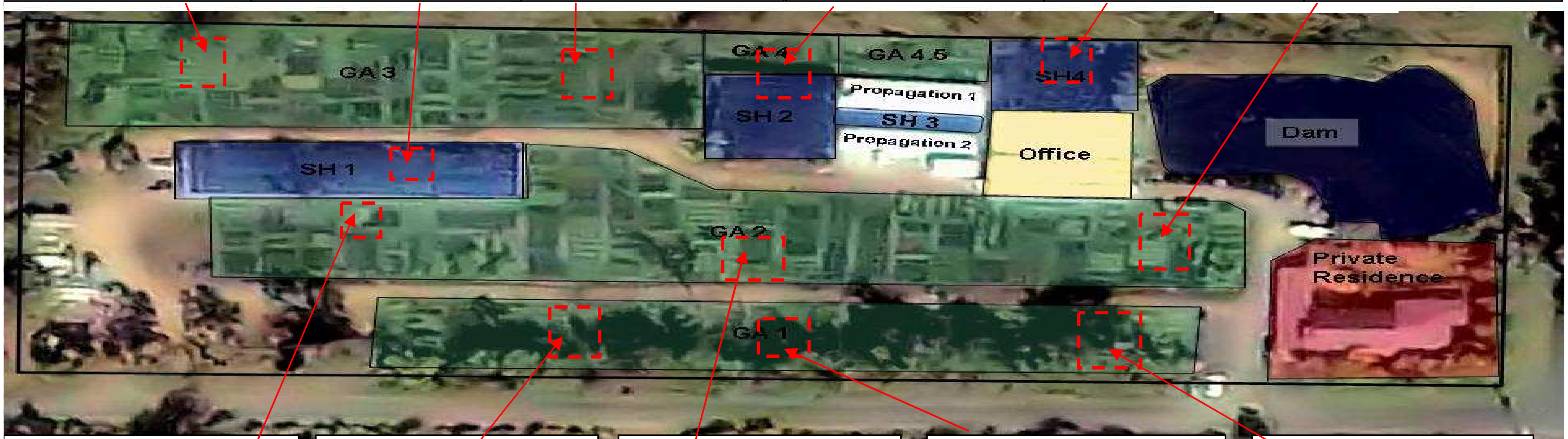
Old irrigation system 70% Town water (15.2 ML/Yr), 30% Dam water (6.5 ML/Yr)

- 15 year old irrigation system built as nursery expanded.
- Installed and added to irrigate dry areas - adhoc
- Sprinkler spacings and riser heights were uneven – multiple sprinkler types
- Irrigation uniformity was poor and application rates inappropriate for media infiltration rates
- Supplemental hand watering and extra irrigations needed to maintain plant growth
- Onsite dam but runoff collection drains inefficient – water pooled in growing beds
- No disinfestation system installed
- High occurrence of disease, algal and fungal growth – requiring excess chemical use
- High number of plant throw-outs & increased labour costs to sort product



Nursery 1

Old MAR = 8.8mm/hr	Old MAR = 7.9mm/hr	Old MAR = 11.4mm/hr	Old MAR = 6.1mm/hr	Old MAR = 11.5mm/hr	Old MAR = 13.1mm/hr
New MAR = 9.1mm/hr	New MAR = 12.9mm/hr	New MAR = 8.6mm/hr	New MAR = 9.7mm/hr	New MAR = 5.1mm/hr	New MAR = 8.7mm/hr
Old CU = 69.6%	Old CU = 60.4%	Old CU = 68.7%	Old CU = 70.5	Old CU = 54.4%	Old CU = 66.4%
New CU = 92.2%	New CU = 91.6%	New CU = 92.2%	New CU = 94.4%	New CU = 86.5%	New CU = 91.6%
Old SC = 1.98	Old SC = 5	Old SC = 2.26	Old SC = 3.23	Old SC = 3.63	Old SC = 3.45
New SC = 1.41	New SC = 1.36	New SC = 1.21	New SC = 1.13	New SC = 1.35	New SC = 1.26



Old MAR = 14.6mm/hr	Old MAR = 6.5mm/hr	Old MAR = 13.1mm/hr	Old MAR = 6.5mm/hr	Old MAR = 6 mm/hr
New MAR = 10.2 mm/hr	New MAR = 10.5 mm/hr	New MAR = 9.7 mm/hr	New MAR = 10.7 mm/hr	New MAR = 8.8 mm/hr
Old CU = 79.6%	Old CU = 82.2%	Old CU = 66.4%	Old CU = 82.2%	Old CU = 47.1%
New CU = 96.3%	New CU = 90.9%	New CU = 94.2%	New CU = 95.9%	New CU = 95.2%
Old SC = 2.10	Old SC = 6.15	Old SC = 3.45	Old SC = 6.15	Old SC = 7.08
New SC = 1.11	New SC = 1.2	New SC = 1.12	New SC = 1.3	New SC = 1.15

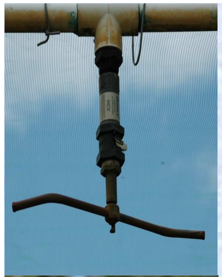
- Replaced irrigation system from sand filters
- new mainline & disinfestation coil
- Outside bed laterals at 5m x 5m
- Shadehouse laterals to suit production type,
- New sprinklers - jets to suit production type,
- Adjusted scheduling to suit new system


BEFORE

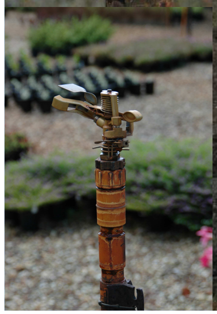
AFTER

BEFORE

AFTER







<u>Nursery 2</u>

Old Irrigation System 100% Dam Water Supply

- 15 to 20 year old irrigation system installed as nursery grew over generations
- Sprinkler spacings and riser heights relatively consistent – similar sprinkler types
- Irrigation uniformity average but **mean application rates excessively high**
- Used 24.5 ML per year
- Growing beds well maintained and clean
- Excellent runoff collection drains running back to onsite dam
- Chlorine dosing system in installed
- Minimal occurrence of disease

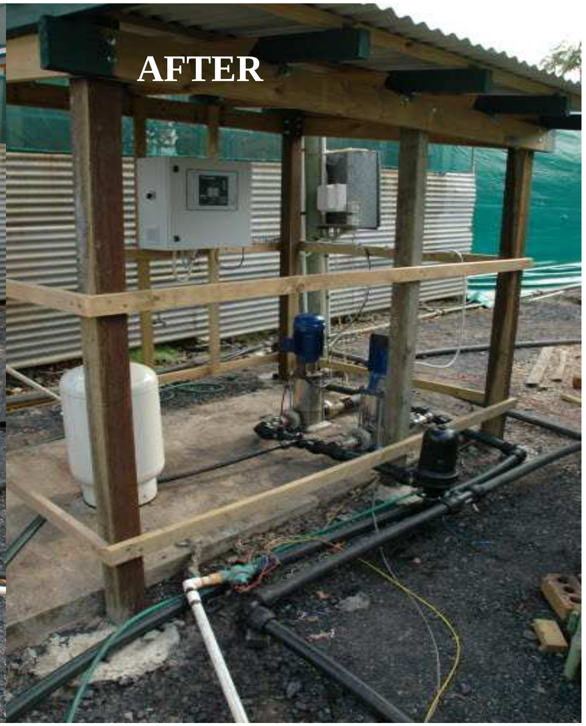

Nursery 2

Old MAR = 27.9 mm/hr	Old MAR = 29.2 mm/hr	Old MAR = 16.6 mm/hr	Old MAR = 16.7 mm/hr	Old MAR = 13.6 mm/hr
New MAR = 10.6 mm/hr	New MAR = 10.6 mm/hr	New MAR = 8.4 mm/hr	New MAR = 17.3 mm/hr	New MAR = 8.4 mm/hr
Old CU = 69%	Old CU = 74.5%	Old CU = 85.7%	Old CU = 61.5%	Old CU = 66.4%
New CU = 88.7%	New CU = 88.2%	New CU = 86.5%	New CU = 97.3%	New CU = 86.5%
Old SC = 3.15	Old SC = 2.10	Old SC = 1.75	Old SC = 2.91	Old SC = 3.09
New SC = 1.2	New SC = 1.4	New SC = 1.33	New SC = 1.03	New SC = 1.33

Old MAR = 32.5 mm/hr	Old MAR = 21 mm/hr	Old MAR = 29.2 mm/hr	Old MAR = 39 mm/hr	Old MAR = 28.6 mm/hr	Old MAR = 50.6 mm/hr
New MAR = 10.6 mm/hr	New MAR = 10.2 mm/hr	New MAR = 12.2 mm/hr	New MAR = 10.7 mm/hr	New MAR = 9.9 mm/hr	New MAR = 9.6 mm/hr
Old CU = 82.6%	Old CU = 85.6%	Old CU = 88%	Old CU = 90.7%	Old CU = 69.2%	Old CU = 61.1%
New CU = 92.5%	New CU = 92.8%	New CU = 92.8%	New CU = 92.3%	New CU = 90.2%	New CU = 91.6%
Old SC = 1.84	Old SC = 2.08	Old SC = 1.65	Old SC = 2.21	Old SC = 2.51	Old SC = 5.01
New SC = 1.16	New SC = 1.25	New SC = 1.25	New SC = 1.23	New SC = 1.31	New SC = 1.27

- Replaced lateral lines but use existing mainline
- Tailored laterals to suit irregular shaped bed & shadehouse
- New sprinklers with different jets to suit production type
- Installed a VFD pump controller – reduced line pressure
- Centralised irrigation controllers - 3 old to 1 new

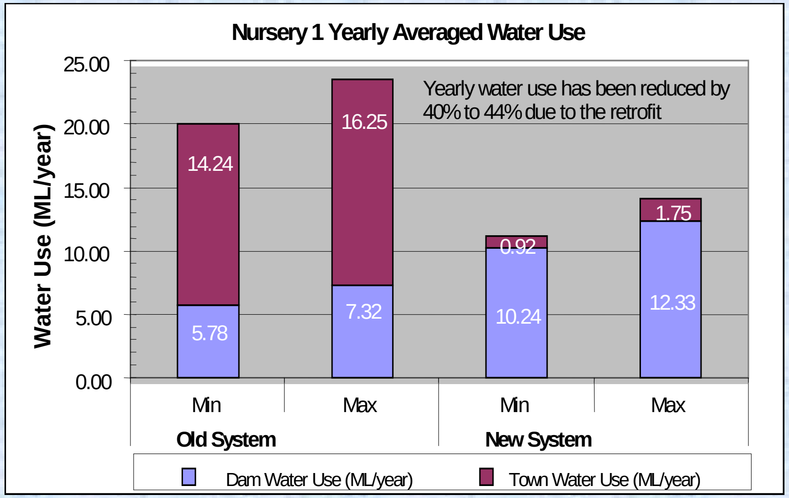

BEFORE


AFTER


New & old sprinklers

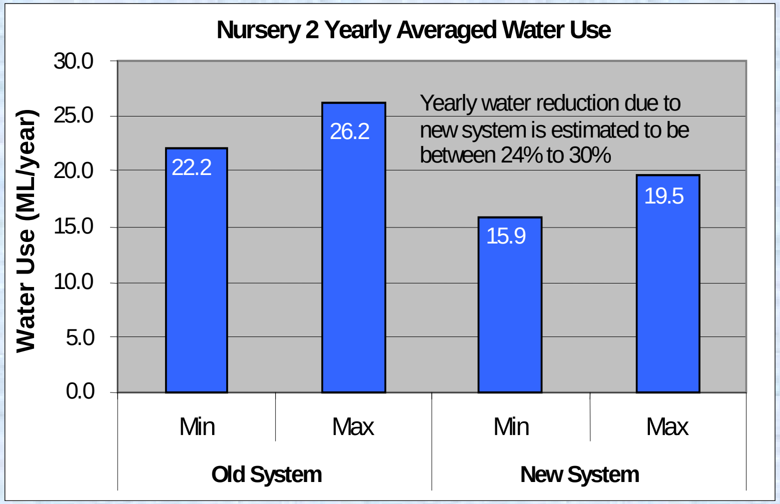
Nursery 1: Uses town and dam water

- Reduced total yearly water use by 40% to 44% (9 ML/ year)
- Reduced town water use from 70% to 13% (14 ML/year)
- Saved approximately $19,000 on town water costs
- Reduced plant throw outs by approximately 5%
- Reduced wet areas throughout the nursery leading to
  - -Reduced outbreaks of plant disease
  - -Reduced herbicide and fungicide usage
  - -Improved plant uniformity and quality
- Improved irrigation efficiencies
- Irrigation application rates match media infiltration rates



Nursery 2: Dam water only

- Due to this nursery only using dam water, cost savings are low but water supply has been prolonged.
- Reduced yearly water use by 24% to 30% (6.5 ML/year)
- Application rates match infiltration rates
- Irrigation line blowouts has stopped – reduced pressure
- Increased irrigation scheduling awareness
- Reduced time required to adjust irrigation scheduling
- Matched application rates to media infiltration rate



- **Water & cost savings are dependent on water supply & old irrigation system efficiencies!**
- **Increasing water use efficiencies will effectively ‘future proof’ a nursery for years.**

Economic Assessment of Nursery Case Studies

Rod Strahan

Senior Agricultural Economist
DPI&F Toowoomba

Queensland Government
Department of Primary Industries and Fisheries

Case Study 1

Annual Water Usage	Old System	New System	Change
Area of Retrofit 1 Hectare	(Klitres Water/year)	(Klitres Water/year)	(Klitres Water/year)
Town Water	15,221	1,314	-13,907
Dam Water	6,534	10,996	4,462
Total Water Usage	**21,755**	**12,310**	**-9,445**

Annual Water savings of 9.4 ML a reduction of 43%

Case Study 2

Annual Water Usage	Old System	New System	Change
Area of Retrofit 0.52 Hectares	(Klitres Water/year)	(Klitres Water/year)	(Klitres Water/year)
Town Water			
Dam Water	24,200	17,700	-6,500
Total Water Usage	**24,200**	**17,700**	**-6,500**

Annual Water savings of 6.5 ML a reduction of 27%

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Case Study 3

Annual Water Usage	Old System	New System	Change
Area of Retrofit 0.6 Hectares	(Klitres Water/year)	(Klitres Water/year)	(Klitres Water/year)
Town Water	9,490	1,095	-8,395
Bore Water		4,015	4,015
Total Water Usage	**9,490**	**5,110**	**-4,380**

Annual Water savings of 4.38 ML a reduction of 46%

Case Study 4

Annual Water Usage	**Old System**	**New System**	**Change**
Area of Retrofit 2.7 Hectares	(Klitres Water/year)	(Klitres Water/year)	(Klitres Water/year)
Town Water	55,480	6,935	-48,545
Dam Water		24,273	24,273
Bore Water		3,468	3,468
Total Water Usage	**55,480**	**34,675**	**-20,805**

Annual Water savings of 20.8 ML a reduction of 37.5%

The benefits of the system changes are:

- Decrease use of town water supply
- An even distribution of water - decrease in the number of plant throw outs
- Savings on pumps and pipes and savings to electricity costs
- Drainage system channels excess water back to the dam for reuse
- Drier plant area
- Reduced plant disease and a decrease in fungicide required and application costs
- A decline in fertiliser leaching, thus improving plant nutrition resulting in improved and more even plant growth
- The drier plant area creates a more efficient working area

Economic Results

Assessment Criteria	Nursery 1	Nursery 2	Nursery 3	Nursery 4
Retrofit Investment	$77,594	$38,240	$78,196	$220,000
NPV	$171,577	-$1,369	$138,290	$586,079
B/C Ratio	**3.2**	**1**	**2.8**	**3.7**
Change in Annual Business Profit	$24,070	$831	$16,375	$89,463

Conclusion

- The Positive results achieved from the installation of more efficient irrigation systems into nursery businesses provides a robust business case to encourage nursery owners to invest in more sustainable production technologies.

SAVE WATER – SAVE MONEY