Department of Primary Industries

Managing perennial horticultural crops during drought

FIRST EDITION

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Image acknowledgements

Cover image: Citrus trees suffering from drought stress. Photo: Tahir Khurshid.

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Contents

Drought

What is drought?

Drought is commonly defined as a prolonged, abnormally dry period when there is insufficient water available to meet normal requirements. Meteorologists monitor the extent and severity of drought in terms of rainfall deficiencies. Agriculturalists rate the effect on primary industries, hydrologists compare ground water levels, and sociologists define it by social expectations and perceptions.

It is generally difficult to compare one drought to another since each drought differs in seasonality, location, size and duration. This is, in part, due to the different climate drivers from the Pacific, Indian, and Southern Oceans that can influence variations in rainfall (such as the El Niño-Southern Oscillation and Indian Ocean Dipole).

Drought in NSW

With a variable climate, drought has been a constant and inevitable feature of the NSW landscape. Dry conditions should be considered the same as other business risks. Over time, NSW has moved away from treating droughts as natural disasters that require emergency responses. Planning for dry conditions over the long term is the most effective way to prepare for drought and other downturns.

History of drought in NSW

During the second half of the 19th century, increased population and droughts led to increasing farming intensity and attempts to 'drought-proof' agriculture by expanding irrigation. While there were localised droughts in parts of the state or country, the major droughts were:

- 1895–1903, Federation Drought
- 1937–1945, World War II Drought
- 2001–2010, Millennium Drought

In addition to these multi-year droughts, there have been several short, intense droughts (e.g. 1914–1915, 1965–1967 and 1982–1983). The most recent drought began in NSW in mid-2017 and it is equivalent to a major drought on the long-term historical record (100 years).

How the NSW Government measures and reports on drought

NSW Department of Primary Industries, working with the independent Regional Assistance Advisory Committee (RAAC), developed the Enhanced Drought Information Systems (EDIS) project and the Combined Drought Indicator (CDI) to track all phases of drought from onset to recovery.

The CDI combines meteorological, hydrological and agronomic definitions of drought using indices for rainfall (RI), soil water (SWI), plant growth (PGI) and drought direction (DDI). The CDI uses the first three indices to account for a combination of variables that affect drought conditions beyond rainfall deficiencies, including factors such as high temperatures (evaporation), run-off, soil infiltration and rainfall intensity. Used together, these indices can indicate the five phases of drought: non-drought, recovering, drought-affected, drought, intense drought (Table 1).

NSW DPI produces the CDI drought indicator maps in conjunction with the Bureau of Meteorology, CSIRO Oceans and Atmosphere, Geoscience Australia, International Centre for Applied Climate Sciences, Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), NSW Local Land Service, NSW Rural Financial Counsellors and the NSW DPI Rural Resilience Network.

Table 1. Description of the Combined Drought Indicator framework.

CDI Phase	Technical definition	Description – typical field conditions
Non-drought	At least one indicator is above the 50th percentile.	• Production is not limited by climatic conditions.
Recovering	All indicators are below the 50th percentile but above the 30th percentile	• Production is occurring but would be considered below average • Full production recovery may not have occurred if this area has experienced drought conditions over the past 6 months
Drought affected (weakening)	At least one indicator is below the 30th percentile and the rainfall trend is positive over the past 90 days.	• Production conditions are getting tighter, but there has been some rainfall over the past month • It is rare to enter the recovering phase from the non-drought category; usually there is a quick (1-2 week) transition into drought affected or drought • When indicators are close to the drought threshold, drought conditions are severe
Drought affected (intensifying)	At least one indicator is below the 30th percentile and the rainfall trend is negative over the past 90 days.	• Conditions are deteriorating; production is beginning to get tighter • Ground cover may be modest, but growth is moderate to low for the time of year • When indicators are close to the drought threshold, drought conditions are severe
Drought	At least one indicator is below the 5th percentile	• Conditions may be very dry, or agronomic production is tight (low soil moisture or plant growth) • It is possible to be in drought when there has been some modest growth or some rain
Intense drought	All three indicators (rainfall, soil water, plant growth) are below the 5th percentile	• Ground cover is very low, soil moisture stores are exhausted and rainfall has been minimal over the past 6-12 months

The NSW DPI supports primary producers to become more resilient and better prepared for adverse conditions and drought by providing assistance with finance, skills and training, information, research and development, animal welfare assistance and social support.

The NSW Government works with industry and stakeholders to enhance farmers' drought preparedness through a suite of assistance measures including:

- Finance: the Farm Innovation Fund provides long-term low interest loans to help improve permanent on-farm infrastructure
- Skills and Training: the Farm Business Skills Professional Development Program provides primary producers with access to vocational training and farm business planning
- Information: including practical advice on seasonal conditions, pest and weed management and livestock management made available through NSW Local Land Services and NSW DPI
- Research and Development: $2.5 million to work with the Bureau of Meteorology to explore an enhanced network of weather stations across NSW and to work with the Commonwealth Government and farming communities to develop a commercial multi-peril insurance product for the cropping sector
- Animal Welfare Assistance: funding to provide transport assistance for animal welfare and donated fodder within NSW
- Wellbeing: the Rural Resilience Program, rural support workers, and a range of services in the public, private and non-government sectors.

For more information, refer to the NSW DPI DroughtHub website (https://droughthub.nsw.gov.au/)

Preparing for drought

When planning for drought conditions, it is helpful to have a clear understanding of your objectives and carefully evaluate all options. Be realistic when assessing the situation and do not underestimate the available resources (e.g. capital, water and management), nor the personal cost of implementing a particular course of action. It is important to have a plan, act early, review and then plan again, revising the plan as each step is implemented.

To make good decisions during a drought it is necessary to assemble as much information as possible on the factors that will influence your decisions. Information on 'what to do?' comes from:

- past dry spells and drought experiences
- past trends and current predictions
- your established rural network
- decision support tools to inform potential strategies.

Drought action plan

Droughts develop progressively, not overnight, so plan your strategies early to ensure the economic survival of your business. Experience from previous droughts has shown that:

- drought decisions are often made on an emotional rather than a logical basis; try to make objective decisions and seek skilled help when necessary
- not all aspects of drought are bad; there can be opportunities for making money from alternative enterprises and this experience can be used to your advantage in normal seasons
- the producers who do best during droughts are those who adopt sound management and financial plans (and regularly review), make firm decisions, and act early and quickly.

Here are some recommended steps for preparing drought strategies:

1. start early in a dry period to establish your short-term and long-term objectives
2. assemble facts and figures on all aspects of alternative strategies
3. cost the strategies for various lengths of drought
4. select the strategies that best fit your objectives, projections and situation
5. write down your objectives and strategies, and whenever possible, set down numbers, dates or dollar figures as benchmarks or triggers for particular actions
6. review your strategies continually and adapt them if necessary.

More information is available at DroughtHub (www.droughthub.nsw.gov.au).

Where to start?

Check the availability of the most limiting factors such as:

- labour
- funds
- water
- surface/sub-soil moisture
- machinery and maintenance

Have an action plan:

- identify priority crops (i.e. the most economical/profitable)
- undertake water budgeting (irrigation, surface and sub-surface available water)
- plan crop management strategies (pest and disease)
- establish a management program for the current drought conditions.

As the drought progresses, monitor and review:

- your current practices and evaluate if they are sustainable
- current drought conditions
- any changes implemented.

Crop management strategies

Crop management strategies will be influenced by drought duration and severity. Each block will have different requirements depending on the plant age, size, growth stage and the season. Growth stages differ according to season, with the most important stages being budburst, flowering and fruit development. It might be necessary to identify the blocks most likely to yield a commercially viable crop and focus your efforts on these.

Conserving moisture will be a priority task in ongoing droughts. When water availability is limited (i.e. limited surface and/or sub-surface water), soil moisture saving strategies will need to be implemented, such as:

- mulching
- canopy management
- inter-row management
- using/adapting/modifying irrigation systems
- purchasing water
- optimum water storage facilities
- monitoring available soil moisture.

Mulching

Mulching is a strategy used to conserve soil moisture, suppress weeds and improve plant growth, if applied at the correct depth (approximately 10 cm). However, mulch should not be placed too close to plant trunks to prevent fungal diseases from occurring. Mulch is also known to tie up nutrients such as nitrogen, so it is important to ensure access to essential nutrients for normal plant development and growth via fertigation or fertilising the plants.

Canopy management

During severe drought conditions, heavily pruning plants might be the only option to save them. Pruning minimises the amount of water required for the plant to stay alive. Not having a crop for one year is cheaper than losing the plant as it can take up to 4 or 5 years before there will be another substantial crop from the plant.

If possible, a section of the orchard or vineyard could be identified as the harvestable crop to provide a source of income. The available water could be dedicated to this section. However, some budgeting/forecasting should be conducted first to determine the potential benefit from this compared with the cost of producing the crop.

Inter-row management

Consideration needs to be given to how the inter-row is to be managed. Are there any weeds present and are they in sufficient quantity to take soil moisture away from the plants? Even small amounts of rain, while not enough to lessen the drought, can encourage weed growth.

Using/adapting/modifying irrigation systems

Water requirements for orchards and vineyards will vary depending on tree, vine or plant size and age and growth stage. When planning for drought, ensure careful consideration is given to the irrigation strategy and water budget. The most efficient irrigation system (e.g. drip) should be installed and regularly maintained. An inefficient irrigation system will only enhance the effects of drought. While correcting these issues might result in only modest water savings, in a drought every drop counts.

Ensure the irrigation system can be used in sections so available water can be directed to more profitable blocks rather than watering the entire orchard with limited water.

Purchasing water

During drought conditions the amount of available produce will be reduced, potentially increasing its value. Therefore, it might be profitable to produce a crop. Available on-farm water may be limited or not available but there may be water for purchase on the free market. In the irrigation growing regions, this water would be made available through irrigation systems.

Some orchard or wine growing regions are not part of an irrigation system and have generally relied on rainfall, surface water storage or underground water sources (through licences). However, given that the crop would be valuable, it might be worthwhile to purchase water. The amount of water needed by the plants, how it will be delivered and where it will be stored will need to be considered.

Optimal water storage facilities

There are several types of water storage facilities. In the large irrigation regions, water is delivered through a shared resource in a catchment. The amount of water an irrigator can use depends on their licence, which will be for secure or non-secure water. Secure water is generally given to perennial crops to ensure plant survival during drier times because it can take years for a replacement plant to become productive. Secure water has a higher price than non-secure water, but there is a guarantee that you will get water. Non-secure water is only available to irrigators if there is enough water in the catchment. During drought conditions, the catchment is often depleted and the water distribution priority is given to those who hold secure water licences.

Alternatively, some orchards and vineyards rely on rainfall and supplementary irrigation, which is often sourced from surface water storage (dams) or sub-surface water (bores). Surface water storage relies heavily on regular refilling from run-off during rainfall. Without regular rainfall, surface water storage can be depleted. If higher temperatures (often associated with drought) occur at the same time, evaporation rates will be increased.

So what is optimal water storage? Well, it depends on your circumstances. Irrigation regions have irrigation infrastructure. Non-irrigation regions have surface and sometimes sub-surface water storage facilities. Optimal water storage is identifying the likelihood of drought and managing available water to the plants.

Monitoring available soil moisture

How much soil moisture is available to plants can be measured by soil moisture monitors. These provide the current water status in the soil and the quantity of available water to the plant. However, consideration needs to be given to the capacity of plant uptake of water, which depends on the hydraulic conductivity of the soil. Various soil moisture monitors can provide this information (for example tensiometers, soil psychrometers, neutron probes or capacitance sensors).

Variations in soil type mean that multiple soil moisture monitors need to be located within each orchard or vineyard. Each soil moisture reader is only representative of that location, not the whole orchard or vineyard.

Case study

Orange Agricultural Institute was severely affected by the 2017–20 drought. The research site has temperate nut orchards (walnut and hazelnuts), apple orchards and a vineyard. The Institute relies predominately on surface water supplies to supplementary irrigate the orchards, with sub-surface water (bore) as a back-up. Protracted drought conditions resulted in surface water supplies being depleted, then sub-surface water was used. However, the bore was becoming increasingly unreliable, such that researchers and orchard managers had to implement alternative strategies.

We identified our priorities as:

1. Plants over data. We agreed that we might need to sacrifice some research data to save the trees and vines because it is less of a loss than losing the plants
2. Identify what soil water was already available. More soil moisture probes were purchased and place throughout each orchard
3. Conserve what moisture we have. A heavy mulching program was implemented. Young plants had straw that was used during lambing as this would have a good source of nitrogen. The older plants had a thick (> 20 cm) layer of wood mulch placed around the root area of each plant.

To consider the drought 'broken', at least 100–150 mm of rain was required with follow-up rain within the next 6 weeks. This was considered to be enough to replenish surface water storage and lost soil water. Fortunately, the rain came in early January, allowing the site to continue with collecting research data and harvest crops.

To make good decisions during a drought it is necessary to assemble as much information as possible on the factors that will influence your decisions.

Water resources

NSW DPI has many Primefacts available on its website that are specifically developed for primary producers preparing for and experiencing dry seasons and drought conditions. Information and support is also available through your NSW Local Land Services offices. Please note that the advice provided in these resources may not address the specific on-farm requirements of each user and individual circumstances should be assessed before adopting advice presented.

DroughtHub has links, fact sheets and the latest information about drought management, preparations and recovery.

The key NSW agencies responsible for water are:

- WaterNSW provides up-to-date information and data on relevant water storage and drought information for Greater Sydney and regional NSW
- NSW Department Planning Industry Environment – Water is responsible for surface and groundwater management including ensuring water security for NSW
- NSW Department of Primary Industries provides information on water sources
- NSW Health provides information on drinking water quality
- The Australian Drinking Water Guidelines give the definition of safe, good quality drinking water.

Household water supply

Check with your local council for water filling stations in your area. The guidelines for collecting water for domestic and stock use, guidelines for professional water carters and links to known participating councils are on the Household Water Supply page.

Town water and water restrictions

Water restrictions are issued through the local council or the local water utility provider. Search water restrictions in your local area through the Bureau of Meteorology or visit www.nsw.gov.au/townwater

What do I do if my surface and groundwater supply dry up?

If the stock and domestic water on your property dries up or is of insufficient quality for its intended purpose, access to an alternative water source will be necessary. Emergency standpipes and water filling stations are located across NSW and are a practical alternative for accessing water for domestic and stock purposes. These sites are managed by local councils or water utilities and are maintained to meet bulk water carting requirements. Conditions of use and access vary across council regions. Your local council or water utility can help establish:

- if water is available locally
- how much is available
- what approvals you need.

Water situation updates during drought

- https://www.waternsw.com.au/supply/regional-nsw/alerts-and-updates
- https://www.waternsw.com.au/supply/drought-information

Water allocations

- https://www.industry.nsw.gov.au/water/allocations-availability/allocations

Water quality

Water quality testing

Water testing is available through the Wollongbar Primary Industries Laboratories. Charges apply. Note, water sampling kits are available for testing dam, creek, river, bore, irrigation and tank water. Sample kits can be ordered online or can be picked up from your local DPI or Local Land Services office.

Water quality alerts

The local water utility or council provides alerts and information on the safety and suitability of drinking water and where water restrictions apply. For information on how boiled water alerts are issued, visit NSW Health to read the guidelines.

Water quality for irrigation

Different crops tolerate different levels of salinity in irrigation water. The tolerance of plants to salinity is mainly influenced by:

- crop species and/or variety
- climate, particularly lack of rainfall
- soil types and drainage characteristics
- salt accumulation
- irrigation method and management
- stage of plant growth

More information is available from Primefact 1345 Salinity tolerance in irrigated crops.

Interpreting water quality tests

General information can be found in Primefact 1344 Interpreting water quality test results. If you have further questions, NSW DPI staff at Wollongbar Laboratories are available to answer your questions about water tests and assist in interpreting results. They can be contacted on 02 6626 1103 or email wollongbar.csu@dpi.nsw.gov.au

Water collected privately

For advice on drinking water quality call 1300 066 055 and ask to speak with an Environmental Health Officer in your local Public Health Unit.

Surface water

Due to the potential for contamination, surface water is not recommended for human consumption unless it is filtered and disinfected. Unless drinking water quality can be assured through disinfection and routine testing, surface water should only be used for purposes other than drinking or cooking such as toilet flushing, garden watering and irrigation. Treatment may still be necessary for such non-drinking uses.

Groundwater

Groundwater poses less of a risk but can still be contaminated with disease causing microorganisms, heavy metals, other chemicals and radioactivity. Your groundwater should undergo comprehensive water quality testing as part of a risk assessment (including considering the aquifer condition) to ensure suitability for drinking water purposes. Treatment systems are available for groundwater. If you want to extract groundwater from an aquifer, you must apply for a water supply work approval to construct a water bore, well or spear point.

Rainwater

A properly maintained rainwater tank can provide good quality drinking water. Providing the rainwater is clear, has little taste or smell and is from a well maintained water catchment system it is probably safe and unlikely to cause any illness for most users. Proper maintenance of the tank, catchment system, roof, gutters and inlet is essential to ensure a safe supply of water. Treatment systems are available for rainwater.

Treatment options

Farm water comes from a number of different sources such as dams, bores, wells, rivers, town water, channels and recycled water, therefore its quality varies. The following resources should help determine if your water is suitable:

- Testing and treating water for stock and domestic use
- Primefact 1337 Farm water quality and treatment
- Primefact 1338 Desalination of bore water.

Blue-green algae

Algal blooms can cause waters to be unsafe. Water NSW provides up-to-date information on algal blooms in NSW. Any river water or farm dam used to irrigate crops vulnerable to blue-green algal (BGA) blooms and may become contaminated. Primefact 1280 Irrigating with blue green algae affected water is designed to assist irrigators who may irrigate with BGA-contaminated water.

Water related assistance

The NSW Government provides information on water supply and testing on the DroughtHub page and a range of assistance packages to help farmers prepare for, and manage, dry conditions:

- DroughtHub shows the available assistance for primary producers in NSW affected by the drought conditions. Several NSW DPI offices are available to assist people accessing assistance. Visit the Assistance Near You map on DroughtHub to search for an office near you
- Drought Transport Subsidy can be applied for the cost of transporting water to a property
- Emergency Water Infrastructure Rebate Scheme can be applied to new purchases and installation of pipes, water storages and water pumps, de-silting dams, and associated power supplies such as generators
- Farm Innovation Fund is a loan scheme for capital infrastructure works (e.g. sheds, silos, water storage) to prepare for dry conditions, to build resilience and improve on-farm efficiency
- Drought Assistance Fund offers interest-free loans to transport water and for water infrastructure.

Managing citrus orchards during drought

Steven Falivene, Development Officer – Citrus, NSW DPI Dareton

Jeremy Giddings, Manager Irrigation – Mallee, Agriculture Victoria Irymple

Mark Skewes, Research Scientist, South Australian Research and Development Institute

Introduction

Managing citrus orchards with less water requires understanding the orchard's water requirements and the effects of water stress. There are many options to consider when managing an orchard with reduced water availability. For example, water requirements will be influenced by tree size and age, so reducing mature tree canopies might be an option. Another strategy is to sacrifice less profitable blocks with minimal water and allocate water to more profitable blocks, rather than watering the whole orchard with a sub-optimal water regime. Implementing irrigation scheduling and drip irrigation practices could also help. When considering these options, careful planning, including using a water budget should be used to guide decision making. Every farm will be different in the selection and degree of water saving options. This Primefact addresses options for managing your citrus orchard with a reduced water allocation as well as describing the experiences of citrus growers from NSW and Victoria who faced limited water availability in 2003 and 2007.

Citrus water requirements

Mature sprinkler-irrigated citrus trees grown in Sunraysia and the Riverland require approximately 1,000–1,200 mm (10–12 ML/ha) of water annually. Yields will decline when less water is applied (Skewes, 2013a; Figure 1).

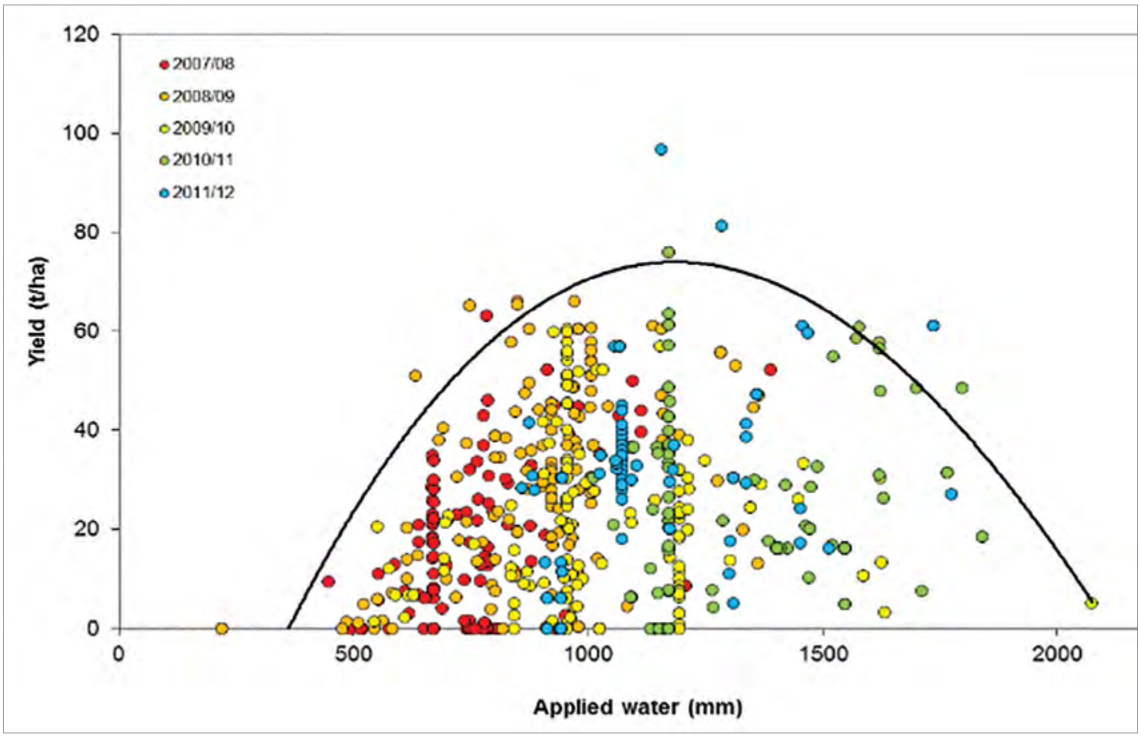

Figure 1. Citrus yield response to water in the Riverland and Sunraysia growing areas.

Water and citrus growth

For unrestricted growth, citrus trees require water all year round. The peak demand for water is during the warmer months i.e. October to March, when 76% of the annual allocation is required (Figure 2). Water use declines during late autumn and winter with the onset of cooler temperatures and slower tree growth.

Water stress can affect citrus production at all development stages and stress can occur before any visual symptoms appear. Water availability will influence flowering, fruit set, fruit drop, fruit size, yield, internal fruit quality characteristics and canopy development. Water stress can also restrict vegetative growth and reduce canopy development, which is especially important in young trees and for next season's flowering. Therefore, the options available for stressing citrus at particular growth stages to save water while remaining productive are limited.

Rootstocks vary in their tolerance to water stress and salinity levels. Recent research at Loxton, South Australia indicated that Cleopatra mandarin, Carrizo and Troyer citrange, and Swingle citrumelo have moderate to good drought tolerance. *Poncirus trifoliata* and Sweet orange have poor drought tolerance as they are relatively shallow rooted (NSW DPI Mandarin Manual). Recognising rootstock drought tolerance can influence which blocks could be prioritised if water rationing decisions are required.

The average water use by mature citrus trees based on long-term data collected at Dareton in south-western NSW is shown in Figure 2. This information can be used as a guide to determine water needs and plan for the coming season. An Excel water budget spreadsheet is available from NSW DPI website (under the Business heading).

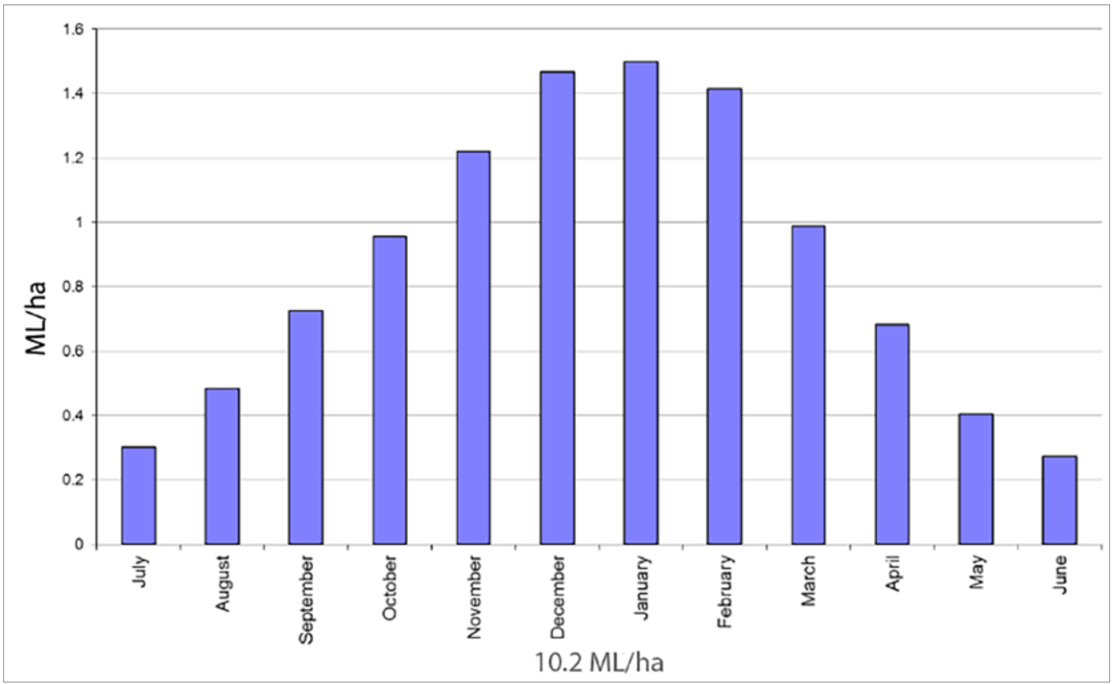

Figure 2. Monthly use of mature citrus trees with full ground cover and under sprinkler irrigation at Dareton.

Citrus growth stages and water requirements

Table 2. Water requirements of citrus at various growth stages.

Growth stage	% of annual water requirement used	Effects of water stress at this stage
Flower bud induction and initiation (mid-May–July)	10	Can increase flowering. Some regions (e.g. Northern Territory) will deliberately use water stress to induce flowering. However, drought periods of more than 30 days are usually required to induce a significant number of flower buds.
Flowering and fruit set (mid-September–October)	14	Can reduce fruit set, cause excessive fruitlet drop, reduce yield and suppress the spring flush.
Stage 1: Fruit growth (cell division; November–December)	26	Cells are dividing and up to 60% of final fruit size is determined. Small fruit at the end of this period tends to be small at harvest. Water stress can cause excessive fruitlet drop and reduce fruit size. Fruitlet drop is usually more severe when water stress is coupled with high temperatures (>35 °C). Trees carrying mature fruit at this time, such as valencias, seem to be able to buffer this effect to some extent, with fruit drop possibly more severe in navels. The summer leaf flush can also be suppressed, which might affect next season's flowering.
Stage 2: Fruit growth (cell expansion; January–April)	40	The first few months (mid-December to February) is the critical time when fruit cells are expanding (cells can increase 1,000 times) and final fruit size is determined. Therefore, water stress in the early part of this stage should be kept to a minimum. An early sign of stress is that fruit stop growing, so it is important to regularly measure fruit size. From January onwards, measure fruit size weekly at the same time each day (7–9 am). If water is supplied at the first sign that fruit growth rate is decreasing, then final fruit size might not be reduced. The best window for extending irrigation intervals is during late summer and autumn. Minor water stress during the latter part of this stage can be tolerated without a major effect on fruit size. However, prolonged water stress will reduce fruit size and the reduction is more pronounced when the crop load is heavy. Prolonged water stress can also influence internal fruit quality characteristics, increasing the acidity and total soluble solids (TSS) of fruit, while slightly decreasing per cent juice. Short-term (i.e. 6–8 weeks) controlled water stress during late summer to early autumn (February to March) is used on some mandarin varieties to increase fruit Brix and acid and to hasten fruit maturity. It is speculated it could provide similar effects on oranges. Mid summer and autumn leaf flush will be suppressed, which can affect next season's flowering.
Fruit maturity (May onwards)	10	Moderate water stress will have a minimal effect on fruit size but it can bring forward fruit maturity slightly, reduce the fruits' shelf life and increase the incidence of stem end rind breakdown. The best strategy for reducing water use at this time is to slightly extend the interval between irrigation.

Effects of water stress on growth

Reducing water application can increase soil salinity levels. Irrigation water salinity can also increase during drought. Irrigating with saline water will increase the severity of stress on trees. Soil salinity and moisture monitoring are therefore critical components of successfully managing orchards with less water, because it is easy to over-stress or over-water trees without a reference point or a way to measure a strategy's effect. Contact your local horticulturist or agronomist for more information about irrigation and salinity management. The following information (Table 3) is a guide to the possible effects of various levels of water reduction on the health and productivity of citrus trees.

Table 3. Effects of water stress on growth.

Reduction in water application	Effects
10-20%	Usually minimal effect on fruit size and yield.
20-40%	Fruit size will decline and some crop reduction can occur.
40-75%	Significant crop reduction, decline in fruit size and leaf flush will occur. Fruit might be too small for traditional fresh fruit marketing. If fruit are at a marketable size, the rind integrity might be poor resulting in postharvest breakdown, and poor internal quality can result in unacceptable eating quality. Trees might take a season or two to fully recover to optimum production. Recovery will depend upon the water reduction severity and how the current season's leaf flush has been affected.
> 75%	Total crop loss would be expected and the trees will be unthrifty with significant twig dieback and leaf drop. It could take multiple seasons for the trees to fully recover.

Water saving practices

Immediate strategies

Water budgeting: estimating the monthly water requirements for each block using average industry data (e.g. Figure 2) and your historical records can be used to develop a drought management plan and prioritise the allocation of water to blocks.

Install irrigation scheduling devices: it is critical to use soil moisture monitoring devices to accurately check soil water levels and allow irrigation to be scheduled more precisely. If you do not currently have any devices, then tensiometers are relatively cheap, easy to install and use (see Primefact 1359 Tensiometer tips). More expensive and sophisticated scheduling tools will allow you to be more accurate and effective with your irrigation applications. However, it generally takes longer to learn how to use and understand the information generated from this equipment (see Primefact 1365 Using capacitance probes for irrigation scheduling).

Check, manage and maintain the irrigation system: irrigation systems should be checked for leaks or blockages. The accuracy of water meters should be checked by cross-referencing readouts with application rates and system specifications. If irrigation uniformity is poor, contact an irrigation consultant for advice on how improvements can be made (see Primefact 1364 Checking above canopy sprinkler performance). The effect an inefficient system has on an orchard will be exacerbated during drought. Correcting these issues might result in only modest water savings, but in a drought every drop counts.

Avoid leaching losses: ensure water is not applied and lost below the root zone by carefully monitoring soil moisture levels and irrigation depth. Sampling for soil salinity is recommended to determine if a strategic leaching program is needed. Water available during drought conditions might have elevated salinity levels.

Mulch the wetted strip: applying mulch over drip irrigation lines helps reduce soil evaporation. In mature orchards this might be of little benefit. However, it can be a useful option for young trees where a large percentage of the soil surface is exposed. Overseas information has shown that plastic mulches can be economically viable for young trees, but organic mulch (either natural leaf litter or imported mulch) might be a cheaper option.

Ensure that the drip line is underneath the mulch. Mulches can act as a barrier to effective water penetration, and once wet can then quickly dry out. Accurate soil moisture monitoring is important in order to recognise this situation.

Reduce the wetted area: this is most applicable to young plantings. If irrigating with low level sprinklers, changing the sprinkler head, adaptor, or installing a sleeve over the head of the sprinkler creates a narrower throw, eliminating water application to the inter-row area where roots have not yet significantly colonised. Run times can be significantly shortened while still ensuring the majority of an under-developed root zone is watered. This might involve moving sprinkler heads closer to the butt of the tree. For drip irrigated orchards, plugs can be installed between trees leaving only functioning emitters near the tree.

Full cover weed control: removing weeds and eliminating sods will reduce competition for water. Sods are best sprayed with herbicide and allowed to form a layer of mulch, protecting the soil and reducing evaporation. For drip irrigation systems it is best to slash the sod and throw the cuttings back over the wetted strip to form a mulch.

Irrigate at night: under-tree sprinkler irrigating at night can provide water savings of 20–30% compared with daytime irrigation by reducing evaporation losses. However, the water savings with drip irrigation systems are variable depending on the amount of mulch, leaf litter and shade over the wetted soil surface.

Eliminate water run-off: irrigation water should be kept in the orchard. If surface run-off is occurring, consider breaking up soil crusts to improve water penetration and soil aeration. The traditional methods of improving water penetration are applying gypsum and/or ripping (see How to manage soil for citrus). Ripping in a low water scenario is not recommended due to the additional stress created through root damage and the reduced ability of the tree to access any rainfall.

Reduce or cease windbreak irrigation: this can save water, but jeopardises the long-term benefits of windbreaks. Additionally, un-irrigated windbreaks can scavenge water from the adjacent crop, so deep ripping or trenching to trim windbreak roots might be required.

Re-use back-flush water: contact an irrigation designer to ensure excessive back-flush volumes are not being generated. The back-flush water that is created from drip irrigation filters can be re-used if run to a settling tank. Media filters generally use 4.0–5.0% of the water pumped to back-flush, disc and screen filters 1.5–2.0%.

Reduce crop load: reducing or eliminating the crop load can help to reduce water stress effects on fruit size. Trees carrying heavy crop loads will suffer more stress than trees with a lighter crop. However, under severe water stress fruitlet drop will occur naturally, reducing the crop load and the resulting tree stress. For trees under light to moderate water stress, monitor crop levels and fruit size and apply appropriate crop thinning strategies to decrease excessive crop loads in line with reductions in irrigation volume.

The choice of strategy depends on the water saving strategy chosen (i.e. trying to grow a crop or sacrificing crop) and the crop stage. Strategies include winter flower suppression sprays, hedging, chemical fruit thinning and hand thinning. The Fruit Size Management Guide Part 1 outlines when and how to implement these crop reduction strategies.

Reduce transpiration: kaolin clay-based foliar spray products are claimed to reduce water losses through leaves. Demonstration trials have shown growth increases in young trees. However, using these products can increase numbers of scale insects, particularly red scale. In trials on mature trees there was no significant effect on tree stress measurements or yield from using foliar sprays (Skewes, 2013b).

New products enter the market frequently and there is always the possibility that some might be beneficial. If using these products, consider leaving untreated areas in order to determine the effectiveness of the product that was applied.

Buy or trade water: buying or leasing water, if available, can be a viable option. Consider the long-term value of the trees and crops compared with the cost of water. If the cost of water is less than the value of produce lost by withholding that volume of water (including any ongoing recovery to production), then buying permanent (water entitlement) or temporary water (allocation) could be considered. Relying on allocation water means greater exposure to price fluctuations. Although developed for winegrapes, spreadsheets such as that produced by Consolidated Co-operative Wineries (CCW) are available to quickly determine if buying water is a viable option.

Keep informed about water reductions: maintain contact with the water supply authority for the latest information on water allocations, water flows and water levels in storage. Obtain information on next season's likely water allocations to enable better long-term decision making. This information can be sourced from state (e.g. WaterNSW) and local water authority websites. Look at long-term weather forecast information to help schedule irrigations.

Longer-term strategies

Install valves for each section: separate valves to blocks that have different water requirements to allow a more accurate match of crop water needs with irrigation applications. Water use differs between varieties and tree age. If adopting canopy reduction on part of a block, the irrigation system should be modified to cater for the significant differences in water requirements that are created.

Install more sophisticated scheduling equipment: more sophisticated scheduling equipment (e.g. neutron probes, capacitance probes) will allow you to be much more accurate in your irrigation applications and in gauging rainfall effectiveness. Also, leaching losses can be completely avoided while still ensuring that irrigations are fully effective. This equipment is more expensive and requires some time to learn how to use and understand the information generated.

Convert to efficient irrigation systems: significant water savings can be made if water is applied efficiently. Drip irrigation is potentially the most efficient irrigation system with possible savings of 40–60% over furrow and overhead sprinkler systems and up to 30% on under-tree sprinkler systems. Figure 3 is an example from a Sunraysia grower showing the differences in monthly water application rates to navel oranges using drip irrigation and a low-level micro-sprinkler system. The same magnitude of savings cannot be guaranteed in all situations, but this demonstrates the savings that are possible.

A new drip irrigation system requires substantial investment and should be professionally designed. If there is a high probability that water restrictions will continue, serious consideration of the long-term financial viability should be given to installing drip irrigation.

Drip irrigation has been very successful when installed in newly developed orchards. Converting a mature sprinkler or furrow irrigated orchard to drip irrigation has had mixed results. Some orchards have declined in productivity and growers have returned to sprinkler irrigation. The variable results are most likely due to management (i.e. good scheduling practices are critical) or existing orchard status (i.e. existing tree health, nematode presence, soil compaction, rootstock choice). Drip irrigation systems are preferably installed in winter immediately following harvest because the water supply needs to be shut down during conversion and trees are less likely to become stressed in the cooler weather and without a crop load.

Some growers have successfully converted to drip irrigation during summer. However, this carries a high risk if the new system is not quickly operational. A delay in irrigation over an extended period in summer can cause serious tree stress and crop loss. The trees will also need to be adequately irrigated and fertigated to hasten root development under the drip line. The time taken for roots to re-establish under the drip line can also cause tree stress.

Converting to drip irrigation from a full cover irrigation system changes the distribution of water in the root zone. Roots take time to respond to this change in water pattern and the tree will experience stress until the root system has adjusted. In a normal season, ample drip irrigation applications are recommended in the first year following conversion. Superimposing a water deficit on top of the conversion during drought conditions is likely to lead to significant tree stress. However, it is highly likely that water savings are still possible in an amply applied drip irrigation program in the first season compared with a typical full cover system (see Primefact 1456 Converting mature citrus from full cover to drip irrigation).

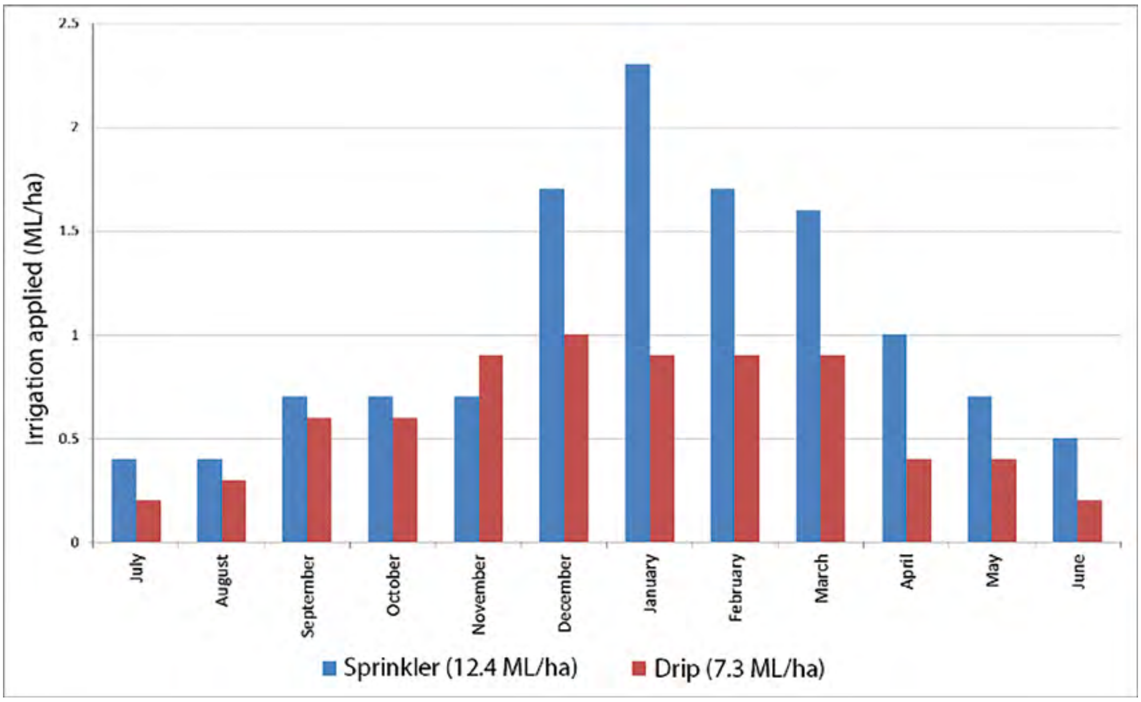

Figure 3. Monthly irrigation applications to well monitored Late Lane navels using drip irrigation and low-level micro-sprinklers in Sunraysia during 2001–2002.

Another benefit from drip irrigation is that trees can withstand higher water salinity levels than when irrigated with sprinklers. Well monitored and managed drip irrigation is able to maintain a more stable and higher level of soil moisture, as well as avoiding foliage contact, thereby minimising salinity effects. Experience on the Darling River showed citrus on drip irrigation was able to tolerate water of 2,000 EC units of salinity.

Selecting a strategy for managing citrus with less water

The following options can be used to develop a program that best suits your situation. Small fruit normally provide poor returns and fruit with poor integrity are unmarketable. During water shortages, often the most viable option is to maintain high value blocks to produce good sized fruit at the expense of less profitable blocks. This can be a difficult decision. Before severely water stressing, removing, skeletonising or hedging trees, discuss your plans with your packer/agent/processor, as these actions can have long-term implications. Consider the probability of an extended drought versus normal water allocations returning in the following season. The first step is to develop a water plan or water budget.

Developing a water budget

A water budget is a plan for your orchard that identifies the present and proposed irrigation allocation for each block and any additional management strategies. These decisions need to be based on several factors, including:

- profitability of the block
- current and long-term plans for the block/orchard
- tree age, variety, rootstock, crop load (on/off year) and growth stage
- packer, processor or agent priorities – current and future
- resources available
- current financial situation
- future water availability predictions.

The following steps can be used as a guide to developing your water budget:

1. Determine the typical monthly water allocation for each block based on historical water use
2. Decide on water-saving strategies or management practices to be implemented such as:
    - maintain block and production, implement management practices (i.e. mulching, night watering) at 10–20% water saving
    - install drip irrigation, and possibly suffer an initial productivity loss at a 30% water saving
    - hedge trees lightly to trim back a heavy crop, produce a viable crop and save up to 30% water
    - hedge trees moderately to eliminate most of the current season's crop and prepare for a crop next season, with water savings of up to 50%
    - hedge trees heavily or skeletonise to sacrifice the crop for the next 3–4 years, but save large amounts of water
3. Adjust monthly irrigation allocations to suit your plan
4. Put the plan into action
5. Regularly monitor tree blocks and re-adjust as necessary.

Tree management strategies

Managing young trees (0–6 years)

Young trees have a smaller canopy and root zone than mature trees, therefore require proportionately less water (Figure 4). Basic water saving practices for young trees include:

- reducing leaching losses below the root zone
- building a small basin around newly planted trees to trap water (low level sprinklers)
- spreading mulches around the tree to reduce evaporation from the soil surface
- using clips to block off drippers between trees where the roots have not yet established
- installing additional sub-mains and valves to separate young plantings from mature trees
- installing sprinkler heads that have a small throw pattern
- installing soil moisture monitoring devices helps accurately determine water required.

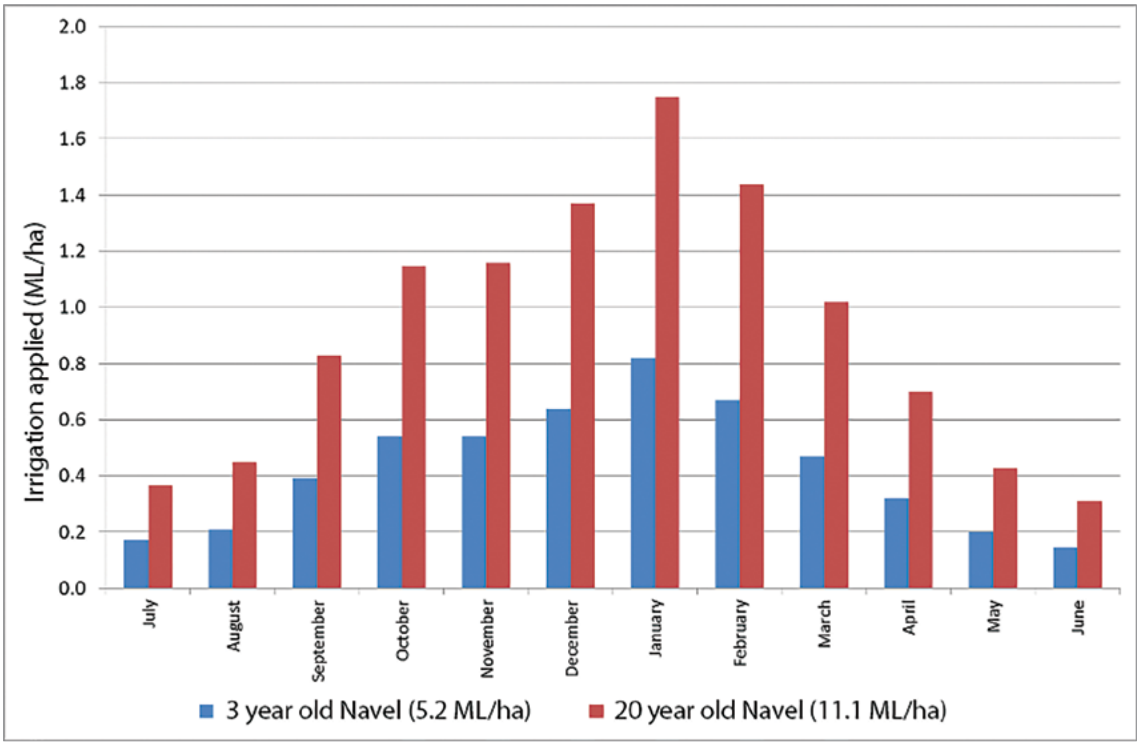

Figure 4. Monthly water requirements of well monitored young and mature navel orange trees in Sunraysia during 2008–2009 (M Skewes, pers. comm.).

Managing mature trees (> 6 years)

Canopy reduction

Tree water use is directly related to canopy size, so reducing the canopy reduces water use. The relationship between canopy size and water use occurs primarily through intercepting solar radiation (sunlight), so the shaded area under the tree at solar noon is a good indicator of relative water requirements. For example, a 50% reduction in shaded canopy area will result in about 50% reduction of tree water use. However, the effect of increased soil evaporation should also be considered when estimating water needs on a block basis. The amount of tree canopy removed for each block should be based on tree age, crop load, stage of growth, long-term block viability and how much water needs to be saved. Providing trees are given sufficient water and nutrients, they should recover to form a vigorous canopy that produces good quality fruit. The time taken for the tree to re-grow and return to full production is related to the intensity of canopy reduction. In some circumstances, resources (labour and machinery) might not be available to undertake canopy reduction, so alternatively any old or unproductive blocks could be abandoned in preparation for replanting when water supplies resume.

Under restricted water conditions, trees with a reduced canopy will recover more quickly than trees without any canopy reduction. Remember to adjust fertiliser applications to suit the tree canopy size and vegetative growth. A heavily pruned tree will require less fertiliser. Gradually increase the amount of fertiliser applied as the tree canopy re-grows. The best time to prune citrus is usually after harvest, but pruning can also be undertaken at other times throughout the year. Having a mix of heavily and lightly pruned blocks in the orchard allows some of the orchard (lightly pruned) to quickly return to full production when water allocations return to normal.

Hedging and skeletonising

Hedging is trimming the sides and tops of a tree (Figure 5). There are different degrees of hedging, from lightly trimming to near skeletonising. The best time to hedge trees is in late winter/early spring to reduce the risk of sunburn to the newly exposed limbs. A light hedging will not significantly affect next season's production. However, a medium or heavy hedging can result in trees being out of production for 1–2 seasons. One option is to hedge only one side of the tree to reduce any effect on yield.

Heavily hedging trees in late spring/summer might require exposed limbs to be painted with white wash to protect limbs from sunburn. Sunburn can occur within a day in hot temperatures (i.e. above 35 °C) and the risk increases significantly as temperatures rise further.

Heavily hedged trees might not require white washing if the hedging is conducted in late winter/early spring because the tree has adequate time for its bark to acclimatise to high light conditions, and an adequate cover of leaves will grow to shade limbs before hot conditions occur. The western side of the tree is more susceptible to sunburn because it is exposed to the afternoon sun.

Skeletonising is the most severe form of canopy reduction, involving removing nearly all of the tree branches and foliage. It is the most expensive form of pruning and is often done with a hedging machine followed by manual chainsaw trimming. Skeletonising is normally used to rejuvenate old trees. The first five or so years of production after skeletonising is recognised as producing large, excellent quality fruit because it is grown on young, healthy, vigorous shoots. Trees that have been skeletonised will use a lot less water, but can take about 2 to 4 years to return to full production. Skeletonised trees that are water restricted can take longer to return to full production because the water stress will reduce shoot re-growth.

The exposed limbs will need to be painted with white wash (1 part plastic paint:1 part water). Spray painting applies the white wash quickly and efficiently. As the trees grow, the re-growth needs to be managed to select the best positioned shoots to re-grow the tree.

Heavy hedging and skeletonising must be carefully considered. If a block of trees is in need of hedging due to row access issues, or old trees need to be rejuvenated due to declining productivity, then skeletonising might be warranted. However, if it is used purely as a water saving strategy then it should be done so as one part of a whole farm strategy, as it will significantly affect production levels for the next 1 to 2 years, even if water allocations immediately return to normal.

Figure 5. Mechanical hedging can be used to reduce the tree canopy.

Pruning for regrafting

Cutting back trees for regrafting (Figure 6) will also reduce water use. It will also regenerate low value plantings at the same time. The exposed limbs will need to be painted with white wash (Figure 7). The 'nurse' limbs can be removed when the grafts are well established and actively growing.

Reducing crop load

Flower manipulation: flower suppression can be done in predicted heavy crop years ('on years'), using a registered gibberellic acid compound at the time of flower initiation in June–July. Refer to the product label, as well as the Fruit Size Management Guide Part 1 or your local horticultural advisor for directions on use and timing. The degree of thinning at the registered rate is about 20% and varies depending on timing, rate, climatic conditions and tree health. Water stress can also induce a strong flowering in the following season, which might require thinning.

Pruning at flowering: hand pruning can be undertaken before or during flowering, with an emphasis on removing weak and dead branches, crossover limbs and water shoots. Hedging can also be used during flowering to remove excess flowers, however, it is non-selective, so care should be taken on how much of the canopy is removed.

Chemical thinning: during early fruit growth (December, stage 1), chemical thinning using ethephon can be used when fruitlets are 10–15 mm in size on heavy crop loads. Chemical thinning has been shown to be cost effective in navel and valencia oranges and Imperial and Murcott mandarins. However, the amount of fruit removed can vary depending on fruit load and application timing. Temperature and soil moisture levels are critical to success. Refer to the product label and the Fruit Size Management Guide Part 1 for more information. The degree of thinning at the registered rate is around 20% but varies depending on timing, rate, climatic conditions and tree health.

Reduced water during the early fruit growth stage will also lead to fruitlet drop. In research conditions, water stress resulted in 65% fruitlet drop compared to unstressed control trees (Skewes, 2013b). This will also result in a reduced crop load and could be considered instead of chemical thinning if total crop loss is desired rather than a controlled reduced crop load.

Hand or mechanical fruit thinning: from January to harvest, after the natural fruit drop has finished in December, a heavy crop load can be further reduced by hand thinning or light hedging. Hand thinning allows you to be selective and remove small, blemished or clustered fruit. Light hedging will remove fruit on the outside of the canopy, but is not selective and caution is required.

Figure 6. Trees pruned ready for white washing.

An example water budget and plan

Table 4 is a sample water budget for a sprinkler-irrigated citrus orchard. The farm has 27 ha of orchard and an allocation of 350 ML water. The orchard's water allocation has been cut by 50%, leaving 175 ML available.

Typical annual water use for each block and the amount needed for the remainder of the season (i.e. September to harvest) needs to be estimated from previous records. The proposed allocation for each block, as well as other management strategies to be implemented, must then be determined. In this example there is 11 ML remaining in surplus to allow for higher than expected water use (i.e. extended hot and/or dry periods).

Figure 7. Trees white washed ready for regrafting.

Experience with drought and water reductions

Bourke district (NSW) 2003 and 2007

Citrus growers using drip irrigation in the Bourke region of northwest NSW experienced drought and severe water restrictions in 2003 and from 2006. This region normally experiences warmer climatic conditions than southern citrus growing districts, and generally uses higher levels of water. The long-term effect of combined water and salt stress on citrus trees is not documented in Australia. Some specific examples of the experience and observations from Bourke include:

- 15 year old mandarin trees that had the eastern side of the tree removed were kept alive with 2.2 ML/ha applied from July 2002 to April 2003 (Figure 8). Any fruit remaining on the tree was unviable for marketing.
- a reasonable crop of Leng navels was harvested from a block watered with 5.5 ML/ha (Figure 9).
- a block of 7 year old navel orange trees received approximately 30% of normal application with 1,500–2,000 EC irrigation water during the summer of 2006–07. The trees were also moderately hedged to remove about 30% of the leaf canopy. As a consequence, trees and the adjacent Casuarina windbreak suffered heavy defoliation due to the combined effects of water and salt stress and some of these trees died (Figure 10). Significant fruit drop occurred in late spring. However, a reasonable crop of good sized fruit remained but, due to the restricted water practices, the fruit was dry and unmarketable. The trees had a reasonable amount of foliage and health to maintain canopy function, but not to grow a viable crop.

Table 4. An example water budget for a citrus orchard under 50% allocation. Note this is an example and should be used as a guide only.

Variety and age	Area (ha)	Typical annual water use (ML)	Proposed water application (ML)	Management strategy
Washington 20 yr	4	42	40	Monitor soil moisture and eliminate deep drainage.
Ellendales 30 yr	1	10.5	0	Abandon, prepare for replanting.
Valencia 40 yr	3.5	38	10	Skeletonise and white wash.
Grapefruit 50 yr	2	21	0	Abandon, prepare for replanting.
Imperials 25 yr	3.5	42	40	Water saving practices. Monitor soil moisture and eliminate deep drainage.
Washington 40 yr	8	88	40	Heavily hedge eastern side of trees and white wash.
Lanes 20 yr	3	30	28	Monitor soil moisture and eliminate deep drainage.
Lanes 2 yr	2	20	6	Install manual valve to separate young Lanes from mature Lanes.
TOTAL	**27**	**291.5**	**164**	

Figure 8. Fifteen year old Imperial mandarin trees showing re-growth on the eastern side of trees, which were previously heavily pruned.

Figure 9. Leng navel trees maintained with 5.5 ML/ha of water.

Figure 10. Young block of navels in June 2007 that recovered from 30% water application and salt stress in summer 2006–07.

Case study 1

The property has 40 ha of citrus and avocados in Mourquong on the Murray River in NSW, 10 km from Mildura.

A 100% allocation was announced for NSW Murray high security entitlements at the start of the 2006–07 season. However, by November 2006, allocations had been severely reduced. This had an enormous impact on NSW Murray irrigators who had developed and prepared their properties under the assumption that ample water would be made available in that season.

NSW Murray high security irrigators initially received zero allocation the following season (2007–08). Suspended water from the previous season was gradually returned to irrigators over the season. Critical water was also obtained for NSW high security licences in an attempt to keep permanent plantings alive but not necessarily produce a crop. This critical water represented approximately 50% of citrus water requirements. At the same time, water prices peaked at over $1,000/ML for the first half of the season (normally $100–$300/ML) making water purchases on the open market uneconomic for many.

Four approaches

The approaches taken on this property involved hedging to various levels in order to reduce canopy size and therefore water requirements. The level of canopy reduction related to the perceived value of each variety at the time.

1. A high value was placed on Washington navels. They were topped as usual (normally done every second year) down to 2.4 m, but the eastern side was severely cut back, almost to the point needed if top working, so that there were virtually no leaves on the eastern side. Water was wound back to approximately half. However, by December, enough water was available to water normally. Recovery was surprisingly good. The first crop following hedging was of good quality and size, and a third to one half the yield of a typical crop. Heavy hedging created biennial bearing from one side to the other for a few years, but removed a lot of dead wood, which provided ongoing benefits.
2. Less value was placed on valencias and these were topped to 2.1 m. No side hedging occurred. In some ways this worked better as the fruiting structure for the following year was not destroyed. These cropped acceptably in the first year

following topping and fruit size improved. Lanky re-growth was hard to handle and needed to be regularly pruned. Gradually the trees grew back to 2.4 m (Figure 11).

3. A neighbouring property was purchased that had been previously drought-affected in the preceding 2 years. The trees were totally defoliated. Watering resumed in July and by spring the trees had satisfactory re-growth, so were heavily hedged in September and October, followed by heavy chainsaw pruning. This rejuvenated the trees and the grower was extremely surprised at how well they re-grew (Leng navels on Citrange).
4. The previous owner of the purchased property had also done some stumping (Figure 12). The stumps were not painted as well as they could have been and sunburn was a problem. Water had been turned off completely and, as a consequence, reshooting was impaired. This resulted in trees re-growing with many sucker limbs that needed intensive pruning, and therefore took longer to re-grow. Trees recovered but needed extensive pruning attention.

Figure 11. Heavily hedged valencias at Mourquong showing re-growth in 2007.

Figure 12. Stumped citrus at Mourquong in 2007.

Grower observations and comments

- Create a hierarchy of crop value, i.e. Imperial mandarin, Washington navel, red grapefruit, late navel, valencia and then grapefruit
- Work at preserving the highest value crops
- If needed, you can then be harsh (with cutting) on the lower value crops. We cut valencias harder than others. If the predictions suggest only half the water will be available, we would hedge hard on crops like valencias and grapefruit and apply severe water cuts, and treat valuable crops more generously
- Do not underestimate how well trees can come back
- Follow up hedging with pruning as clustered growth occurred. I would hedge to 2.1 m again, but only if the forecast and predictions suggested a really dry year. Many other growers did nothing, using up their emergency water, but by Christmas things returned to normal and trees looked okay. Meanwhile we used up significant resources reducing the canopy
- Water more at critical stages early in the season to keep options open in case the water situation improves. I would then apply water a little more in December–January and then be more restricted in autumn
- I would not rush any decisions
- I would hedge and box again to create water savings as we found long-term benefits to the trees by doing this
- Consider removing unthrifty trees.

Case study 2

The property has 130 ha of citrus and avocados in Colignan on the Murray River in Victoria, 40 km from Mildura.

Unlike NSW irrigators, Victorian irrigators experienced an unaffected seasonal allocation for 2006–07 (95% allocation received). Then in the following season (2007–08) the market price of water reached more than $1,000/ML in the first half of the season, as irrigators responded to a seasonal outlook of very low allocation being made to entitlements. While some held carryover water from the previous season, it was insufficient to maintain crops.

The market price of water reduced significantly later in the season as other states increased allocation. Demand for water reduced as large horticultural operators had already purchased sufficient water to preserve their crops.

The initial allocation at the start of the 2007–08 season was 0%, and 23% by 15 November 2007. Increases throughout the season resulted in a total allocation of 43% by the end of the season. In the following season (2008–09), a total allocation of 35% was eventually received, with 100% returning from 2009–10 onwards.

Four approaches

1. Washington navel trees (Figure 13) were skeletonised and had no water applied. The success of this was dependent on rootstock. Some trees on sweet orange rootstock were lost. We could have skeletonised too hard, perhaps some extra limbs could have been retained. The western side of the trees became a little burnt as paint was not applied quickly enough following cutting.
2. Valencia trees were boxed to 2.4 m high and 1.8 m wide. Prunings were mulched immediately. These trees are now more manageable which is a long-term benefit. They were previously large and constantly water stressed, but are now smaller and their water requirements are able to be met every 8–9 days.
3. Previously top-worked grapefruit had the water turned off and left like this for 3 years. When water became available they were 'pretty sick' and were top-worked again and reverted to valencias, which produced a crop in 2 years.
4. A block of lemons and Late Lane navels was turned off and left unpruned. They were provided 5% of their water requirements by irrigating for approximately 4 hours using overhead sprinklers immediately following any rain during the season. This resulted in 3–4 irrigations only. Lemons were weakened by the drought and suffered Elephant Weevil damage, which is an ongoing problem along with limb breakage.

Grower observations and comments

- Some rootstocks are better than others at handling stress
- After a couple of years must follow up with pruning, one side each year; 2 years later you have a revitalised tree
- Prepare to paint early after cutting.

Figure 13. Skeletonised trees at Colignan in 2008.

Further information

Kriedemann PE and Barrs HD. 1981. Citrus Orchards, in: Kozlowski TT (Ed.), *Water deficits and plant growth*. Academic Press Inc, New York, pp. 325–417.

Primefact 1359 Tensiometer tips (https://www.dpi.nsw.gov.au/agriculture/irrigation/irrigation/scheduling/tensiometer-tips)

Primefact 1364 Checking above canopy sprinkler performance (https://www.dpi.nsw.gov.au/agriculture/irrigation/irrigation/systems/checking)

Primefact 1365 Using capacitance probes for irrigation scheduling (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/165078/using-capacitance-probes-for-irrigation-scheduling.pdf)

Primefact 1456 Converting mature citrus from full cover to drip irrigation (https://www.dpi.nsw.gov.au/agriculture/irrigation/irrigation/crops/converting-mature-citrus-full-cover-to-drip)

Skewes MA. 2013a. Citrus Drought Information Package, Factsheet. PIRSA, Adelaide, p. 8.

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Managing temperate fruit orchards during drought

Kevin Dodds, Development Officer – Temperate Fruits, Tumut
Jessica Fearnley, Development Officer – Temperate Fruits, Orange
Jeremy Bright, Development Officer – Macadamias, Wollongbar

Introduction

Water is a critical input in any fruit production system. It plays a vital role in plant processes including nutrient transport, cell turgor and growth, photosynthesis and temperature regulation. Modern temperate fruit orchards use irrigation systems to ensure adequate water supply to the soil and crop as required. These systems rely on stored or pumped water being available. In severe drought, on-farm water resources can reach critically low levels, placing crop and tree performance at risk.

Efficient water use in the orchard is always a high priority, but even more so when rainfall and water resources reach potentially limiting levels. During droughts, orchardists must implement all possible management strategies to maximise water use efficiency and minimise the negative effects of reduced water on crops and trees.

The following are some strategies growers can consider implementing to help mitigate the effects of drought.

Water management strategies

Pre-season planning and irrigation system checks

A pre-season water plan might include estimating the water requirements per block, expected irrigation period (i.e. October–April), scheduling, frequency, run times and prioritising blocks if water becomes limited. Planning ahead for blocks that will be placed on tree survival irrigation if necessary will be easier than during the season.

System checking usually involves a test run before the irrigation season to assess system output and identify any problems such as breakages, blockages or off-target water losses.

Plan well ahead for new orchard blocks and aim to have irrigation water available to young trees from the day of planting.

Prioritise young blocks

Newer blocks are often the most valuable because they contain high value varieties and represent the future of the orchard (Figure 14). Water stress on young developing trees can result in stunted growth and poor block establishment.

When developing your irrigation plan, prioritise young blocks more highly than older blocks and those which do not perform well. In extreme circumstances, you may need to walk away from some blocks and focus on those with the highest known value and returns.

Another option may be to chemically remove the crop early in the season to reduce the risks associated with normal cropping and stress.

Drought can also be a strong motivator to remove those old orchard blocks that have been under-performing for some time.

Figure 14. Young trees are a high priority for irrigation in drought because of their shallow root systems and high value.

Soil moisture monitoring

Using irrigation water efficiently during water shortages is paramount. Monitoring the fate of water applied to the soil is the only way to properly understand if is meeting crop needs whilst not resulting in waste and nutrient loss via leaching. To efficiently use irrigation water requires knowledge of how the water applied affects soil moisture levels and how far the moisture travels in the soil. There are two main types of soil moisture probes; those measuring soil water tension (i.e. tensiometers or gypsum blocks; Figure 15) and those measuring volumetric soil moisture (i.e. capacitance probes; Figure 16).

Tensiometers measure how hard a plant must work to extract the available moisture at a given time, whilst capacitance probes measure total water in the soil and indicate how this changes over time. Typically, tensiometer probes have a single sensor meaning multiple probes are required to track soil moisture at various depths. Capacitance probes usually include sensors at multiple depths built into one probe.

Estimating crop water use

A crop water budget provides a method for estimating crop water needs based on crop evapotranspiration (ETc), irrigation efficiency, rainfall, soil type and crop coefficient (Kc). There are a number of online resources for water budgeting in temperate tree fruit crops. The publication 'Guide to best practice in water management: orchard crops' (2009) by Dr Anne-Maree Boland is a useful document that covers all aspects of temperate tree fruit irrigation including estimating crop water needs across a range of crops using the budgeting method described above.

Figure 15. An example of a gypsum block probe.

Figure 16. An example of a capacitance probe.

This document is available (along with many other useful publications) via the Apple and Pear Australia Limited Future Orchards Library (https://apal.org.au/programs/future-orchards/future-orchards-library/).

Water wisely

Wise water use includes practices such as avoiding irrigating during the hottest part of the day (if possible). This will reduce losses due to surface evaporation. Depending on your irrigation system capacity, this may not be practical as many systems need to be run almost constantly in summer to cycle around your blocks in a 24 hour period. In these situations, consider scheduling daytime irrigations on blocks that are least likely to be affected by evaporation. For example, those covered with protective netting and those in areas less exposed to drying winds. Leave the exposed and windy sites for night time irrigating.

Always aim to use shorter, more frequent irrigation intervals (i.e. pulse irrigation). This helps to keep valuable water and fertigated nutrients in the active root zone and is less likely to result in leaching. This is particularly important in shallow-rooted dwarf orchards on drip irrigation as the main root systems can be concentrated around dripper zones.

Take advantage of stone fruit growth patterns

Apple and pear fruit grow at a fairly constant rate throughout the season and therefore generally require adequate soil moisture throughout the fruit growth phase. Conversely, stone fruits exhibit rapid fruit growth following fruit set and in the lead-up to harvest, but in the middle of the season (when the pit or stone is hardening), fruit diameter growth is minimal and any water applied is more likely to result in vegetative shoot growth. The 'pit hardening' period in stone fruits is an opportunity to reduce irrigation inputs without negatively affecting fruit growth or tree health. Reducing irrigation during this phase saves valuable water and reduces the likelihood of excessive vegetative growth. Regular fruit growth monitoring can help to identify when pit hardening starts and finishes.

Reducing moisture loss

Ensuring good weed control, particularly near the effective root zone, will minimise moisture losses due to competition. Weed control can be physical or chemical.

Applying organic mulches where practical will help reduce evaporation, retain soil moisture and increase soil carbon, thus improving long-term soil water holding capacity and general soil health. Mulches can provide the added benefit of suppressing weeds, provided the depth of the mulch is sufficient to block out light and prevent seed germination and growth (Figure 17).

Studies have shown that protective hail netting over orchards reduces the level of solar radiation, evaporation and crop water requirements. Monitoring soil moisture in netted and un-netted blocks may help growers to take advantage of reduced water demand in netted blocks.

Crop and tree management strategies

Start your crop load planning in winter

Have a plan for the optimum fruit size (weight) and number per tree that will deliver your desired yield per hectare. The target number of fruit per tree can then be used to guide winter pruning. Removing excess fruit buds at pruning (either by snipping or spur removal) will reduce the spring bud load and potential hand thinning costs. Note:

when counting buds to retain, it is important (particularly in varieties that are prone to biennial bearing) to plan to retain sufficient buds so that some will be free of fruit and resting in the current season to develop buds for next season.

In drought, consider reducing the number of fruit buds retained at pruning. This will take some pressure off your primary and secondary thinning programs in spring.

Adjust thinning regimes

During drought, aim to reduce crop load early and by more than usual. Plan for aggressive blossom thinning and early fruit thinning. Also be prepared to sacrifice some yield to achieve the desired fruit quality and average size.

Be prepared to carry out additional hand fruit thinning if required (Figure 18). Use fruit size monitoring and fruit size curves (trend lines) to help you to decide when additional fruit thinning is needed.

In apples, complete crop removal is an option when the block is to receive tree maintenance irrigations only. Certain registered products with the active constituent ethephon include label recommendations for aiding complete removal of apple fruit.

Figure 17. Organic mulches can help retain soil moisture in the profile by reducing evaporation and competition from weeds.

Figure 18. Fruit thinning programs may need to be adjusted to ensure the target fruit size is achieved. It might be necessary to accept a lower overall yield in drought years.

Monitor fruit size

Establish fruit size monitoring plots in each orchard block and measure the same 20 fruit per block weekly starting when fruit reach 20 mm in diameter and continue until harvest. Comparing the weekly average fruit growth rate can help identify any slow-down in growth that might be due to water stress and/or over-cropping. Comparing the seasonal fruit growth curve with past seasons can also help identify if the crop is on track to reach the target fruit size. Accurate fruit size monitoring involves returning to the same fruit each week and recording the growth rate and progressive fruit size. The online program OrchardNet (https://www.hortwatch.com/orchardnet/) has a good tool for recording and graphing fruit size and comparing seasons based on growth from full bloom. OrchardNet also includes target fruit growth trend lines for the key varieties.

Any spreadsheet could also be used to track fruit growth data.

Re-think timing of pruning

Historically, most temperate fruit trees are pruned in winter. This typically results in a strong spring growth response, which creates a high demand for water and nutrients in the early part of the growing season. Conversely, summer pruning will suppress vigour and reduce canopy area, resulting in more efficient use of available water and nutrient resources to help support satisfactory fruit growth.

Summary

Water is a critical input in any fruit production system, but especially during drought. Water management strategies including pre-season planning, prioritising young blocks, monitoring soil moisture, estimating crop water use, watering wisely, taking advantage of stone fruit growth patterns and reducing moisture loss can be implemented to help. Additionally, crop and tree management strategies such as planning in winter for crop loads, adjusting thinning regimes, monitoring fruit size and considering different times to prune can also help with efficient water use in orchards.

Useful resources

Australian Cherry Production Guide: https://www.cherrygrowers.org.au/assets/australian_cherry_production_guide.pdf

Dry Season Information for Stone Fruit: http://agriculture.vic.gov.au/agriculture/horticulture/fruit-and-nuts/stone-fruit/dry-season-information-and-cstone-fruit

Future Orchards Library: https://apal.org.au/programs/future-orchards/archive-library/

Irrigation Requirements for Peach and Nectarine Orchards: http://agriculture.vic.gov.au/agriculture/horticulture/fruit-and-nuts/stone-fruit/irrigation-requirements-peach-and-nectarine-orchards

Managing blueberry crops during drought

Melinda Simpson, Development Officer – Blueberries, Wollongbar

Introduction

Efficient water use in horticulture crops is a key management strategy for growers. It can help reduce production costs and minimise the negative effects of reduced water availability to plants, including during drought. The following are some strategies blueberry growers should consider implementing to help mitigate the effects of limited water availability and make their orchards more resilient during drought.

Pre-season planning and irrigation system checks

A pre-season water management plan might include:

- estimating the water requirements per block
- expected irrigation periods e.g. September–February
- irrigation scheduling and frequency during these periods
- run times per irrigation
- prioritising blocks if water becomes limited (this will be easier if it is done before the season rather than during the season).

System checking involves a test run before the irrigation season to assess the system output and identify any problems such as breakages, blockages or off-target water losses.

For blueberries grown on slopes, checking the distribution uniformity and drain percentage are very important.

Where sub-mains are not pressure-compensated and are on steep slopes, excess water will be distributed to the lower drip lines until they finish draining (Figure 19). There have been instances where plants at the lower end of the blocks were receiving four times more water than the intended amount because of drainage issues (Figure 20).

Figure 19. Check valves can reduce the drainage from mains to the lowest dripper. Photo: Robert Hoogers.

Operating pressure is another common issue that greatly reduces distribution uniformity. Check that you have:

- at least 120 kPa operating pressure
- 200 kPa pressure at the highest or furthest point in every block.

This will ensure the pressure compensating (PC) drippers can effectively meter out the same volume to every plant being irrigated.

Prioritise blocks

Newer blocks are often the most valuable because they contain high-value varieties and represent the future of the plantation. Water stress on young developing plants can result in stunted growth and poor block establishment.

When developing your irrigation plan, prioritise young blocks above older blocks and those which do not perform well. In extreme circumstances, you may need to walk away from some blocks and focus on those with the highest known value and returns. Drought can also be a strong motivator to remove those old blocks or varieties that have been under-performing.

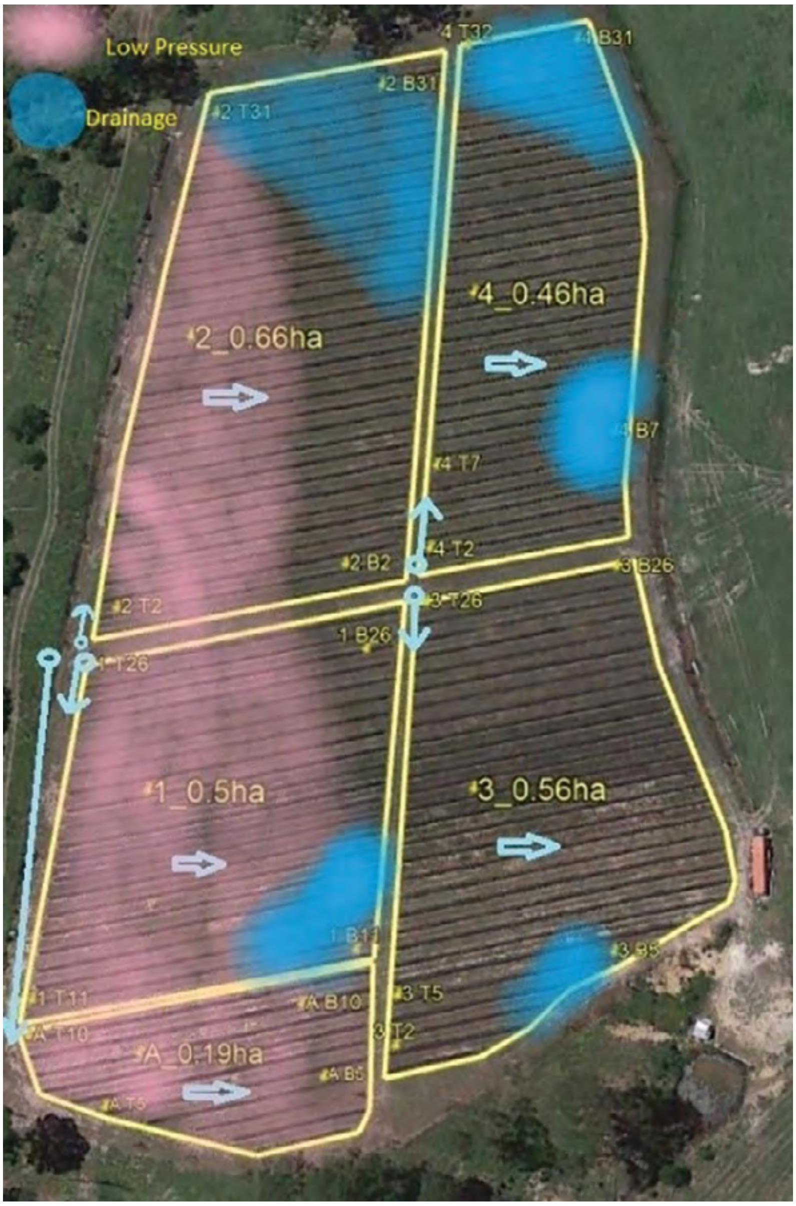

Figure 20. An example property showing areas where sub-main drainage could be a problem (blue shaded areas). Photo: Robert Hoogers.

Soil and substrate moisture monitoring

Using irrigation water efficiently during water shortages is paramount. Monitoring the fate of water applied to the soil is the only way to properly understand if it is meeting crop needs and not resulting in waste and nutrient loss through leaching.

An effective monitoring regime can reduce water use by up to 40% without affecting yield.

There are two main types of soil moisture probes (Table 5); those measuring soil water tension (i.e. tensiometers or gypsum blocks) and those measuring volumetric soil moisture (i.e. capacitance probes).

Tensiometers measure how hard a plant must work to extract the available moisture at a given time, whilst capacitance probes measure the total water in the soil and indicate how it changes. Typically, tensiometer probes have a single sensor, meaning multiple probes will be required to track soil moisture at various depths.

If you do not want to use a monitoring system, an alternative is to use a soil auger (or equivalent device) that you can push down and take a soil sample from the root zone. The presence/absence of saturated/moist/dry soil will provide a rough estimate of whether you are over or under watering.

Water wisely

Blueberry plants have a relatively shallow root system, with most roots in the top 20–30 cm of the soil. This means that irrigation should be applied in short, frequent bursts (i.e. pulse irrigation) so the water and nutrients stay within the root zone and are therefore available to the plant. Knowing your soil and understanding root zone depth will help you determine how much water can be held in the root zone. In general, sandy soils are free-draining and will hold less moisture and therefore need to be irrigated more frequently and for a shorter duration than loams or clays.

Reducing moisture loss

Ensuring good weed control, particularly near the effective root zone, will minimise moisture losses due to competition.

Applying organic mulches (where practical) will reduce drainage loss by improving field capacity and will also reduce the loss of important nutrients through leaching.

Additionally, mulch (Figure 21) will:

- reduce evaporation from the topsoil
- provide protection from erosion during heavy rain
- prevent crusting and sealing of the soil surface, thus allowing better water infiltration
- modify soil surface temperature
- suppress weeds, provided the mulch is deep enough to block out light and prevent seed germination and growth.

Table 5. A comparison of the main soil and substrate moisture monitoring systems.

System	Measures	Advantages	Disadvantages
Tensiometer	Soil water tension	• relatively inexpensive • easy to install • easy to use	• labour-intensive to collect data • require regular maintenance • inaccurate at high tensions • can be inaccurate in sandy soils
Gypsum block	Soil water tension	• relatively inexpensive • easy to install • easy to use	• inaccurate at low tensions • have limited life as gypsum dissolves
Capacitance probe	Volumetric soil moisture	• continuously logged • very sensitive and responsive to soil moisture	• costly • can require skill and training in interpretation • removal and re-installation can be considered difficult if re-developing mounds every few years
Moisture sensors and weigh scale (substrate monitoring)	The moisture level of the substrate using a weighing scale, the data collected are used by a moisture balance module to control water and fertiliser dosing and timing	Determines the optimal irrigation start strategy based on three important influences: • the quantity of water evaporated • the desired amount of drain water • the water content of the substrate.	• costly • can require skill and training in interpretation

Test water quality

Water quality is highly variable and is dependent on the water source (e.g. rainwater, farm dams, river, bore, town reservoir). Water quality can also vary throughout the year and after high rainfall or drought.

Water quality should be tested, particularly when water sources are getting low. There can be significant differences in water quality between a full dam and an almost empty dam. This is important because iron and iron-loving bacteria can cause blockages in drippers. Blueberries are sensitive to high salinity (Figure 22) and chloride levels. Certain varieties, such as Snowchaser and Rabbiteye, are highly susceptible to damage from high salt levels.

If using an underground water source (e.g. bore water), obtain a full laboratory test annually. If extending the interval between tests to 2 years, use test strips to check water quality in between tests. If a significant change in pH or hardness is noticed on the test strips, the water should be retested by a laboratory.

Table 6 provides a summary of the ranges for specific water quality parameters and the levels of salt, chloride, iron and pH that are applicable when irrigating blueberries.

Figure 21. Mulch will reduce evaporation from the topsoil as well as provide protection from erosion.

Figure 22. A blueberry plant showing early signs of suffering from salinity.

Table 6. Water quality parameters to consider when irrigating blueberries.

Test	Fine	Be careful	Problem
Electrical conductivity (salinity)	< 0.8 dS/m	0.9–2.3 dS/m	> 2.3 dS/m
pH	5.5–6.5	6.6–8.5	> 8.5
Chloride	< 350 mg/L	350–450 mg/L	> 450 mg/L
Iron	–	0.1–1.0 mg/L	> 1.0 mg/L

Summary

Efficient water use is especially important during drought. By implementing a few water-saving strategies on your blueberry farm, you can mitigate some of the effects. Consider doing pre-season irrigation system checks to ensure you are getting the desired output and there are no blockages or breakages. Ensure that your irrigation is uniformly distributed, especially to blueberries grown on slopes. If necessary, consider prioritising water to the higher-value blocks and perhaps remove non-performing blocks or varieties.

Knowing how much water is going onto your crop and where exactly that water is going is essential, so consider installing some sensors to measure soil moisture. Apply mulch as it has many benefits for blueberry crops and make sure the water you are using is suitable for blueberries; they are highly sensitive to high levels of salt and chloride.

Useful resource

Primefact 1509 Irrigation management of blueberries in Northern NSW (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/693341/irrigation-management-of-blueberries-in-nthn-nsw.pdf)

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Lessons from the drought for macadamia growers

Jeremy Bright, Development Officer – Macadamias, Wollongbar

The NSW north coast has a large proportion of the countries' macadamia farms. It is normally lush, green and beautiful, but during 2019, it turned brown, dry and smoky. With very limited rainfall, dams were getting low and fires were burning almost everywhere.

This scenario continued for months, not just days, leaving growers anxious about the fires yet somewhat helpless as well because most of the everyday macadamia activities, such as spreading mulch and applying nutrition, rely on having moisture in the soil, which was not there.

The prolonged drought and intense fire season provided us with a good opportunity to work out strategies to enhance the resilience of our macadamia trees to give them a better chance of surviving a drought. These strategies can be applied not just whilst enduring drought, but before drought conditions set in.

Most of this information has come directly from growers who experienced these conditions. Interestingly, one of the main outcomes is that it is not the drought stress that kills the trees, but rather, the more serious secondary pest and disease infestations in the following years.

Hopefully, by implementing some of these strategies, you will be able to make your farm more resilient for the next drought and more 'climate-ready'.

Retaining soil moisture

Grass

Depending on the time of year, keeping the grass in the inter-rows longer by mowing less frequently will help with moisture retention. For instance, during spring and summer (September–January) leaving the grass long can be beneficial by reducing evaporation. However, after January when the orchard floor is being prepared for harvest, it is better to reduce the grass height to help with harvest operations yet still maintain adequate soil moisture. One of the concerns growers had with this was that the longer grass would be a corridor for rats. However, by implementing an 'alternate row mowing' system whereby growers would mow a row and leave a row (Figure 23), 'rat highways' were prevented from establishing.

Mulch

Mulching is excellent for retaining soil moisture and is most effective when it is at least 10 cm deep, especially around the trees. Regularly re-applying mulch to keep this thickness provides the best results.

Applying mulch to dry, bare soil will not assist with retaining moisture. If you are fortunate enough to have irrigation or a system for delivering moisture to the soil, then this could be used to break down the mulch and assist in further retaining moisture.

As well as moisture retention, mulch also builds soil organic matter and cation exchange capacity (CEC). Organic matter causes soils to clump and form aggregates, which improves soil structure, while the CEC influences how the soil retains essential nutrients and provides a buffer against soil acidification.

A 1% increase in soil organic carbon (SOC) equates to about a 2% increase in water holding capacity. Therefore, soil with a water holding capacity of 200 mm will hold an additional 4 mm of water, although this assumes the increase in SOC is consistent for the profile of interest (Edwards 2019).

An increase in SOC is especially important during dry spells such as the dry springs which have been occurring lately. While these dry spells are not classed as drought, they effectively call on moisture resources for the plant to provide energy for cell structure development, i.e. nut sizing. This additional water holding capacity will allow the plant more resilience in these extended dry times.

Additionally, run-off and erosion are minimised when the soils are protected by mulch compared to being left bare. Therefore, applying mulch should be a routine practice (Figure 24).

The inter-row

Macadamia tree roots extend into the inter-row (Figure 25) so it is important to build up the organic matter in this area. An easy way to do this is to leave any organic material out in the inter-row instead of broom-sweeping it back in under the tree, then regularly bring in more mulch or compost to place under the tree. If this mulching is done early enough, the fine roots will grow up into the previously spread mulch and hold it firmly in place.

For orchard floor clean up just before harvest, it may be necessary to sweep any material that may compromise harvest efficiency in under the tree. It might seem like a balancing act between keeping sufficient mulch in the right areas but at the same time not hindering harvest.

Figure 23. A tree-to-tree alternate row mowing system. Photo: Paul O'Connor.

Figure 24. Applying mulch in macadamia orchards should be a routine practice.

Figure 25. Macadamia tree roots extend into the inter-row so it is important to build up the organic matter in this area.

Managing phytophthora

According to Dr Femi Akinsanmi, Associate Professor at the Centre for Horticultural Science at the University of Queensland, one of the core principles that should be entrenched in standard orchard practice is that of 'good soil health equals good tree health'. Dr Femi has written many articles and has mentioned numerous times that growers and industry should be concentrating their efforts on building organic matter within the soil. This provides the trees with more resistance and resilience to phytophthora and ultimately builds orchard resilience for the next dry period or drought.

"good soil health equals good tree health"

To determine the strength of your soil and thus tree root structure, you can conduct a simple 'snap test'. This involves pushing a shovel into the soil and if the soil does not 'snap' with the shovel entering it (the 'snap' being the breaking of fresh roots), this could indicate insufficient root structure in the soil. These are the roots that need to get the moisture from the soil, and if they are not structurally sound, then it is highly likely that the trees will decline relatively quickly when put under severe moisture stress. This snap test (Figure 26) can also be used to determine whether the root structure is sufficiently robust to resist pathogens such as phytophthora.

Pruning

Macadamia trees are usually pruned as part of normal orchard maintenance (Figure 27). However, the trees should not be pruned when they are stressed, including during dry periods. The exception to this is if you need to prune out dead or diseased limbs to prevent further disease spread (Figure 28). Commonly these limbs will harbour bark beetles (Scolytidae beetles) and possibly *Botrysphaeria*, so you should ensure dead and dying branches are cleaned out annually.

Pruning for rejuvenation should not be done when there is limited moisture availability because the tree will not be able to support new flush. It is better to have an effective pruning program that builds resilience and provides a good structure to help the trees withstand stresses such as drought.

Figure 26. Dr Femi Akinsanmi explaining the snap test.

Figure 27. Macadamia trees that have not been pruned, showing dead and dying branches that need removing.

Figure 28. Dead wood can be taken out in dry times.

Nutrition

During drought, and especially when there is no irrigation, it is often not practical to apply fertiliser to the ground. Unfortunately, the nutrition program will need to be stalled during this time.

Growers with irrigation should consider reducing their nutrient application so they can still supply adequate nutrition to support nut production but not enough to encourage new flush as this will create a competitive pull for resources from the flower and developing nut.

Another problem that can arise from prolonged fertiliser application without irrigation or rainfall is that the level of salts in the soil can build up because they are not flushed through the soil. These excessive salts can contribute to root burn and potential disease.

New plantings

When planting new trees in ‘normal’ conditions, ensure that the soil is of reasonable depth and has sufficient organic matter to give the trees the best possible chance.

Planting new young trees should be delayed where drought is probable. On many occasions during this current drought we have seen some very quick tree decline. Further investigation revealed that most of the trees were planted on very shallow soil with underlying rock shelves (Figure 29). This meant that the plants were struggling to find adequate moisture to support themselves. Once the soil moisture was depleted, the trees shut down, making them susceptible to bark beetles, which attacked the trees and quickly put them into decline.

Summary

The extreme conditions experienced over the last few years have revealed the macadamia industry to be remarkably resilient. The important lessons presented here from growers, consultants, researchers and NSW DPI staff will hopefully help the industry to prepare their orchards to be more resilient to drought, or perhaps even become 'climate-ready'.

Figure 29. Trees originally planted on shallow rock shelf suffered from water stress during drought.

Reference

Edwards T. 2019. Soil organic matter - frequently asked questions (FAQs). Department of Primary Industries and Regional Development, Western Australia. Available at https://www.agric.wa.gov.au/soil-carbon/soil-organic-matter-frequently-asked-questions-faqs

Recovering from drought

When the drought breaks

After prolonged periods of drought, crops and soils will have suffered and pests and disease pressures might increase.

When drought breaks, drought-affected soils and horticulture crops can potentially return to their normal state in time if given a little help. Here are some strategies and information to help you bring your horticulture crops back to life.

Managing weeds

Droughts can often set back long-term weed control strategies for both pasture and cropping weeds. An accurate risk assessment and well-planned, long-term management strategies are essential parts of an effective weed control program. See the Drought recovery guide for information on weeds and their control strategies.

Managing soils

Maintaining adequate ground cover is vital for soil health, water infiltration and nutrient retention. Research has shown that erosion during drought-breaking rain can make up 90 % of the total soil loss in a 20–30 year cycle. See the Drought recovery guide for information on topsoil, soil nutrients and acid soils.

For more information on managing soils, see:

- Soil management – drought recovery
- Drought and your soils – webinar (YouTube)

Crop specific information

Pome and stone fruit

- Cherry Growing in NSW
- Orchard plant protection guide for deciduous fruits in NSW
- Water and crop management strategies for temperate fruit orchards during drought

Berries

- Berry plant protection guide
- Crop nutrient replacement: calculator for fertiliser requirements
- Growing blueberries using recycled organics
- How to compost on farm
- Irrigation and moisture monitoring in blueberries
- Soil and water management practices for blueberry growers in northern NSW
- Soil management in orchards
- Water use efficiency in blueberries

Citrus

- Citrus nutrition
- Citrus plant protection guide
- Converting mature citrus from full cover to drip irrigation
- Managing citrus orchards with less water
- NSW DPI lemon growing manual

- NSW DPI mandarin growing manual
- Spanish irrigation research

Grapes

- Alternative weed control measures for vineyards
- Developing heatwave management strategies through grapevine phytomonitoring
- Grapevine management guide 2014-15
- Grapevine management guide 2015-16
- Heatwave management in Riverina vineyards
- Monitoring and maintaining your drip irrigation system
- Monitoring vine water status – Part 1: Some physiological principles
- Monitoring vine water status – Part 2: A detailed example using the pressure chamber
- Using weather tools to make vineyard management decisions

Nuts

- Crop nutrient replacement: calculator for fertiliser requirements
- Hazelnut production
- Horticultural fertigation - techniques, equipment and management
- Macadamia Integrated Orchard Management
- NSW Macadamia plant protection guide
- Reducing erosion and other soil degradation in macadamia orchards
- Using compost in macadamia orchards

Tropical fruit

- Banana growing guide - Cavendish bananas
- Bananas - response to temperature
- Crop nutrient replacement: calculator for fertiliser requirements
- Soil and water best management practices for NSW banana growers
- Sub-tropical banana nutrition – matching nutrition requirements to growth demands

Finance

Primefact 48 Financial management during drought recovery outlines some practical suggestions to support farmers on the road to recovery from drought.

NSW DPI research and development

Several projects are underway which will deliver outcomes that support farmers as they adapt their farming operations and business practice to cope with climate conditions, and seasonal variations including drought. NSW DPI has been ranked in the top 1% of world research institutions in agricultural science, and plant and animal science.

DPI is focused on building productive partnerships with businesses, industry, research institutions and the community to accelerate opportunities and maximise benefits. Here are a few of the key NSW DPI research projects:

Performance-based management of ground cover for drought mitigation

This project aims to develop an appropriate framework for the implementation of a regional incentive program for retaining rangeland ground cover in western NSW.

Biophysical and economic impact of adaption options in a changing climate for low rainfall mixed farms

This project will result in improved information on the potential effects of climate change on low rainfall mixed farms in the Murrumbidgee, Murray and Lachlan Catchment Management Authority areas. The project will also contribute to building climate change impact assessment expertise within NSW DPI.

Evaluating transformative adaptation options for Australian extensive farming systems

This project provides insight into the challenges associated with substantial changes in land use and the potential trade-offs that might with between climate adaptation practices.

Improved use of seasonal forecasting to increase farmer profitability

This is a national project which aims to bridge the gap between seasonal climate forecasts and farm business decisions to improve productivity and profitability.

Seasonal conditions reporting

This project delivers monthly State Seasonal Updates containing information on rainfall, water storages, crops, livestock and other issues. The reports are a strategic advisory tool to support farmers' preparedness and resilience. The reports are also used by the Regional Assistance Advisory Committee (RAAC) to trigger the implementation of appropriate drought support strategies.

Available drought assistance in NSW

NSW DroughtHub

DroughtHub (www.droughthub.nsw.gov.au) is a one-stop online resource to help primary producers, their families and communities to prepare for and manage drought conditions. This provides up-to-date information about assistance and support available. When new in-drought assistance or packages are announced, the DroughtHub page will provide the latest information and can connect you to the relevant NSW or Commonwealth agency. For help navigating the NSW DroughtHub page, call the NSW Rural Assistance Authority on 1800 678 593 or contact your local Rural Financial Counsellor.

Support available during drought

Farming in Australia requires constantly managing a wide variety of risks. Natural disasters, disease, pests, market fluctuations and policy changes provide ever-present challenges to business and personal resilience. This is most evident when dealing with drought. Long dry periods extending to severe drought are part of a repetitive climatic cycle where farmers are either managing, recovering from, or preparing for drought conditions. Flexibility and sound risk management strategies are essential for the health and well being of the farm business, its natural assets and the people within.

The current drought in NSW is having a significant effect on the economic prosperity of rural communities. During challenging times, it is more common for people to feel greater distress, anxiety and depression, which can affect their relationships and businesses. If you or someone you know is being affected by the drought on a personal or business level, then there are services available that can help make a positive difference. For a list of services that can assist you or someone you know, to seek help or develop tools and strategies to support stronger mental health and wellbeing, see the DroughtHub Well being website (https://www.dpi.nsw.gov.au/climate-and-emergencies/droughthub/wellbeing).

Drought Support Program

Across the Hunter New England, Murrumbidgee and Western areas of NSW, Drought Support teams are on hand to provide a free, mobile and confidential support service which is available on farm, in town or over the phone. The teams are comprised of people who have experience living and working on the land and who understand the difficulties drought can cause in people’s lives. The Drought Support Program is suitable for individuals, couples and families; whether they require short-term conversations and information, or ongoing formal counselling options.

The Drought Support teams know that the drought has hit hard and that farmers are not the only people affected. That is why these services are open to anyone whose livelihood is associated with rural industry/primary production, whether that's farm workers, contractors or small business.

If drought is affecting your well beingthen these teams can offer ongoing support with the ability to be there through difficult times in decision making, transitioning and connecting you to more specialist services if required. To access the Drought Support Program contact:

- Hunter New England 0477 322 851
- Murrumbidgee 0436 811 692
- Western NSW 0436 815 940

Business Connect – Support for Farm and Non-Farm Businesses

Business Connect provides tailored, trusted advice for your small farm or non-farm business. Register online or call 1300 134 359 to connect with your local Business Connect advisor.

Drought Resilience Fund

Supporting drought-affected communities in NSW with community driven initiatives that bring people together and support connected communities and the well being of their people. This may be small community BBQ events, or larger family gathering style events. For more information and to access the fund, contact your local DPI Rural Resilience Program staff member.

Farm Debt Mediation

This is a NSW Government service offering farm debt mediation service to provide a structured negotiation process where an accredited, independent mediator helps the farmers and their creditors to negotiate and reach agreements about farm business debt. Visit The Rural Assistance Authority's Farm Debt Mediation page for more information and links to accredited mediators in your area.

Local Land Services

Local Land Services staff are technical experts who can provide farmers with on-the-ground support and advice on agricultural production, biosecurity and pasture management. Visit Local Land Services for more information or visit the Assistance Near You map to find an office near you. Contact your Local Land Services today on 1300 795 299.

NSW Rural Assistance Authority

The Rural Assistance Authority (RAA) administers a wide range of assistance measures to the rural sector, both State and Commonwealth funded. To apply for a Drought Transport Subsidy, Drought Assistance Fund, Farm Debt Mediation or to see the full range of assistance measures administered by RAA, visit NSW RAA or call 1800 678 593 or visit https://www.raa.nsw.gov.au

Revenue NSW

Revenue NSW is offering assistance to any individuals and businesses affected by the drought, including farmers receiving government drought relief assistance. Anyone experiencing difficulties meeting obligations is invited to contact the relevant business area at Revenue NSW to discuss their individual circumstances and which assistance measures are available.

Rural Adversity Mental Health Program

The NSW Government is funding the state-wide Rural Adversity Mental Health Program (RAMHP) program to help link people in regional and remote areas of NSW with mental health support. The RAMHP team is comprised of coordinators based across regional, rural and remote NSW who can provide specialist knowledge and support. They are available to educate, encourage and link people to mental health support, where and when it is needed. Visit RAMHP for more information on services, training and the location of a counsellor near you.

Rural Financial Counselling Service

The Rural Financial Counselling Service is jointly funded by the State and Commonwealth governments and the counsellors help farmers who are dealing with, or are at risk of, financial hardship. Rural financial counsellors can help identify options, develop action plans and access the Farm Household Allowance (FHA). Rural Financial Counsellors are also available to assist farmers to lodge Drought Transport Subsidy forms. Visit RFCS for more information.

Rural Resilience Program

The Rural Resilience team are dedicated to building both personal and business resilience of farming communities. The team works proactively with farming communities and service providers across NSW to strengthen networks and deliver relevant initiatives to build personal and business resilience skills and knowledge. To find a Rural Resilience Officer and Rural Support Workers near you, search the Assistance Near You map or visit Rural Resilience Program for more information. Visit www.dpi.nsw.gov.au/rrp

NSW GOVERNMENT

Department of Primary Industries