Department of Primary Industries
and Regional Development

NSW GOVERNMENT

Bushfires in orchards: a guide to preparedness, response and recovery

NSW PRIMARY INDUSTRIES MANAGEMENT GUIDE

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Hort Innovation Frontiers

Government of South Australia
Department of Primary Industries and Regions

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Document 24/910. Job 17058.

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Funding

Developing management strategies to enhance the recovery of horticulture from bushfires (AS19002) is funded by the Hort Frontiers strategic partnership initiative developed by Hort Innovation, with co-investment from NSW Department of Primary Industries and Regional Development (NSW DPIRD) and South Australian Research and Development Institute (SARDI), and contributions from the Australian Government.

Image acknowledgements

Cover photo: an aerial photo of a slow-cooker fire-affected apple orchard showing the random pattern of autumn colour onset. Photo taken 29.5.2020, 150 days after the fire.

Unless otherwise stated, the images in this guide have been sourced from NSW DPIRD.

How to cite

Dodds K and Pitt T (2024) *Bushfires in orchards: a guide to preparedness, response and recovery*. NSW Department of Primary Industries and Regional Development, https://www.dpi.nsw.gov.au/agriculture/horticulture/pomes

Department of Primary Industries and Regional Development

Bushfires in orchards: a guide to preparedness, response and recovery

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The authors would like to thank the following for their contribution to the project: Oluyoye Idowu, John Golding, Bruno Holzapfel, Jessica Fearnley, Aphrika Gregson, Amanda Warren-Smith (NSW DPIRD); Paul Petrie, Darren Graetz, Kavitha Shanmugam (SARDI); and Professor Kerry Wilkinson (University of Adelaide).

Contents

Introduction

In the Spring and Summer of 2019–20, the south-eastern states of Australia experienced one of the worst bushfire seasons in recorded history. From August 2019 to the end of February 2020, the Black Summer bushfires burnt close to 19 million hectares, destroyed 3,000 homes and killed 33 people across New South Wales (NSW), Victoria (VIC) and South Australia (SA) (Filkov et al. 2020).

Agriculture and forestry industries suffered significant stock, crop, forest, pasture and infrastructure losses. Temperate fruit orchards in the Bilpin and Batlow districts of NSW and the Adelaide Hills of SA were among the most severely affected intensive horticulture industries.

In the aftermath of the fires, various government and community organisations provided support to affected agricultural producers and communities. For those working to assist horticultural producers, it quickly became evident that there were almost no technical resources available to inform assessments and decision making for survivability and management of damaged orchards.

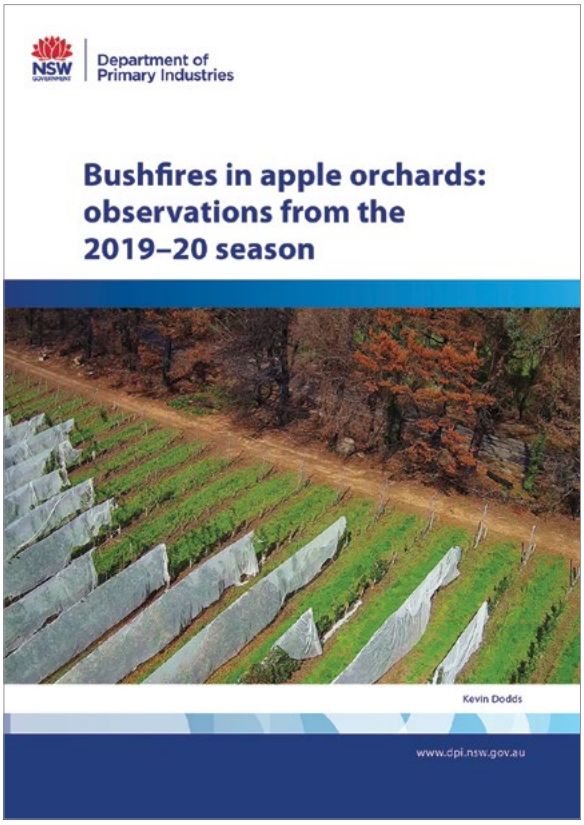


Figure 1. *Bushfires in apple orchards: observations from the 2019-20 season* is available on the NSW DPIRD website.

In the months following the Black Summer bushfires, New South Wales Department of Primary Industries and Regional Development (DPIRD) documented the initial damage in a report titled '*Bushfires in apple orchards: observations from the 2019-20 season*' (Figure 1). The document includes insights into fire types, their associated effects on orchard trees, and some initial regrowth responses. Damage to orchard infrastructure, including netting and structures, buildings, irrigation systems and machinery, was also recorded. This study identified several strategies that could be used to prepare for future bushfires, such as reducing under-tree dry matter, maintaining green inter-rows, establishing orchards with a buffer to neighbouring vegetation, ensuring adequate firefighting resources, and securing adequate water supplies.

It also identified some important areas requiring research, generating questions such as 'How much conductive tissue damage can a tree survive?' and 'Is there a preferred post-fire canopy management strategy for tree and long-term crop recovery?'.

The general lack of information available before the 2019–20 bushfires, along with NSW DPIRD's initial observations, led to Horticulture Innovation Australia Ltd (Hort Innovation) establishing the Hort Frontiers 5-year research project 'Developing management strategies to enhance the recovery of horticulture from bushfires (AS19002)'.

The project was a partnership between Hort Innovation, NSW DPIRD and the South Australian Research and Development Institute (SARDI). This publication, '*Bushfires in orchards: a guide to preparedness, response and recovery*', is a key output of the project that condenses practical research findings into one accessible publication that will support industry preparedness, response and recovery to any future bushfires affecting intensive horticulture.

Understanding fire types in orchards

Observations made following the 2019–20 bushfire season identified several types of fire in and around orchards that resulted in immediate and ongoing tree losses and infrastructure damage.

Damage to fruit trees and the productive capacity of orchards have been a major focus of researchers from NSW DPIRD and SARDI between 2020 and 2024. The 3 most important fire types resulting in fruit tree losses are discussed here.

The blow-torch fire

The blow-torch fire type is characterised by intense flame and wind-driven scorching heat from a fuel source external to the orchard, such as native roadside vegetation, adjacent pine forest or *Pinus* species windbreaks, heavy dry pasture or timber bin stacks. In a blow-torch fire, the orchard rows closest to the fire source will be the most severely affected, and there is a gradient of reduced damage moving further away from the heat source. The most severe blow-torch fires can reach up to 15 or more rows (60+ metres) into the orchard with enough heat to kill or severely scorch entire rows of trees (Figure 2). The severity and reach of a blow-torch fire are determined by factors such as fuel type and load, aspect, position on the slope and location of the orchard relative to the prevailing wind. There will be a distance from the fire where trees (even if scorched) can fully recover (Figure 3 and Figure 4). Given sufficient time to observe regrowth responses, it is possible to determine the point beyond which trees are likely to fully recover with appropriate management. Refer to 'Assessing fire-damaged trees' on page 25 and 'Proposed fire damage assessment scale' on page 26 for more detail.

Figure 2. An example of damage caused by a blow-torch fire that was fuelled by native vegetation on the property boundary. Note the transition from scorched to green trees approximately 12–15 rows from the fire source.

How does a blow-torch fire affect orchard trees?

In a blow-torch fire, trees can be affected in several ways including:

1. Trees killed by **direct flame** (100% of above-ground tissues are killed by direct flame). The below-ground parts might survive and produce rootstock suckers.

2. Trees killed by **heat scorch** (100% of above-ground tissues killed by heat). The below-ground parts might survive and produce rootstock suckers.
3. Tree trunks, branches and foliage are severely damaged by heat scorch, but not completely killed. These trees have a poor prospect of regrowth or recovery.
4. Tree trunks are relatively undamaged but canopy structures and foliage are severely scorched. These trees might have a moderate prospect of recovery.
5. Trees with only foliage scorched have good prospects for regrowth and recovery (Figure 5).
6. Heat-affected, but no visual symptoms. Fruit quality is likely to be affected in the surviving crop (refer to 'Fruit quality and postharvest considerations' on page 13).

Figure 3. A blow-torch affected apple block. The area of melted netting corresponded with dead trees. Photo: South Australian Department of Environment and Water (DEW).

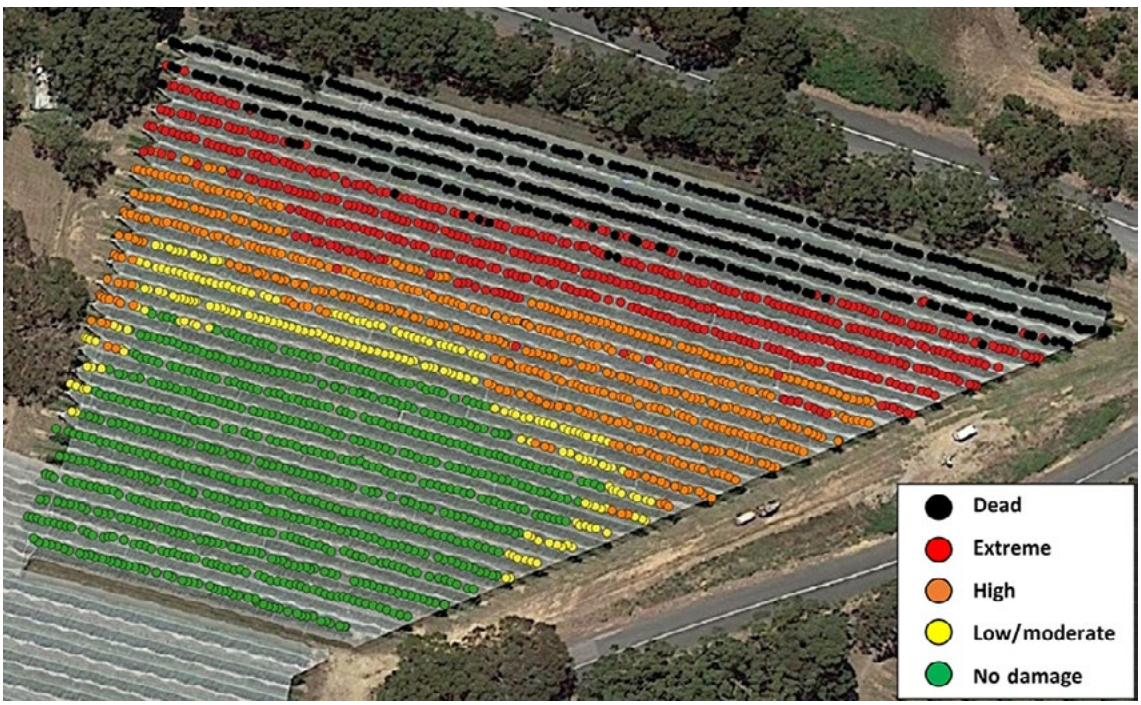


Figure 4. Initial post-fire classification of tree damage severity in an apple orchard affected by a blow-torch fire in the Adelaide Hills, SA. Note the reasonably well-defined area of damage and gradient from the boundary vegetation into the orchard. Photo: SARDI (2020).

Figure 5. A blow-torch affected orchard 44 days post-fire. Note the 4 rows closest to the fire were killed. From rows 5 onward into the block, the trees re-grew after pruning.

The slow-cooker fire

Slow-cooker fire occurs when sufficient dry matter is present under the trees or in the inter-rows to sustain fire that directly affects the trees (Figure 6). The fire will gradually travel along tree rows (Figure 7), consuming dry vegetation and mulch, burning with variable intensity depending on the fuel load and prevailing wind. The effects of slow cooker fires on trees are hard to predict due to the variable fuel load and fire intensity from tree to tree. This variability makes it difficult to assess and respond to in the recovery phase. This type of fire typically results in a random patchwork of tree losses (Figure 8 and Figure 9) and is likely to be associated with protracted tree mortality for several years after the fire.

How does a slow-cooker fire affect orchard trees?

In a slow-cooker fire, trees can be affected in several ways including:

1. Phloem death to 100% of the circumference of the trunk. Trees might show an initial regrowth response (if the xylem is unaffected) but will decline over the season or in the following spring.
2. Partial phloem death in the trunk. Depending on the amount of phloem loss, trees might fully recover, partially recover or gradually decline and die.
3. Branch and foliage burning and scorching. If trunk phloem is undamaged, trees have a good prospect of recovery as the canopy regrows.
4. Foliage only scorch. Trees with scorched foliage only are likely to recover to full canopy and crop within 2 seasons (Figure 10).

Figure 6. An example of the damage left by a slow-cooker fire in an apple orchard at Batlow. Note the unburnt row on the left, which indicates the type and level of fuel present at the time of the fire.

Figure 7. An example of the damage left by a slow-cooker fire in an cherry orchard at Lenswood. Note the fire travelled along the tree rows. Photo: SARDI (2020).

Figure 8. A cherry orchard affected by a slow-cooker fire in the Adelaide Hills, SA, January 2020. Photo: South Australian Department of Environment and Water (DEW).

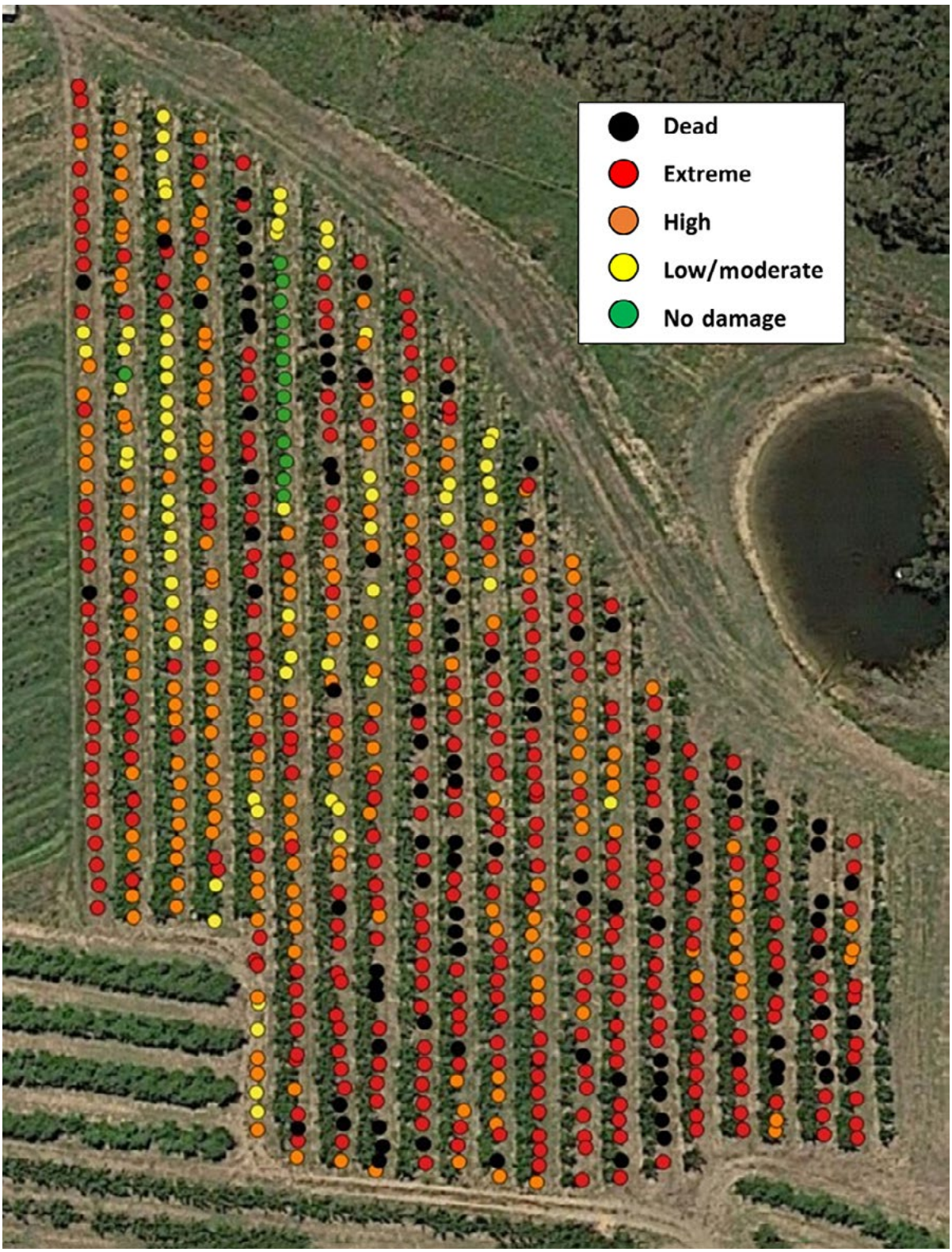


Figure 9. Initial post-fire classification of tree damage severity in a cherry orchard affected by a slow-cooker fire in the Adelaide Hills, SA. Photo: SARDI (2020).

Note the random nature of the damage throughout the block and the run of undamaged trees in the northern section of row 6 (from the left), where the grower managed to wet the area using a spray cart before heat forced him out of the block.

Figure 10. This low-intensity slow-cooker fire caused leaf scorching in the lower canopy, while the vascular tissues in the trunks were undamaged.

In orchards that have high fuel loads on both the boundary and in the under-tree zone, both blow-torch and slow-cooker fires are likely to occur.

Nursery stool bed fire

Sawdust is commonly used in orchard nursery stool beds and is mounded around the new growth to encourage root formation on rootstock plants. Entire stool beds were killed in the 2019–20 fires when embers from the fire ignited the dry sawdust, causing a smouldering fire throughout the nursery (Figure 11). Growers reported these sawdust fires were very difficult to extinguish. The loss of nursery stool beds in 2019–20 resulted in a shortage of new rootstock plants for replacement trees in the years following the fires and an associated delay in re-establishing orchards.

Figure 11. Sawdust fires in orchard nursery stool beds were very difficult to extinguish and can lead to significant loss of future rootstocks.

A detailed description of the various types of fire experienced in orchards, their effects, recovery strategies and prevention/mitigation strategies is provided on Page 44.

Fruit quality and postharvest considerations

Fruit quality and storability are crucial for consistently delivering high-quality fruit to the consumer throughout the year. Preharvest growing conditions, fruit maturity and quality at harvest are critical in determining the final fruit quality. In storage trials to assess the effects of fire on fruit quality and storage, researchers found that fire had major effects on fruit size, firmness, acidity, sugars and maturity.

How does bushfire affect apple quality?

Depending on the timing and severity of the bushfire, it is possible to salvage marketable fruit from the orchard following a fire, however, this fruit should be processed and sold as quickly as possible and not put into long-term storage.

In Batlow, with the fires occurring 9 weeks before harvest, it was possible to harvest marketable fruit from severely affected trees. While these trees did have some physical damage with leaf loss (described in previous sections), the fruit did not have any physical symptoms of direct damage (Figure 12). However, this fruit was smaller and firmer, had a higher starch index (i.e. lower starch reserves), low fruit acidity and much lower sugar levels when the fruit ripened (i.e. fire-affected fruit had lower carbohydrate reserves). Differences in total soluble solids (TSS) between fire-affected and non-fire-affected fruit at harvest and during storage were observed for at least 2 seasons after the bushfire. This demonstrated the ongoing effects of fire on damaged fruit trees and the fruit they produce.

Can I safely store my fire/heat-affected apples?

Poor carbohydrate allocation in fruit growth and maturation reduces fruit quality and storability. Therefore, due to the lower starch and carbohydrate reserves in fire-affected fruit, these apples do not store as well as non-fire-affected fruit. Therefore, it is recommended that fire-affected fruit is sent to market as soon as possible and not stored.

If my trees are without irrigation for a while after a fire, will this affect their quality or storability?

Regulated deficit irrigation (RDI) is commonly practiced to save irrigation water and to maintain and improve fruit quality. However, the longer-term excess deficit that can occur when the irrigation lines are burnt can result in smaller fruit with short storage life. Restoring the irrigation to the fire-affected orchards as soon as possible will help salvage the current fire-affected fruit and help the trees recover.

What level of heat exposure is acceptable for fruit quality?

In trials with apple fruit from Batlow and the Adelaide Hills, the negative effects on fruit quality increased with increasing fire damage. Fruit from trees with only slight symptoms had similar starch levels at harvest as those from trees with no symptoms (Figure 13). However, there were still some effects of fire damage, even on trees with slight damage as this fruit had lower sugar levels during and after storage. It is difficult to predict the quality and storage life of fire-affected fruit, but our experience shows that any fire damage can affect fruit quality, and this fruit should not be put into long-term storage.

Figure 12. An example of undamaged Pink Lady apples on a tree with slight leaf scorch due to bushfire (photo taken 2 months post-fire).

Figure 13. Starch staining demonstrated that fruit from trees with severe foliage scorch reached an over-mature state before fruit from trees with only slight or nil scorch. SD = severe damage, SL = slight damage, NS = no symptoms and FF = fire free.

Are my apples susceptible to bushfire smoke taint?

Yes. Dodds et al. (2024) investigated smoke taint of apples and cider at Batlow following the 2019–20 bushfires. The study confirmed the uptake of volatile phenols associated with smoke taint by apples and their subsequent detection in cider (Figure 14). Sensory assessment of ciders made from smoke-affected apples revealed undesirable smoke characteristics were perceivable. This study was part of the larger Hort Innovation project 'Developing management strategies to enhance the recovery of horticulture from bushfires' (AS19002). Further sensory studies are required to determine if smoke taint of apples is perceptible when consumed as fresh whole fruit. In 2019, a cider maker in Tasmania reported that cherry juice from a bushfire smoke affected orchard had an ashy flavour and was unsuitable for use in a blended cider product (Koch 2019).

Figure 14. Ciders and whole fruit from smoke affected apple orchards were tested at Affinity Laboratories (SA) using protocols developed for the detection of smoke taint in wine and grapes.

Damage to infrastructure and equipment

Damage from the 2019–20 bushfires to infrastructure and orchard equipment was extensive and brought challenges to safety, access and the operational recovery of orchards. Assets affected by fire and extreme heat included protective netting and associated structures, trellising, sheds, harvest bins, irrigation systems, water tanks and machinery.

Protective netting

The most obvious damage to protective netting occurred on the edge of blocks hit with blow-torch fire (Figure 15) or within blocks receiving slow-cooker fire where direct flame and the most intense heat was able to reach (Figure 16). Netting melted and became welded to tree canopies and trellis structures, making it very difficult to remove when cleaning up.

Figure 15. Melted netting was closely associated with the dead trees, particularly in blocks affected by a blow-torch fire.

Figure 16. Melted netting in an orchard that sustained a slow-cooker fire. These trees suffered severe damage to the trunk conductive tissues.

Structured hail netting (i.e. the type suspended above the crop on a trellis structure) was a useful indicator of likely tree death in blow-torch fires. In most cases where the netting was melted or completely missing, the trees underneath were dead.

When viewed from a distance, large areas of protective netting seemed to have escaped serious damage. However, closer inspection revealed that extensive areas of netting had been compromised by ember attack (Figure 17). Holes in hail netting were observed hundreds of meters away from the main fire. Even minor ember damage to structured high-tension netting is concerning, as its ability to withstand future storms and the weight of hail is diminished.

Figure 17. Ember attack caused extensive damage to hail netting, reaching hundreds of metres away from the fire.

Structures

Fire caused significant damage to timber trellis and hail netting posts. Treated pine posts presented a particular challenge during the initial clean-up due to the toxicity of the resulting ash (Figure 18). Care was required to ensure livestock in neighbouring paddocks could not access the burnt treated pine posts. Some livestock deaths were recorded at Batlow when cattle licked the ash residue.

Further information on treated timber and how to deal with it after a fire is available in the *Bushfire Recovery Information – CCA Timber fact sheet* prepared by NSW Government (https://www.tenterfield.nsw.gov.au/content/uploads/2020/03/IECU-Fact-Sheet-Bush-Fire-Recovery-CCA-Timber_Oct-19.pdf).

The loss of posts, end stays and cables (Figure 19) caused danger as the integrity of the trellis and netting systems was compromised, and the risk of collapse was high. Assessing and securing netting and trellis structures and clearing obstructions from orchard rows were important tasks in the initial stages of recovery.

Steel trellis systems resisted fire damage more readily than timber, however, the wire and posts in these systems also suffered damage as protective galvanised coatings were burnt, raising concerns about the exposure of the metal to rust and corrosion.

Many timber harvest bins stored in sheds were burnt and generated substantial heat. In some cases, there was enough heat to soften and bend steel beams (Figure 20).

Figure 18. Chemical ash residues from burnt treated pine poles present a risk to stock and human health and require careful management.

Figure 19. Structural damage to timber strainer posts in a block with structured hail netting.

Figure 20. Harvest bin storage sheds can generate enough heat to soften and bend steel beams.

Irrigation systems

Significant damage to above-ground irrigation system components including poly pipe, fittings, valves, filters, water tanks and pumps can occur from bushfires (Figure 21 and Figure 22). Damage to power poles and supply lines causes the local electricity supply to be cut, further hampering efforts to re-establish irrigation systems. Poly pipe laterals laid on the ground or suspended just above the orchard floor sustained significant damage, whilst those suspended higher in the trellis generally suffered less damage. With the latter, most damage occurred at the row ends where the pipe drops to ground level to meet the main irrigation line.

Figure 21. Damage to irrigation pumps delays efforts to re-establish irrigation in the orchard after the fires.

Figure 22. Low-density polyethene irrigation tubes that supply irrigation to trees via dripper or sprayer were exposed to fire damage.

Machinery

Vehicles, tractors, sprayers, orchard implements, power ladders, forklifts and other heavy machinery are at risk during a bushfire. During the 2019–20 bushfires, equipment was lost despite the efforts of growers to move machinery to areas of the property perceived as lower risk. Severe fire intensity and ember attack meant that few places were safe (Figure 23 and Figure 24). Large areas of concrete or sealed surfaces free of any combustible material such as packing shed car parks and sealed roadways appeared to offer the best protection for machinery.

Figure 23. Despite being placed in the centre of a dry dam, this orchard machinery was lost due to the intense fire and ember attack.

Figure 24. This excavator was parked in an open area but was adjacent to a stack of timber harvest bins.

Effects of fire on orchard pests and pollinators

The effects of abiotic stress (e.g. bushfire) on pest and disease populations and the associated damage to fruit crops are not well understood. There is a general belief that stressed or injured plants are more vulnerable to insect attack and disease infection. Observations since the Black Summer bushfires suggest temperate tree crop growers should monitor for increased pest activity in fire-affected trees.

Researchers and orchardists working in commercial apple orchards and hazelnut groves following the 2019–20 fires noticed that injury and/or stress to trees resulted in elevated pest populations and damage. In the Adelaide Hills, researchers noted increased levels of woolly apple aphid (WAA) in a blow-torch fire-affected apple orchard, with the highest pest levels noted in the surviving trees closest to the fire front. Similar observations of increased WAA were made by researchers at Batlow (Figure 25). It is not clear if the increase in WAA in fire-affected trees was due to a direct effect on the pest, its predators, or a change in the availability of suitable feeding sites due to the post-fire growth response or heavy remedial pruning treatments applied.

Figure 25. Elevated levels of woolly apple aphid were noted in fire damaged trees in several research trial sites following the bushfires.

Also at Batlow, elevated levels of apple rust mite (*Aculus schlechtendali*; Figure 26) and reduced levels of phytoseiid predatory mites (*Galendromus* spp.) were noticed under the scales of dormant buds in apple trees that had suffered from leaf scorch during the fires (Dodds 2021).

Figure 26. Elevated levels of apple rust mites were discovered on dormant bud scales in fire-affected trees at Batlow.

A hazelnut producer at Kunama near Batlow reported increased populations and damage in fire-affected trees caused by a pest weevil (*Aades cultratus;* Figure 27; Bindi Vanzella, personal communication, 4 November, 2024).

Figure 27. Pest weevil larvae (*Aades cultratus*) at a fire-affected commercial hazelnut grove at Batlow. Photo: Bindi Vanzella.

In a separate Hort Innovation-funded study titled 'Loss of horticultural pollination services from wild insects following bushfire' (PH20002), researchers from Western Sydney University (WSU) compared pollinator behaviour before and after the 2019–20 bushfires.

Data collected in apple orchards at Bilpin in NSW before (Bernauer et al. 2021, 2022a,b, 2024; Gilpin et al. 2022; Tierney et al. 2023) and after (Cook et al. 2023) the fires showed there were fewer flower visits by introduced honey bees and native stingless bees in the spring following the bushfires. The same data also showed there were increased visits by flies in the same period. Cooler spring temperatures during crop flowering seasons following bushfires in combination with reduced off-crop floral resources and pollinator nesting substrates in the burnt landscapes around the orchards are likely to have contributed to these results.

Additionally, a bee mark-recapture study identified that around 50% of honey bees visiting apple flowers were not from hives on that orchard, suggesting they originated from feral colonies or managed hives at other properties. This highlights the risk to pollination services by any loss of feral honey bee colonies due to bushfire and the recently established honey bee pest *Varroa destructor*. With this knowledge, orchardists in fire-affected regions should consider managing the potential loss of honey bee populations in the spring following bushfires and encourage additional floral resources to support both native and introduced pollinator species wherever possible.

Figure 28. Marked Western honey bee females on apple flowers (left) and at the hive entrance (right) at Shields Orchard, Biplin NSW. Photo: Simon Tierney, Western Sydney University.

Assessing fire-damaged trees

Visual symptoms

Assessing visual damage to tree foliage, limbs and the main trunk in the initial period post-fire can help growers understand the type, distribution and severity of fire damage in their orchards. For blocks affected by a blow-torch fire, such assessments can help determine where most tree losses are likely to occur. This information can be used in the months and years following a fire to compliment observations of regrowth responses and destructive assessments. Using multiple assessment methods gives a better overall understanding of the potential for tree mortality or recovery (refer to 'Assessing vascular damage in trees' on page 29).

Researchers in the Adelaide Hills (SA) assessed tree damage in a blow-torch fire-affected apple orchard and a slow-cooker fire-affected cherry orchard at Lenswood immediately post-fire, and repeated the assessments biennially over several years. A comparison of the initial visual assessment and scorch rating (Figure 29) for each tree (January 2020) with a mortality assessment conducted 3 seasons later in 2024–25 showed that almost all trees with an initial rating of 'low/ moderate to high' leaf scorch and many with an extreme damage rating in the blow-torch affected apple block have successfully recovered (Figure 40). It is likely that leaf scorch was the predominant type of damage in these trees and that vascular tissues were largely undamaged.

Figure 29. An example of a fire damage assessment classification system used in the South Australian Research and Development Institute assessment for cherries (top) and apples (bottom). Photos taken March 2020. Source: SARDI.

Proposed fire damage assessment scale

The assessment scale (Table 1) developed by SARDI researchers and used in the production of the initial fire damage assessment maps (Figure 4 and Figure 9) could be used by growers to assess and record fire damage in their apple and cherry orchards. It includes assessment criteria for damage to tree canopy, fruit, trunk, soil surface, irrigation and netting, and initial regrowth.

Table 1. A proposed fire damage assessment scale, developed by SARDI (2024).

Damage rating	Canopy	Fruit	Trunk damage	Soil	Irrigation/ netting	Regrowth
1: none	No signs of damage	Fruit in sound condition	0%	Soil surface organics intact	Intact	Canopy developing as normal
2: low/ moderate	Leaf shrivel (minor desiccation)	>50% fruit sound or persisting	0–25%	Soil surface organics largely intact	Intact	Healthy regrowth from laterals and trunk
3: high	Leaves and shoots scorched (incomplete desiccation)	>50% fruit damaged or has dropped	25–50%	Soil surface organics charred/ consumed	Intact	Regrowth on >50% of laterals and trunk
4: extreme	Severe scorching to foliage and shoots	Fruit consumed, desiccated or dropped	>50%	Soil surface organics charred/ consumed	Intact but deformed	Regrowth on <50% of laterals; sporadic/stunted growth on trunk
5: dead	Foliage and smaller shoots consumed	Fruit consumed	>50%	Soil surface organics consumed	Consumed	Zero regrowth (or regrowth has collapsed)

Results for the slow-cooker affected cherry block showed a highly random pattern across the orchard in both the initial and subsequent assessments. This illustrates the challenges associated with a patchwork of tree mortality following this type of fire.

It is important to note that assessing visual symptoms post-fire is likely to be a less reliable indicator of tree recovery in slow-cooker fire-affected blocks compared with blow-torch blocks.

Premature autumn colour in a slow-cooker fire-affected orchard

In one slow-cooker affected orchard at Batlow, apple trees exhibited premature autumn leaf colour ranging from red to yellow to green randomly across the orchard (Figure 30 and Figure 31), which was an indicator of trunk ring-barking from fire. When a sample of the different coloured trees was destructively assessed by debarking, trees with red leaves were found to have suffered vascular tissue death around 100% of the trunk, trees with yellow leaves had some undamaged vascular tissue and trees with green leaves sustained minimal damage (Dodds 2020).

Figure 30. Royal Gala apple trees with 3 levels of early autumn leaf colouration. Photo taken 23.4.2020, 113 days after the fire.

Figure 31. An aerial photo of a slow-cooker fire-affected apple orchard showing the random pattern of autumn colour onset. Photo taken 29.5.2020, 150 days after the fire.

The expression of premature autumn colour in apple trees following trunk girdling due to fire might be linked to an accumulation of carbohydrates (soluble sugars and starch) in the leaves and tree structures above the girdle. In a study of young apple trees, Cheng et al. (2008) measured carbohydrate accumulation and a decrease in photosynthetic rate following branch girdling. Quentin et al. (2013) measured soluble sugar and starch accumulation in the foliage of girdled cherry trees and reported that the elevated carbohydrates led to reduced photosynthesis.

The importance of xylem and phloem

The most damaging and lasting effects to orchard trees from fire are those that relate to vascular tissue damage. When assessing fire-damaged trees, it is important to understand and consider the effect the fire has on the tree's vascular system. Some basic knowledge of plant conductive tissues and the processes of transpiration and photosynthesis will help the grower make informed decisions about tree recovery or removal.

Transpiration drives the movement of water and minerals from the soil to the roots, trunk, branches and eventually leaves of plants. Fruit trees use water and minerals transported in the **xylem** to produce photosynthates (carbohydrates and amino acids) through the processes of transpiration and photosynthesis. Photosynthates are transported throughout the tree (including back to the root system) via the **phloem** to support tree growth and fruit production. The xylem and phloem are part of a complex transport system in the tree known as the vascular system (Figure 32). Any event that damages or interferes with the tree's vascular system or photosynthetic tissues will have a negative effect on transpiration, tree health and productivity.

During a fire, heat damages the phloem, xylem and photosynthetic organs (leaves) of trees, disrupting normal water and mineral uptake, photosynthate production and movement within the tree. The severity of the damage will determine tree survivability or mortality and will depend on many factors including fuel load, fire intensity and duration, and any thermal insulation offered by the bark (Figure 33).

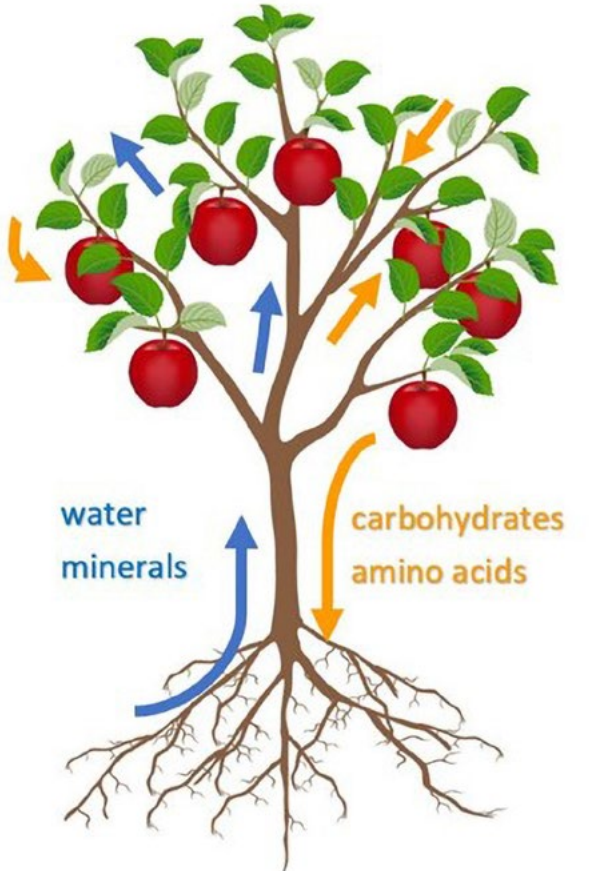


Figure 32. The xylem (blue) carries water and minerals from the roots to the tree canopy, while the phloem (orange) transports photosynthates (carbohydrates and amino acids) throughout the canopy, the crop and root system for growth.

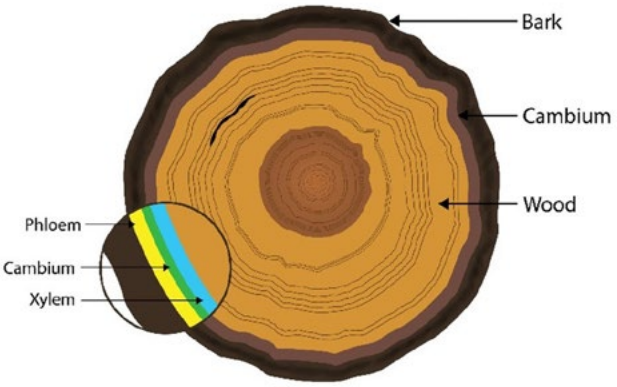


Figure 33. A cross-section of a tree trunk showing the location of vascular tissues.

Assessing vascular damage in trees

Currently, there is no cheap and reliable non-destructive method for determining the degree of vascular tissue damage in trees. Instead, in the initial weeks post-fire 2019–20, growers and their advisers cut small bark windows using pocket knives and used bark discolouration as indicators of vascular tissue damage (Figure 34). These methods did not provide a complete picture of the condition of the underlying vascular tissues and were found to be unreliable and misleading.

Research since the 2019–20 fires has shown that monitoring tree growth responses in conjunction with some selective destructive assessments could be a reliable method of determining long-term tree survivability.

Figure 34. Bark discolouration (left) and small bark windows (right) are not reliable indicators of underlying vascular tissue damage and should not be used to make decisions about tree viability.

Destructive assessments (i.e. complete trunk bark removal) following the Black Summer bushfires identified significant phloem and xylem damage in apple and cherry orchards resulting from fire and heat. In blow-torch-affected sites, trees that were not killed outright by the intense heat suffered the greatest amount of vascular tissue damage on the prevailing fire side of the main trunk (Figure 35 and Figure 36), as well as the canopy generally. In slow-cooker affected sites, the damage was mainly recorded in the lower tree trunks, with loss of phloem ranging from partial to 100% of the circumference (Figure 37). The location of phloem damage around the trunk was less predictable in slow-cooker blocks compared with blow-torch. In slow-cooker affected trees, the most severe vascular tissue damage was often on the side of the trunk facing away from the fire, as flames wrapped around the leeward side during strong winds.

It is hoped that non-destructive methods can be developed to detect vascular tissue damage without the need to remove the bark, effectively killing the tree. Electrical resistivity tomography has great potential, having been used on some forest and fire-exposed trees to detect pathogen-caused decay and assess fire damage, respectively (Bär et al. 2019; Bieker et al. 2009).

Figure 35. A debarked trunk of an apple tree affected by a blow-torch fire.

Figure 36. The cross-section shows the vascular tissue damage penetrating through the phloem, xylem and into the heartwood of the trunk.

Figure 37. The worst affected apple trees in this slow-cooker block sustained vascular tissue damage around 100% of the circumference of the lower trunk. The phloem connection between the canopy and root system was completely disrupted.

How to debark a tree (destructive assessment)

Use a large, sharp, broad blade knife to slice the bark off the tree's trunk from just below the lowest branch all the way down to soil level. This is best achieved standing or kneeling behind the tree while you slice the bark on the opposite side. Hold the knife handle in one hand while pushing down on the top of the knife with the other hand at the other end of the blade. The aim is to remove the bark only. There is no need to cut into the wood of the tree. Repeat this moving around the trunk until all the bark is removed. Any areas of vascular tissue that have been damaged by the fire or heat will be discoloured compared to the undamaged tissues (Figure 35 and Figure 37).

Recover or remove

Initial regrowth can mislead

A tree that has phloem damage around 100% of the trunk circumference, but retains a functioning xylem, can initially produce new leaf and shoot growth following a fire (Figure 38). In this situation, the tree canopy continues to receive a supply of water and minerals from the roots via the surviving xylem. Undamaged and/or latent buds arise from the scorched canopy and are fed via the xylem flow and stored carbohydrates, resulting in some leaf and shoot growth and photosynthesis. This initial regrowth can give the impression that the tree is recovering and will survive, but it will most likely die or severely decline by the season following. The lack of phloem connection between the canopy and the roots prevents the transfer of photosynthates back to the root system, which eventually leads to root decline and tree death.

Figure 38. Wilted regrowth 35 days post-fire in an apple tree that had 100% circumference phloem damage in the tree trunk.

Longer-term regrowth plus destructive assessments are more reliable

Strong, healthy regrowth over several months post-fire can indicate the potential for recovery in blow-torch fire-affected orchards. Investigations following the 2019–20 fires at Batlow found that trees were recoverable if regrowth 4–5 months post-fire included healthy shoots >300 mm long (Dodds 2020). In the study, this amount of regrowth was associated with minimal to no vascular tissue damage in the tree trunk (Figure 39). This work demonstrated the benefit of combining non-destructive regrowth observations with destructive methods to improve grower confidence in the recoverability of blow-torch affected orchards.

Figure 39. Tree regrowth (a), conductive tissue damage (b) and trunk cross-section (c) for trees with very poor recovery prospects (top) and good recovery prospects (bottom), 139 days post-fire. Photos: Dodds (2020).

Destructive assessment methods (including complete trunk bark removal and trunk cross-sections) can be used in blow-torch blocks to determine the reach of the fire into the orchard and the associated vascular tissue damage. Confidence in canopy regrowth observations increases the further you are from the heat source. By debarking a sample of trees on a gradient from the boundary fire into the orchard, a grower can determine which part of the blow-torch-affected orchard has the highest likelihood of successful recovery.

Destructive methods would be unreliable as selective assessment tools in severe slow-cooker blocks due to the random nature of the damage resulting from this fire type. However, in a low-intensity slow-cooker fire, debarking a sample of trees might help confirm the absence of vascular tissue damage and the potential for recovery of the entire block.

Destructive assessment methods can be used in blow-torch blocks to determine the reach of the fire into the orchard and the associated vascular tissue damage, but would be unreliable in severe slow-cooker blocks due to the random nature of the damage from this fire type.

Deciding to recover or remove the orchard

The decision to recover or remove a fire-damaged orchard is complex. It requires understanding the type of fire that has affected the trees, damage intensity and distribution, initial and ongoing tree mortalities, the potential for recovery of damaged but surviving trees, the cost of returning trees to full production, and the economics of recovery versus re-establishment. This section focuses only on the tree health aspect of this decision and provides a suggested 4-step approach to help decide whether to recover or remove an orchard based solely on the observable damage to the trees.

Step 1. Understand

Take time to determine if your orchard has suffered a blow-torch fire, slow cooker fire or a combination of both by observing the visible signs of damage. Refer to 'Understanding fire types in orchards' on page 6.

- Blow-torch: fire/heat came mainly from outside. The amount of scorched foliage reduces as you move into the block away from the edge.
- Slow-cooker: dry matter will be burnt around the trunks and foliage scorching will mainly be in the lower canopy. Damage will appear to be random throughout the block (i.e. no definite edge effect).

Step 2. Assess and wait

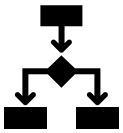
Note the percentage of leaf scorch and its distribution for both fire types. Take photos or drone images (if possible) for later reference. Refer to 'Assessing fire-damaged trees' on page 25.

- Give the trees some time to show their regrowth potential. In 2019–20, healthy regrowth between the fire in January and early Autumn (April) was a useful indicator of tree recoverability. In trees with significant leaf scorch, observe and note shoot regrowth in the weeks and months following the fire.

Step 3. Destructive sampling

Remove the trunk bark of a sample of trees to expose the vascular tissues and determine the amount of damage.

- For blocks that received blow-torch fire, this should be conducted on a transect from the fire edge into the orchard. Sample a tree from each row until you find the point where there is no obvious vascular tissue damage. This will help you to define the area with the most affected trees.
- For blocks that received slow-cooker fire, this should be a random selection of trees. The optimum number of trees to sample is unknown for slow-cooker sites, but we suggest debarking at least 10 trees from areas in the block that look to have sustained the most fire damage. This will help identify the worst-case scenario.



Step 4. Decide

Use the foliage scorch, shoot regrowth observations and debarking assessment results to decide whether to remove or recover trees or blocks. Table 2 and Table 3 provide some damage categories to help interpret these assessment findings for the 2 main fire types.

Other important factors to consider (that are not covered in this guide) should include:

- age of the orchard block
- productivity and profitability of the block
- available recovery funding (e.g. loans, grants)
- your financial capacity to cover the costs of orchard removal, new investments and ongoing development.

Table 2. **Blow-torch** post-fire symptoms and recovery prospects.

Damage observed	Recovery prospect	Action
- Foliage burnt - Leaves gone - No surviving vascular tissue	Nil	Remove trees in this area
- Foliage extensively scorched - Leaves remain on the tree - Some surviving vascular tissue - Nil or very poor initial shoot regrowth	Very poor to nil	Remove trees in this area
- Foliage extensively scorched - Leaves remain on the tree - Very minor vascular tissue damage in the trunk - Some initial shoot regrowth	Moderate. There is likely to be some ongoing mortality in this situation.	Remove or recover. The long-term survival of these trees is uncertain.
- Foliage partially scorched - No vascular tissue damage to the trunk - Reasonable initial shoot regrowth	High	Recover block
- Very minor foliage scorch - No vascular tissue damage to the trunk - Good initial shoot regrowth	High	Recover block

Table 3. **Slow-cooker** post-fire symptoms and recovery prospects.

Damage observed	Recovery prospect	Action
- Foliage substantially scorched throughout the canopy, will be most severe in the lower half - Vascular tissue damage around 360° of the trunk circumference - No regrowth	Nil	Remove block
- Foliage scorched in the lower half of the canopy - Partial vascular tissue damage to the trunk - Nil or poor regrowth	Very poor. Some potential for individual tree recovery. High risk of tree losses and decline throughout the block.	Remove block
- Minimal leaf scorch in the lower canopy only - Very minor vascular damage - Healthy regrowth	Moderate. Tree has good potential for recovery. If this is the worst damage observed in a random sample of trees, block recovery might be possible.	Consider the potential for recovery of the block.
- Minimal leaf scorch in the lower canopy - No vascular tissue damage observed in the trunk - Healthy regrowth	High	Recover block

Delayed tree mortalities

The potential effect of delayed tree mortality on orchard productivity and profitability following a bushfire is an additional consideration when deciding to remove or recover an orchard. Monitoring tree health status in NSW and SA orchards following the 2019–20 bushfires revealed that tree decline and deaths can persist for years after a fire (Figure 40 and Figure 41). At one slow cooker-affected apple orchard in Batlow, 12% of trees died in the season of the fire, another 7% in the first season post-fire, 11% in the second and 1% in the third (with an

additional 5% of trees recorded as sick and likely to die). In this situation, delayed tree deaths accounted for the greatest proportion of overall losses.

Ongoing tree decline and death are most concerning in severe slow-cooker affected orchards. In these orchards, deaths will occur randomly throughout the block and will have a lasting effect on productivity and profitability.

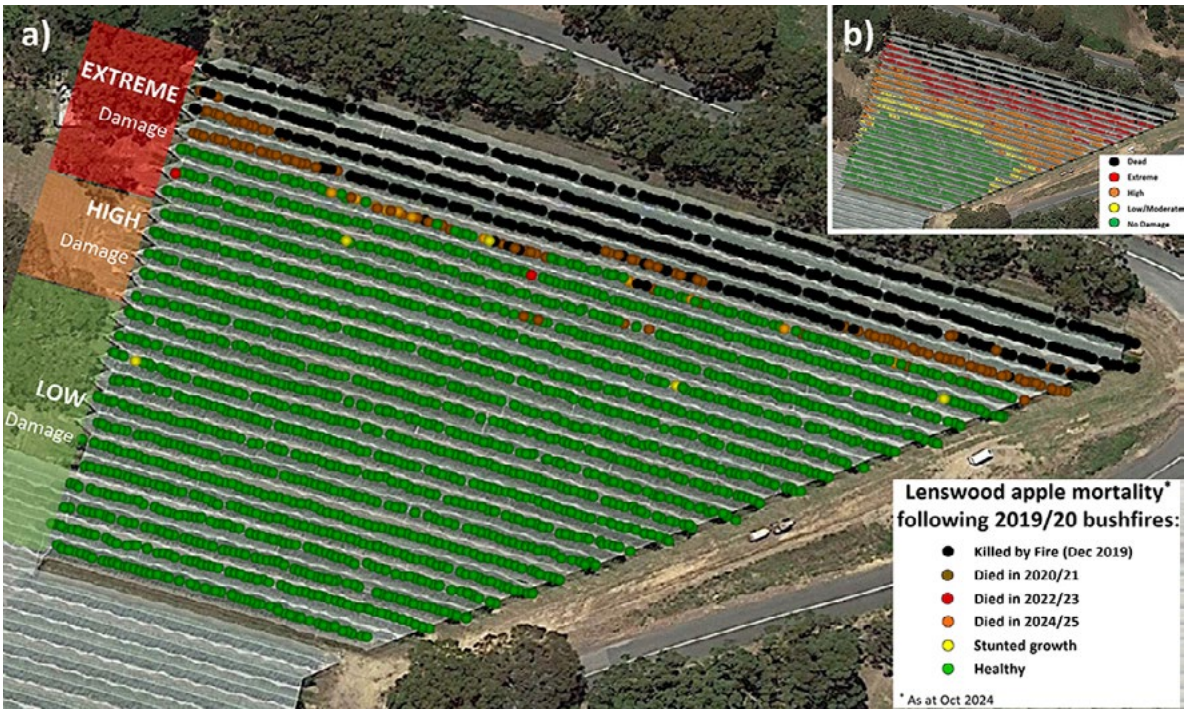


Figure 40. Apple tree mortality in 2024–25 (a) and initial assessment 2020 (b, inset) show a reasonable correlation between death and extreme damage at the initial assessment and 5 seasons later. Source: SARDI (2024).

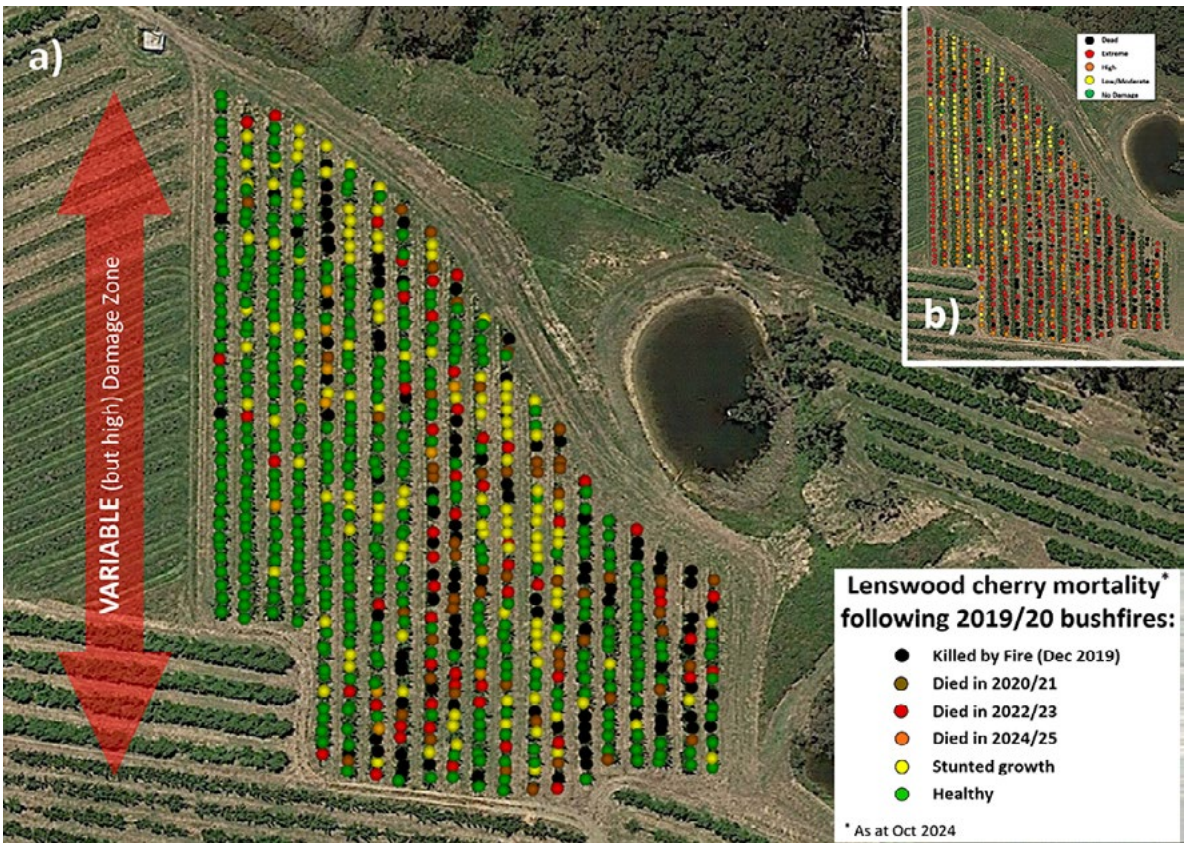


Figure 41. Cherry tree mortality in 2024–25 (a) and initial assessments from 2019–20 (b, inset) illustrating the random nature of tree damage at initial assessment and 5 seasons later in a slow-cooker fire-affected cherry orchard. Source: SARDI (2024).

Pruning strategies for tree recovery

Following the 2019–20 bushfires, researchers applied several pruning and canopy management treatments to fire-affected apple and cherry trees in trial sites in NSW and SA. The aim was to investigate which methods would result in the best canopy recovery and the fastest return to normal yields. The treatments included branch shortening, semi-poling, complete poling and complete canopy removal by heading (Figure 42).

At the time of writing, these studies were approaching their fifth growing season since the fires. Early outcomes were published by Idowu et al. (2021, 2023a, 2023b, 2024) and Rossouw et al. (2023, 2024), with final results to be published upon project completion in winter 2025.

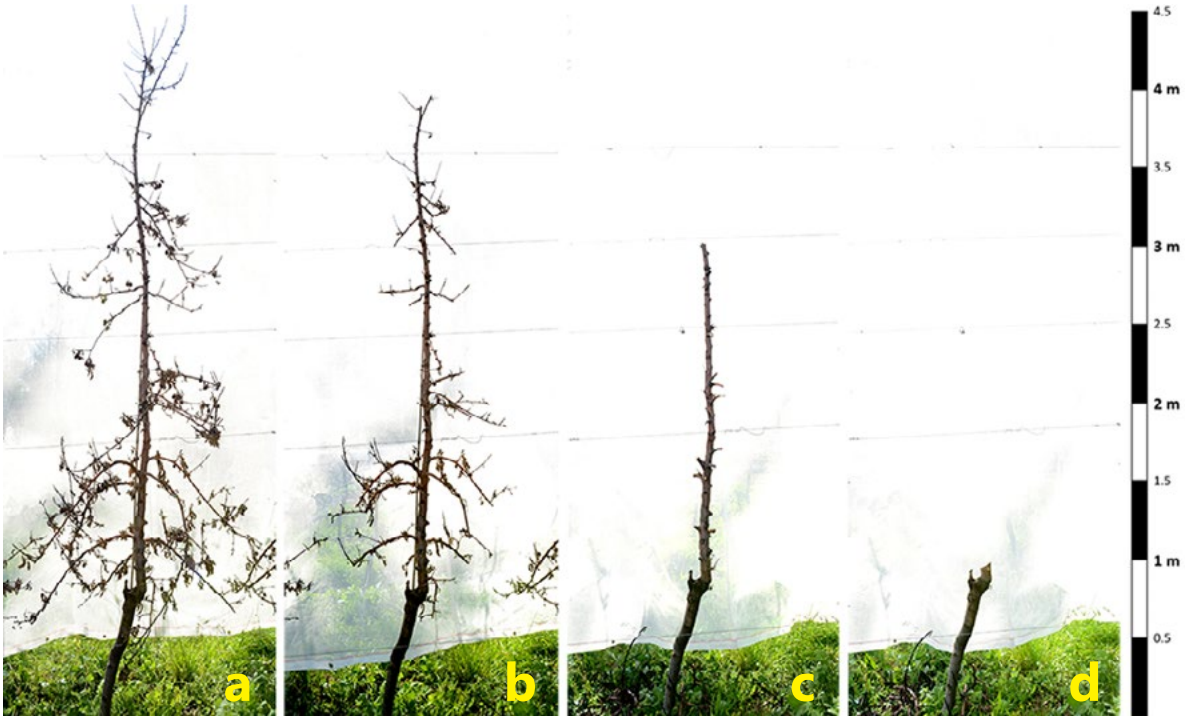


Figure 42. Examples of remedial pruning treatments examined at bushfire-affected apple orchards in NSW and SA: a) fire-affected tree before pruning; b) pruned with semi-poling treatment; c) pruned with poling treatment; d) pruned with heading treatment. Photo: SARDI (2020).

At both the NSW and SA study sites, tree response to pruning treatments varied with the type of fire (blowtorch or slow cooker), the extent of damage (low to extreme) and varietal production habits. Early findings suggest:

- Remedial pruning treatments were most successful for trees that retained vascular connection between the roots and the canopy:
  - At all trial sites, there was a greater chance that pruning treatments would succeed if the dominant source of fire damage was radiant heat from outside the orchard (blowtorch) rather than prolonged exposure to flame directly contacting the trunk (slow cooker).
  - Orchard recovery was difficult to predict when the entire trunk circumference was burnt, particularly if trunks had a small diameter.
- For trees rated as having moderate to high damage (scorched leaves with regrowth from >50% of laterals and trunk), the semi-poling pruning strategy was the most successful (Figure 42b).

- Semi-poling could be applied as either a targeted or prescribed shortening of lighter calliper scaffold branches and leader/s.
- The most successful, and time-consuming, version of semi-poling involved the targeted removal of dead wood (i.e. chasing the dead wood). This version of semi-poling needed to be applied during the growing season so that the presence/absence of live growth could guide pruning decisions. This resulted in a quick return of productive canopy with minimum retention of dead wood.
- A more rapidly applied, but indiscriminate, version of semi-poling was the prescribed shortening of scaffolds and canopy height to set lengths. This version of semi-poling did not require live growth to guide pruning decisions. It could be applied during dormancy but risked the accidental retention of dead wood.
- In both options, the semi-poling pruning strategy to moderately damaged trees resulted in the greatest retention of viable scaffolding and the quickest return to normal yields.

- For those trees rated as being extremely damaged (severely scorched leaves with poor regrowth from laterals and trunk), the complete poling strategy was most successful (Figure 42c).
  - For extremely damaged trees, rather than wasting time chasing the dead wood, the complete poling strategy offered an easily instructed, quick to apply, remedial pruning option that could be managed at any time through the growing season (no need for live growth to guide pruning decisions).
  - The complete poling treatment produced an equivalent or better canopy and yield return as the semi-poling for the worst fire-affected trees.
- Complete canopy removal by heading produced the slowest recovery and delayed the return to normal yields.
  - If the extent of fire damage is sufficient to contemplate complete canopy removal through heading cuts, then the economics of orchard replacement should be seriously considered.
- Varietal features will also influence how quickly fire-affected trees resume normal yields. For example, Rockit™, which crops on one-year-old wood, can be expected to yield more quickly from poling treatments than varieties that carry their crop on two-year-old wood.

Provided the conductive tissues of the main trunk and leaders are undamaged, apple and cherry trees are capable of regrowth from the trunk and main stem after poling or heading.

Figure 43 shows the return growth of fire-affected Kanzi™ apple trees 2 years after semi-pole and poling pruning treatments. Blowtorch-affected apple trees are more likely to recover if the vascular connection between roots and canopy is retained.

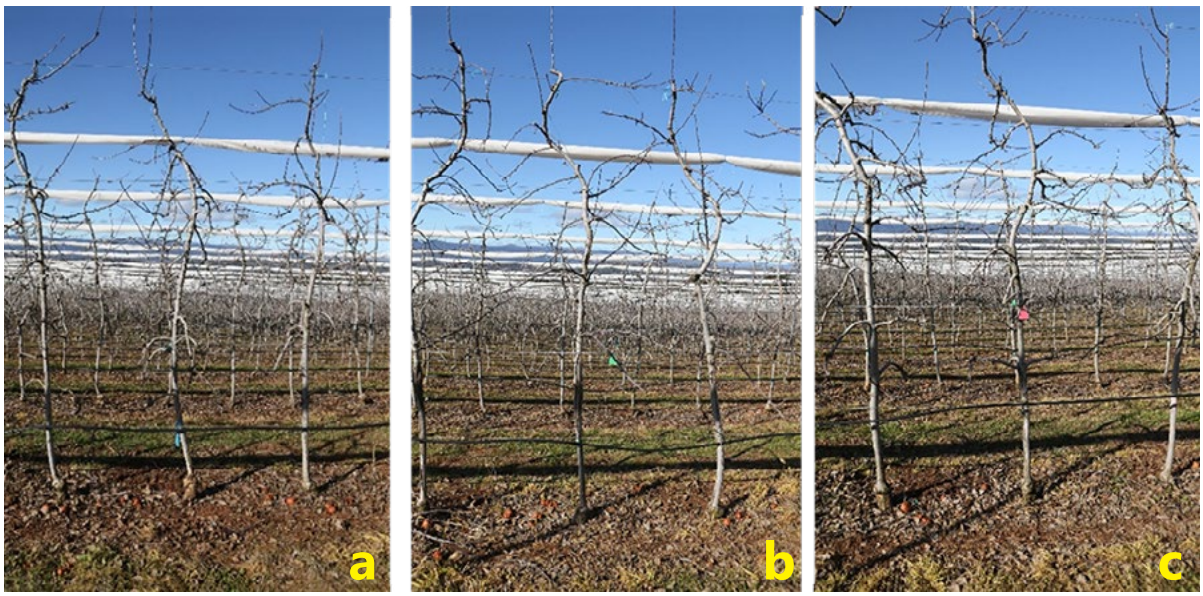


Figure 43. Return growth two seasons after remedial pruning in a blowtorch fire-affected Kanzi™ apple orchard in Batlow NSW: untreated control (a), semi-poling (b) and poling (c).

Similar pruning treatments applied at a Rockit™ apple orchard in the Adelaide Hills (SA) confirmed poling to be an effective post-fire renovation method for apple trees that were classified as having sustained extreme fire damage (Figure 44).

Figure 44. Return growth and crop following complete poling of a bushfire affected Rockit™ apple tree in Lenswood, SA. This was a blowtorch-affected tree with an extreme damage rating: a) January 2020; b) complete poling in May 2020; c) crop load in March 2024. Photo: SARDI (2020).

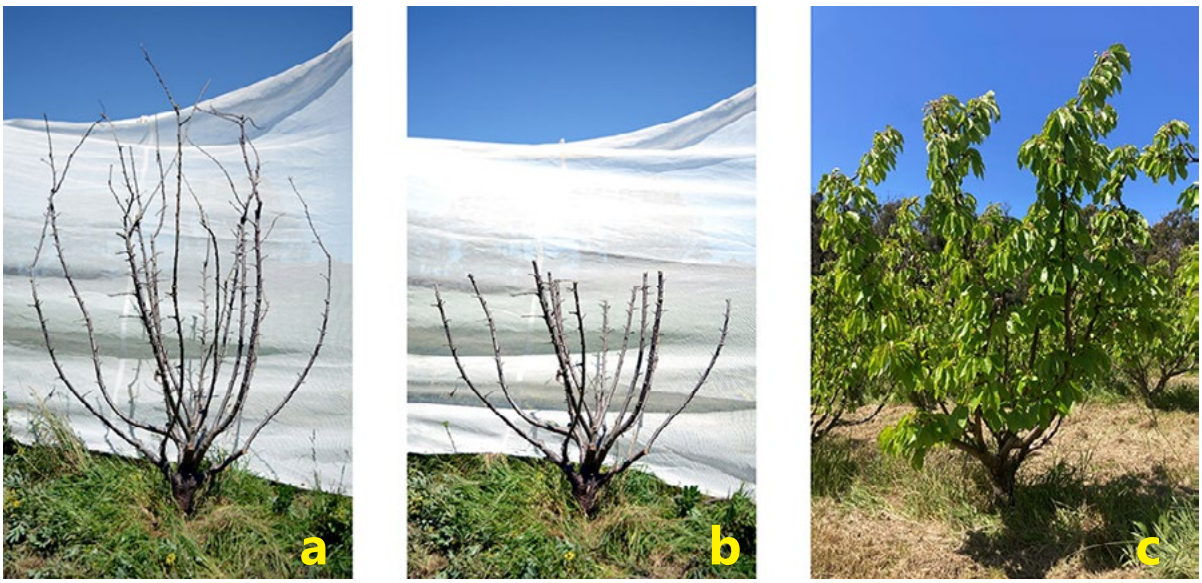


Figure 45. Return growth two seasons after remedial pruning to a slow-cooker fire-affected Stella cherry tree (high damage rating), Lenswood SA: a) pre-pruning in August 2020; b) semi-poling in August 2020; c) return growth in October 2023. Note the return canopy for slow-cooker affected trees was slow to generate strong yields. Photo: SARDI (2023).

The success of any pruning treatment for the recovery of fire-affected trees will depend on the level of underlying vascular tissue damage. In a blowtorch fire, trees with foliage scorch that are furthest away from the heat source will have a greater regrowth potential and better response to pruning. Responses to post-fire pruning treatments in slow-cooker affected orchards will be variable throughout the block, depending on the degree of conductive tissue damage in the trunk of each tree. Refer to 'Deciding to recover or remove the orchard' on page 33 for information on how to assess fire-damaged trees.

Overall, research to date has generally indicated that lightly scorched trees should be pruned back to live wood, while heavily scorched trees will respond best to complete branch removal (poling).

Post-fire priorities

Depending on the severity and extent, bushfires can be extremely disruptive to the normal operation of a horticultural business. In 2019–20, the extent of damage to orchards and infrastructure presented growers with a significant number of unplanned tasks and urgent decisions. Some growers described the situation as overwhelming, with no clear starting point for their response or orchard recovery. The following information should help provide growers with some focus in the days, weeks and months following a major bushfire.

The first priority

The affects of bushfire can be confronting. The first priority during and following a bushfire is to take care of your well-being and those around you. Assistance is available and the following links provide guidance and resources that will help you during a very stressful time post-fire.

- Managing your mental health during and after a bushfire (https://www.health.nsw.gov.au/mentalhealth/resources/Pages/bushfire-mental-health-support.aspx#selfcare)
- Bushfire information and support (https://www.dss.gov.au/about-the-department/bushfire-information-and-support#).

The first days

- For those who choose to evacuate, access back to your property after the fire is unlikely to be immediate. Emergency response agencies will prioritise safety over access and roads might be closed for an undetermined period due to the risks to public safety. Identify the agency responsible for road closures during bushfires and follow their website or social media channels for the latest updates.
- When roads re-open, follow the directions of emergency services and exercise extreme caution while moving within the fire-affected area, including on your own property. The risk posed by fire-damaged trees, farm structures and infrastructure such as electricity poles and wires can be very high.
- If you have produce in cool storage, check the refrigeration is operating. If the electricity supply is cut, ensure that any automatic backup generators have started or install temporary generators as soon as possible.
- Survey the damage to the orchard and farm assets. Prepare a list of damaged or destroyed items including machinery, sheds, orchard infrastructure, netting, and irrigation systems and estimate the productive area damaged. Contact your insurance provider to report the incident, share your initial assessment findings and request an assessor to visit as soon as possible. Early assessment and reporting will help expedite any claims and the replacement of essential equipment.
- Determining tree mortality immediately after the fire is difficult without using destructive assessment techniques. Tree deaths are likely to be ongoing for several years after the fire (particularly in the case of a slow-cooker fire). It is recommended that the scorching of trunks, branches, foliage and fruit, and damage to hail nets and irrigation lines be recorded as initial measures of damage.

Emergency services and government agencies will be seeking reports of damage to help inform their reporting and potential assistance for affected landholders. It is important to engage with these agencies to ensure they have a thorough understanding of the impact of the fire on your enterprise as well as the broader local community.

The first weeks

The bushfire danger season in the main temperate horticultural regions of Australia is usually during spring and summer. Deciduous fruit orchards are likely to be in their growing season. After a fire, there should be a percentage of the crop that is not directly affected and can be successfully managed through to harvest. Refer to 'Fruit quality and postharvest considerations' on page 13. Focusing on the surviving crop will help secure some income while giving the damaged trees time to show their potential for recovery.

Some post-fire actions to continue growing the undamaged portion of the crop will include:

- ensuring safe access to the orchard for staff; this might include removing dangerous boundary trees
- repairing damaged irrigation systems
- thinning fruit to compensate for lack of irrigation and lost growth
- re-establishing protective netting
- resuming crop protection programs.

Monitor tree regrowth during the initial weeks. Growth responses in fire-affected fruit trees can be a useful indicator of recoverability. For more information on tree assessment, recovery or removal, refer to 'Assessing fire-damaged trees' on page 25 and 'Recover or remove' on page 31.

Clean-up operations will also be part of the initial activities in the orchard. Stockpile damaged irrigation materials, netting and trellis poles and keep a detailed record of the quantities removed from the orchard. These records might form part of a future insurance claim or grant application. Depending on the extent of the damage across a region, government agencies may help with waste management.

The first 6–12 months

- Decide which blocks will be recovered and which will be removed. Allowing the trees some time to show their regrowth potential, this decision should be possible within the first 6–12 months post-fire (refer to 'Deciding to recover or remove the orchard' on page 33).
- Look for available financial assistance (i.e. grants or low interest loans) and consider engaging a financial adviser to assist with grant application writing and administration.
- Order nursery stock for replacement trees or new orchard blocks.
- Remove blocks that are chosen for replacement and complete site preparation for the new orchard.
- Continue to monitor blocks that were chosen for recovery. Take note of general tree health, pest and disease incidence and any second-year mortalities.
- Apply pruning and canopy management treatments to the blocks being recovered.

Farm and orchard bushfire preparedness

A key step in preparedness is having a bushfire survival plan for your family, employees, home and farm. A bushfire survival plan lists the steps you, your family and staff will take to prepare your property for fire and what you will do during a fire emergency. Bushfire authorities in all states and territories of Australia have checklists and templates on their websites to help you develop your bushfire survival plan. We encourage readers to visit their state authority website and start their bushfire planning today.

The NSW Rural Fire Service recommends 4 simple steps to develop a home bushfire survival plan: **discuss, prepare, know and keep** (Table 4). These steps can be easily adapted to include the additional considerations necessary for a horticultural enterprise. Visit the NSW Rural Fire Service bushfire survival plan webpage (https://www.rfs.nsw.gov.au/plan-and-prepare/bush-fire-survival-plan) to start your simple 4-step survival planning process.

Table 4. A 4-step bushfire survival planning process with some considerations for horticulture.

	Domestic considerations	Additional considerations for horticulture enterprises
	Have a discussion with family over dinner when everyone is present.	Hold a special meeting of farm staff at least once before every fire season to review the bushfire survival plan. Talk with your neighbours about their plans. Consider taking a community approach with others planning to stay and defend.
	Prepare your home and get it ready for bushfire season.	Include bushfire preparation and maintenance as part of your routine horticultural business management. Include activities that are once per fire season and those that are ongoing during the risk period.
	Know the bushfire alert levels.	Know the unique risks for your enterprise and know how best to manage those risks.
	Keep up to date with all bush fire information, numbers, websites and apps.	Keep an updated list of staff contacts on your phone. Share contacts with neighbours. Consider additional communication options that are independent of power or mobile service (i.e. UHF).

Source: adapted from the NSW Rural Fire Service.

Developing and maintaining fire-resilient orchards

Lessons learned from the 2019–20 Black Summer bushfires in the temperate fruit growing regions of Batlow and Bilpin (NSW) and the Adelaide Hills (SA) have helped identify some tips for orchard bushfire preparedness that will complement your home and farm survival plans (Figure 46). In addition to the tips provided here, details of the damage type, description, effects, and recovery strategies and prevention/mitigation strategies for bushfires in orchards are listed in Table 5.

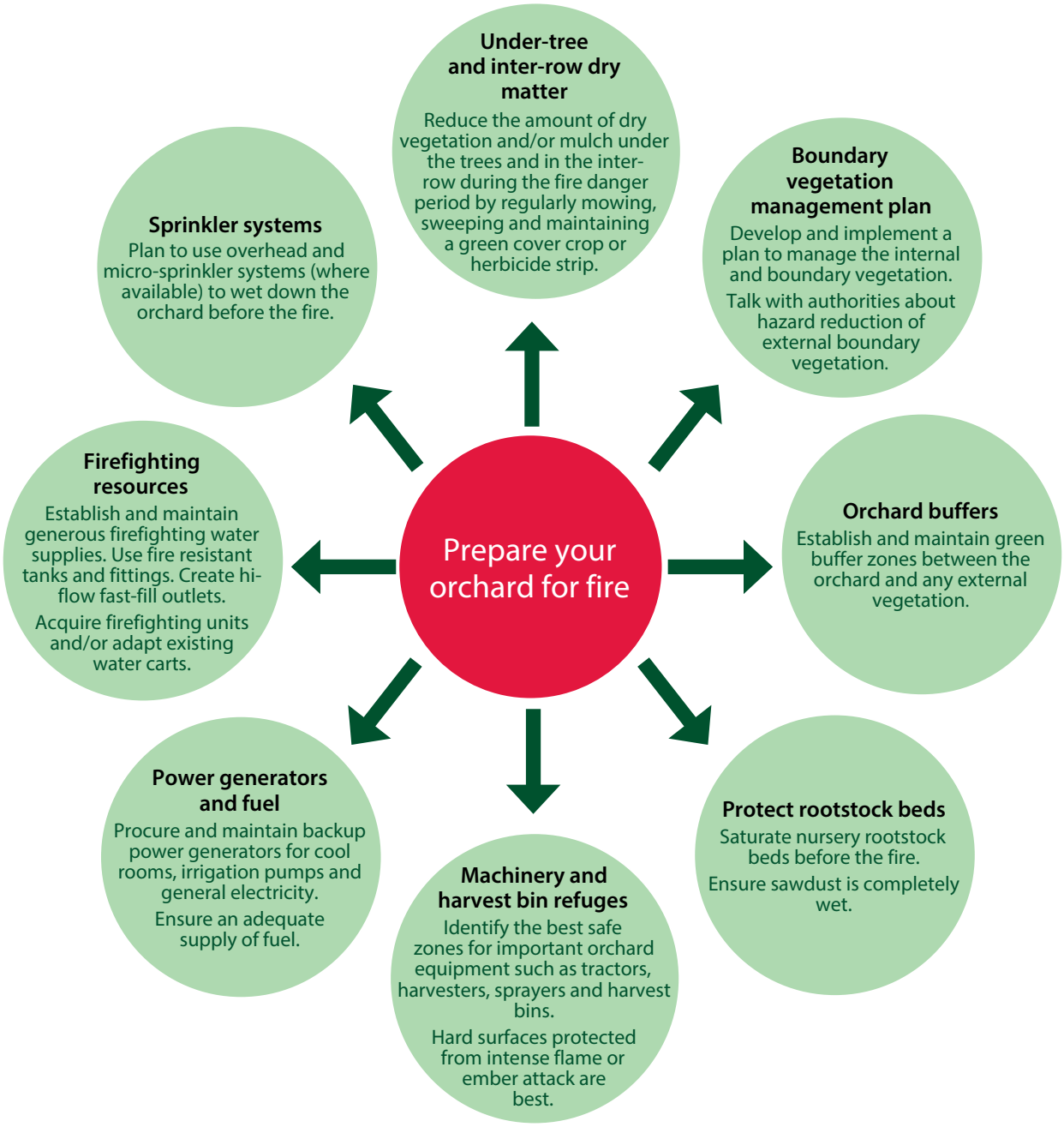


Figure 46. Tips for orchard bushfire preparedness.

Table 5. Major damage types, description, effects, recovery and prevention/mitigation strategies for bushfires in orchards (page 1 of 2).

Damage type	Description	Affect	Recovery strategies	Prevention/mitigation strategies
Heat scorch or '**blow torch**' to orchard trees 	Fuel sources (commonly native trees, shrubs, and fuels) are adjacent to the orchard, producing windblown heat that scorches trees on a gradient from the source into the orchard.	Tree damage ranges from death to minor foliage scorching. Severe heat scorching results in tree deaths up to 10–15 rows (35–55 m) from the heat source. If the fire source is close enough, some trees might be damaged by direct flame. Tree deaths are fairly uniform along the tree row and into the orchard on a gradient from the heat source.	1. Determine fire type. 2. Wait and assess how the trees respond. 3. Identify the distance from the fire source where dead trees end and recovering trees begin. 4. Remove dead or dying trees and decide which part of the block will recover. 5. Consider selective debarking to inform decision-making. 6. Replant the cleared section. 7. Choose a canopy management strategy for recovery of the retained trees (refer to 'Pruning strategies for tree recovery' on page 36)	1. Create buffers between the property boundary, fuel sources and the orchard. 2. Vegetation management. In NSW, vegetation management on private property is regulated under the Land Management (Native Vegetation) Code 2018 under the *Local Land Services Act 2013*. Readers in other states and territories are encouraged to identify similar legislation in your jurisdiction. Bushfire fuel management on private land is regulated under the *Rural Fires Act 1997* Part 4 Divisions 1 and 2, and the *Rural Fires Act* Regulations Part 4, 5 and 6. Management of vegetation on public lands (i.e. roadside) is the responsibility of your local council and/or land managers, often with hazard reduction support from the rural fire service in your area.
Direct burning or '**slow cooker**' to orchard trees 	Dry weed matter in the tree row produces flames and heat, damaging the tree canopy, trunks and vascular tissues. Tree damage ranges from complete vascular conductivity loss to partial phloem loss or minimal lower leaf scorching.	Tree vascular tissues (mainly in the trunks) are damaged to varying degrees along the tree row depending on the amount of fuel around each tree. The result is a patchwork of damaged trees with varying levels of severity, from 100% ringbarking to minor vascular tissue loss or only bark damage.	1. Determine fire type. 2. Determine the severity of the burn across the block. Debarking the trunks of a sample of affected trees might help with this. 3. If the under-tree fuel load was high before the fire, there would likely be significant damage to trunk vascular tissues. Blocks affected by severe slow-cooker fires will feature a patchy recovery and suffer from significant ongoing tree mortalities for at least 3 seasons post-fire. Consider immediate removal and re-establishment. 4. Blocks that suffer a low fuel level slow cooker burn might have a greater potential for recovery. Consider allowing such blocks a season to express initial tree mortalities.	1. Maintain a weed-free and dry matter-free tree row. 2. If under-tree mulch is part of your soil management strategy, keep it moist as the fire approaches. 3. Green inter-rows will help reduce the movement of fire within orchard blocks and the scorching of outer tree canopies. 4. If overhead sprinklers or under-tree micro-sprays are part of your irrigation system, use these to dampen the orchard floor as the fire approaches.
Nursery rootstock beds 	Dry sawdust results in a slow, hot burn that kills rootstock plants and crowns in nursery beds. Fire will persist through dry sawdust material once alight.	This can result in a complete loss of rootstocks and stool bed production capacity, significantly reducing rootstock supply for post-fire recovery.	1. Allow time to see if the crowns are still alive and can re-shoot. 2. If the crowns are dead, source new rootstock plants from another nursery to start re-establishing stool beds in the winter immediately following the fire. 3. Enquire with unaffected nurseries for an alternative supply of rootstocks to meet new orchard planting needs until in-house production is re-established.	1. Ensure nursery rows and stool beds are thoroughly soaked ahead of the fire front. 2. Check nurseries immediately after the fire front has passed and extinguish any active fire.
Hail netting and structures 	Netting melted and/or burnt by heat or direct flame. Netting sustained numerous small holes due to an ember attack. Timber netting/trellis posts catch fire and partially or completely burn through.	Areas of orchards become completely unprotected from hail, birds and flying foxes. Ember-affected netting is no longer suitable and might fail in a significant hail storm. Structural integrity is compromised. Damaged or broken posts, fallen cables, and wires might be a safety hazard.	1. **Safety first**: close the orchard to all staff, visitors and vehicles until inspection and risk assessment are completed. 2. Inspect all posts, wires and stays for damage. 3. Photograph and record the location of all damaged items, including the netting. 4. **Make it safe**: re-establish a safe operating environment. Repair damage affecting the structural integrity of the netting and/or trellis. 5. Ensure any undamaged crop is protected from hail and pest damage as soon as practical after the fire. 6. Keep a record of materials purchased and repair costs.	1. Keep timber posts clear of any dry vegetation or other combustible materials. 2. Pay particular attention to protecting the end (edge) posts and stays that are critical for the structural integrity of a trellis or netting system. 3. Consider alternative materials for posts (i.e. steel or concrete if available). 4. Avoid having poly pipes close to timber posts. This could be a sustained source of flame to ignite posts.

Table 5. Major damage types, description, effects, recovery and prevention/mitigation strategies for bushfires in orchards (page 2 of 2).

Damage type	Description	Affect	Recovery strategies	Prevention/mitigation strategies
Irrigation and water supply systems 	Poly pipe laterals melt, burn and carry fire along tree rows. Pumps can be directly damaged by fire. Plastic water tanks and above-ground fittings melt and burn.	Unable to irrigate the crop until the system is repaired, negatively affecting tree recovery and any undamaged surviving crop. Damage to the water supply during the fire could hamper fire-fighting.	Following a major fire, replacement irrigation pipes and fittings might be in short supply. 1. Assess the damage: prepare an estimate of how many metres of poly pipe and the number of fittings required to repair the system. 2. Consider keeping some pipes and fittings on hand. 3. Enquire early about pipes and fittings supplies with local suppliers.	1. Keep the under-tree area free of dry matter that could cause poly pipe laterals to ignite. Pay particular attention to the point where the poly pipe rises from the sub-main pipes. This could be the primary ignition point, and once alight, the pipe can continue to burn into the orchard. 2. Consider suspending dripper lines onto a trellis wire approximately 500–700 mm above soil level. 3. Replace plastic water tanks with metal or concrete and consider upsizing their capacity. 4. Replace plastic tank fittings with metal ones. 5. Ensure all plastic mainlines and fittings are below ground.
Harvest bins and sheds 	Timber harvest bins burn due to ember attacks or small fires adjacent to farm sheds. The resulting intense fire destroys bin storage sheds.	The supply of harvest bins for the undamaged portion of the crop will be compromised. Sheds require reconstruction.	1. Consider a harvest bin sharing arrangement to fill immediate shortages among local growers and packing sheds. 2. Order replacement bins.	1. Move harvest bins to an area as far as possible from sources of ember attack or direct flame. 2. Store bins out of sheds to prevent shed loss in a bin fire. 3. Store bins in several locations (including off-farm if available) to spread risk.
Machinery 	Farm machinery burns due to direct flame from grass or shed fires or ember attack.	Ability to resume routine management activities (e.g. spraying, mowing, harvesting) after the fire. The surviving crop is compromised due to a lack of timely pest, disease and weed control. Funding and sourcing replacement machinery could be slow, delaying the return to normal operating capacity.	1. Insurance claims and machinery replacement will take time. 2. If undamaged backup equipment is not available on the farm, there might be a need to borrow or lease equipment locally.	1. Have machinery refuge areas. 2. Identify one or more locations on or near the property where machinery can be parked safely before the fire arrives. 3. Large areas of concrete or sealed surfaces free of combustible material and away from significant ember sources make the best machinery refuges. 4. Space equipment such that if one item burns, it cannot ignite the next item.
Electricity infrastructure 	Timber power supply poles can be destroyed, cutting off power for days to weeks in some locations. Pumps serviced by on-site power generation units are also prone to fail if CoGen air intake is fowled by ash and molten net. Locate these units away from high fire pressure zones.	Electrically powered irrigation pumps do not work. Cool rooms and fridges lose power, placing stored fruit and other products at risk.	1. Ensure backup generators are functioning. 2. Set up portable generators to keep irrigation pumps functioning.	1. Install and maintain a backup power generator for coolstores. 2. Purchase or hire portable generators for electric irrigation pumps.

Some authorities may have bushfire preparedness and planning resources specifically for farms on their websites (Table 6), which are good starting points. However, they do not always provide tailored recommendations on bushfire preparedness for horticulture.

Table 6. Links to online resources for farm bushfire preparedness by state agencies.

State/Territory	Farm bushfire preparedness resource
New South Wales Rural Fire Service	Farm fire safety (https://www.rfs.nsw.gov.au/plan-and-prepare/farm-fire-safety) Preparing your property (https://www.rfs.nsw.gov.au/__data/assets/pdf_file/0006/187467/Prepare-Your-Property-Factsheet.pdf) Information on Fire Permits (https://www.rfs.nsw.gov.au/__data/assets/pdf_file/0011/187445/Fire-Permits-Information-for-rural-landholders-and-farmers-web.pdf) Preparing your home (https://www.rfs.nsw.gov.au/__data/assets/pdf_file/0009/3114/Prepare-Your-Home.pdf) Rural Boundary Clearing Code (https://www.rfs.nsw.gov.au/__data/assets/pdf_file/0014/231422/Rural-Boundary-Clearing-Code-for-New-South-Wales.pdf)
Australian Capital Territory Emergency Services Agency	Farm FireWise (https://esa.act.gov.au/sites/default/files/2022-09/Farm FireWise Information Booklet.pdf)
Agriculture Victoria	Preparing your farm for bushfire (https://agriculture.vic.gov.au/farm-management/emergency-management/bushfires/how-to-prepare-for-a-bushfire)
South Australia Country Fire Service	Farm fire safety and prevention (https://www.cfs.sa.gov.au/plan-prepare/business-farms/farm-fire-safety-prevention/)
Western Australia Fire and Emergency Services	Fires on farms in WA (https://www.agric.wa.gov.au/fire/fire-farms-western-australia-%E2%80%93-reducing-risks)
Tasmania Fire Service	Bushfires on farming properties (https://nre.tas.gov.au/agriculture/natural-disaster-support/bushfires-on-farming-properties)

In addition to providing bushfire survival planning information and guides, all state and territory governments of Australia host information and updates on their websites (Table 7). These resources include current incident maps, which provide up-to-date fire status information and alerts for your area.

Table 7. State and Territory bushfire authorities, their survival plans, checklists and current incident webpages.

State/Territory	Survival plans/checklist	Current incidents
New South Wales Rural Fire Service (www.rfs.nsw.gov.au)	Bushfire survival plan (https://www.rfs.nsw.gov.au/resources/bush-fire-survival-plan)	Fires near me (https://www.rfs.nsw.gov.au/fire-information/fires-near-me)
Australian Capital Territory Emergency Services Agency (https://esa.act.gov.au/rural-fire-service)	Bushfire ready (https://esa.act.gov.au/cbr-be-emergency-ready/bushfires/bushfire-ready)	Incidents map (https://esa.act.gov.au/?fullmap=true)
Victoria Country Fire Authority (https://www.cfa.vic.gov.au/)	Your bushfire plan (https://www.cfa.vic.gov.au/plan-prepare/before-and-during-a-fire/your-bushfire-plan)	Incidents and warnings (https://www.emergency.vic.gov.au/respond/)

State/Territory	Survival plans/checklist	Current incidents
South Australia Country Fire Service (www.cfs.sa.gov.au)	Bushfire survival plan (https://www.cfs.sa.gov.au/plan-prepare/before-a-fire-be-prepared/make-a-plan/bushfire-survival-plan/)	Incidents and warnings (https://www.cfs.sa.gov.au/warnings-restrictions/warnings/incidents-warnings/)
Queensland Fire and Emergency Services (https://www.fire.qld.gov.au/about-us/frontline-services/rural-fire-service-queensland)	Bushfire survival plan (https://bushfire-survival-plan.qfes.qld.gov.au/)	Bushfire warnings and incidents (https://www.qfes.qld.gov.au/Current-Incidents)
Northern Territory Police, Fire and Emergency Services (https://pfes.nt.gov.au/)	Bushfire survival plans (https://securent.nt.gov.au/prepare-for-an-emergency/fires/bushfires/survival-plans)	Fire incident map (https://pfes.nt.gov.au/fire-and-rescue-service/fire-incident-map)
Western Australia Fire and Emergency Services (https://www.dfes.wa.gov.au/about-us/rural-fire-division)	My bushfire plan (https://mybushfireplan.wa.gov.au/)	Emergency warnings and incidents (https://www.emergency.wa.gov.au/)
Tasmania Fire Service (https://www.fire.tas.gov.au/)	Bushfire survival plan (https://www.fire.tas.gov.au/Show?pageId=colbushfirePrepareActSurvive)	Alerts map (https://alert.tas.gov.au/?view=both)

Acknowledgements

The authors would like to thank the NSW Department of Primary Industries and Regional Development, the Department of Primary Industries and Regions, South Australia and Hort Innovation for supporting the research that has helped to inform the content of this guide.

Thank you to the growers who gave us access to their fire-affected orchards in support of our research. We would particularly like to acknowledge the Mouat family of Batlow and the Duffy family of Willigobung; the staff of Batlow Fruit Company at Batlow; and Rob Green, Kym Green and Robert (Bob) Barnard of the Adelaide Hills.

Thanks also to Dr Simon Tierney and colleagues at the Hawkesbury Institute for the Environment at Western Sydney University, Richmond, NSW for their contribution to knowledge of fire affects on pollinators.

Jon Gregory ESM JP, District Manager – Riverina Highlands District RFS, provided helpful information on vegetation management and preparing for bushfire.

Developing management strategies to enhance the recovery of horticulture from bushfires (AS19002) is funded by the Hort Frontiers strategic partnership initiative developed by Hort Innovation, with co-investment from NSW Department of Primary Industries and Regional Development (NSW DPIRD) and South Australian Research and Development Institute (SARDI), and contributions from the Australian Government.

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Apples in Batlow, NSW

Grower	Ian Cathels
Property name	Ardrossan (Woodburn) Orchard
Property location	Old Tumbarumba Rd, Batlow, NSW, 2730
Primary crop	Apples
Irrigation type	Drip
Inter-row/tree line management	Organic
Netting or cover system	NA

Tell us a bit about the fire at your properties

Before the fire hit, we had decided to stay and defend. The fire that caused most of the damage reached our Woodburn Orchard on 4 January 2020, four days after it started (31 December 2019) near Ellerslie Nature Reserve, about 30 km to our north-west. The fire behaviour and direction of travel were erratic over those 4 days. Initially it ran very quickly on New Year's Eve from Ellerslie to Tumbarumba on the back of strong north-westerly winds. When the winds changed to westerly, it turned the eastern fire edge into a very long fire front. Firstly, we used the slip-ons (fire units that slip-on the back of utes) and spray carts to fight the fire at our Ardrossan Road properties, then we moved to Woodburn on 4 January. The fire conditions on that day were catastrophic, and we took shelter at our family home when the main front hit. After the worst of the fire had passed, we emerged from our safe zone and began actively controlling spot fires and doing what we could to protect the packing shed and other assets.

What was the predominant fire type and what damage occurred?

We experienced both blow-torch and slow-cooker fire damage in our orchards. If I had to say which caused the greatest losses, it would be the blow-torch fire coming from unmanaged roadside native vegetation outside the property boundary (Figure 47), which contained very high fuel loads and was a source of scorching wind-driven heat.

Figure 47. An example of severe blow-torch fire damage at Woodburn Orchard.

Our slow-cooker damage was mainly due to some dry matter in the inter-rows and under the trees. Dry mulch is a problem.

In addition to the blow-torch and slow-cooker damage to orchard trees, we also lost a few farm sheds, one tractor, a farmhouse and most of our nursery rootstock beds were destroyed when the sawdust mulch caught fire and smouldered through the entire nursery. Most of our hail netting was damaged by embers, causing holes that meant it all had to be replaced. A significant portion of our irrigation system was damaged, with driplines and other above-ground components destroyed.

We saved most of our machinery by parking these in our main sheds surrounded by clean gravel surfaces.

Did you have any bushfire fighting equipment before the 2019–20 bushfire?

Yes. We had some existing capacity for firefighting, but it was not enough. We had two utility slip-on firefighting units and our orchard sprayers were fitted with hoses on the back. Our safe zone was the family home, which was fitted with a rooftop sprinkler system. Our water supply was gravity-fed and therefore independent of power supply or pumps.

What fire mitigation was undertaken in the days leading up to the main fire?

Slip-on units were installed on tray-back utilities in readiness for the firefront. The gutters were cleaned. Checks were done to ensure the water supply was working. We checked that we had sufficient fuel for vehicles, machinery and pumps. In the days before the fire reached Woodburn, we were wetting down the areas surrounding key assets, including the packing shed.

Evacuate or stay and defend; would you make the same choice again?

Yes, the decision to stay and defend with some of our key staff members and neighbours was the right one for us. Being on the farm enabled us to save some assets and extinguish spot fires after the fire front had passed. After the experience of 2019–20, we would always stay and defend.

Working with neighbours who also decided to stay and defend was vital to our collective safety. We had discussions with them in the days leading up to the main fire and agreed on an alert system to quickly communicate to each other our current circumstances. We relied on UHF radios firstly and mobile phones secondly for communication. When it was time to shelter, we were in communication with neighbours, and we retreated to our safe zones for approximately 30 minutes.

What was the biggest challenge(s) immediately post-fire?

After the fire, there was so much devastation and so many things that needed attention; the hardest thing was knowing where to start. Damage like that cannot be fixed on day 1; it is a long haul and it takes years to recover.

Road closures were a key challenge. We needed to get staff in to harvest berries that were ripening so we did not lose that important income. We also needed people to help with the recovery effort and manage the surviving crop.

Sourcing generators for temporary power to run cool rooms, pumps and general electricity was a priority. We managed to find a supplier in Canberra.

The supply of irrigation material to re-establish driplines was insufficient to meet the immediate demand.

What was your initial response to crop and tree recovery?

We evaluated each block to determine how badly each was affected. In the worst areas, we pruned all the branches off, while in others, we just removed a limb here or there. The edges of the blow-torch-affected blocks were the worst and had the most uniform damage from tree to tree and across rows. It was easier to make a decision in these blocks. The effect was less clear in the areas where we sustained slow-cooker fire and it was harder to make decisions in these blocks.

We did carry out supplementary thinning in some blocks, but I am not sure this made much difference. Thankfully, there was significant rainfall in the third week of January (2 weeks after the fire), which took the pressure off the need for irrigation as our systems were still not operational.

Do you have any thoughts on replacing or recovering damaged orchard blocks? Which gave the fastest return to normal production?

Replacement was good, but it is a big investment. Even with government grants available, you need to consider if re-investing is the right option. Some damaged blocks we chose to recover (particularly those with slow-cooker damage) have not really returned to normal full production, even 4 years later. There are trees in these blocks that will probably never return to full production.

What recovery success stories would you like to share?

The support from our staff during the long journey of recovery was amazing. Grant money that helped with the recovery was great. I am not sure about the capital investment grants, as there is a risk of over-investing.

What would you do differently?

I would make sure the relevant authority was managing roadside vegetation and that fuel loads were under control. We have added a buffer to replace blocks adjacent to boundaries with native vegetation. I would consider establishing a deciduous tree buffer along property edges shared with native vegetation (Figure 48). Exotic deciduous tree species seemed to provide some screening of heat and embers during the 2019–20 fires.

Figure 48. An example of a replacement orchard at Ardrossan Woodburn Orchard that incorporates a grassed bushfire buffer.

Take the time to develop a financial plan for the recovery to make sure you can manage the financial burden associated with redeveloping the orchard. It is tempting while there are grants available to take on more than the business can sustain, particularly during those years of production recovery.

Have you made any changes to orchard infrastructure or equipment to add resilience against fire?

Yes. We have installed more steel water tanks with clear space around them. We have added more firefighting slip-on units to our fleet, including converting some old spray units to fire control pumps and high-flow hoses. We are managing our boundary vegetation and including green buffer space between boundaries and new orchard blocks. We are tending towards shorter orchard row lengths to facilitate faster movement between rows when trying to access spot fires.

Do you have any advice for orchardists who might find themselves confronted by bushfires?

Make sure you have plenty of firefighting capacity, including:

- Slip-on units (Figure 49, left).
- Adequate and secure water storage that are gravity feed (Figure 50) or pumps that are independent of the electricity grid.
- Fast filling points (we have re-designed our general sprayer fill-up points to large diameter pipes for high flow and fast filling during a fire.

If you plan to stay and defend, always have a safe zone to fall back to.

During recovery, ask yourself, 'Will the prevailing market conditions for my product support my recovery investments?'

Figure 49. Firefighting units can be purpose made (left, photo: Trans Tank, https://www.tti.com.au/product/firedefence-portable-fire-fighter-800-litres/) or retrofitted to old orchard sprayer vats (right).

Figure 50. Water supplies should be secure, uninterrupted and offer high flow for fast filling of firefighting units. Ardrossan Orchards installed high capacity, fire resistant steel tanks, gravity feed and large diameter pipes to facilitate fast filling.

We need to explore future funding methods to support landholders to purchase and maintain firefighting assets. One suggestion would be to direct some of the Essential Services Levy to a grant scheme for fire resilience infrastructure.

Nurseries and rootstock stool beds are vital assets in the recovery phase. Make sure these are protected from fire. Water them heavily just before the fire arrives.

Plan to fight the fire on your own; that way, you will know the minimum resources you will have available in the worst-case scenario.

Take a community approach to the stay-and-defend decision. Work with your neighbours and have clear plans for communication and safety protocols.

Apples in Batlow, NSW

Grower	Greg and Kris Mouat
Property name	Wyola Orchards, Batlow
Primary crop	Apples and cherries
Irrigation type	Inline dripper
Inter-row/tree line management	Grass clover inter-row and under tree mulch.
Netting or cover system	Mostly structured hail netting.

Tell us a bit about the fire at your properties

The fire reached our property on 4 January 2020. We experienced both slow-cooker and blow-torch damage to orchard trees and we lost most of our machinery in the fire. All of our hail netting was ember damaged and needed to be replaced. Our irrigation system also sustained significant damage when the dripper tube caught fire and melted. We lost around 30% of our planted area of orchard, some sheds and their contents and fences.

Delayed tree mortality, particularly in slow-cooker-affected areas, has been an ongoing concern affecting the economic viability of some blocks.

Did you have any bushfire mitigation equipment before the 2019–20 bushfire?

No. We had no fire protection strategies in place. A fire of this nature was totally unexpected for our location, so we did not think fire protection was needed.

What fire mitigation was undertaken in the days leading up to the main fire?

We moved machinery to an area we thought would be safe from direct fire. This was a dry dam totally clear of vegetation or debris, but this location did not save our machinery. The ember attack must have been so heavy at the peak of the fire that it was enough to ignite the equipment and everything we had placed there was lost.

We pushed in some fire breaks around the edge of the orchard, but again, the intensity of the fire and ember attack rendered these ineffective.

We spent some time clearing flammable materials from around key infrastructure including sheds.

Evacuate or stay and defend; would you make the same choice again?

We chose to evacuate to Tumut. Warnings in the days leading up said conditions were going to be catastrophic and the area would be 'un-defendable'. We were not really equipped to stay and defend.

In the future, the decision will depend on many factors, including weather conditions, fire danger ratings, and the advice of fire authorities.

Unless we invested significantly in firefighting capability, we would decide to evacuate.

What was the biggest challenge(s) immediately post-fire?

Growing the surviving crop through to harvest was challenging. The fire happened in early January, so we still had 4 to 5 months of growth to manage the remaining fruit to a marketable yield.

Making the time to host and inform visiting officials about the extent of the damage was challenging but necessary. We had to spend this time making sure the government was fully informed about the significance of the fire. This effort led to some really meaningful and effective financial support.

The clean-up was a challenge, but we received some excellent help from local groups (like a local rugby club) and government agencies, who assisted us with removing dangerous trees and disposing of damaged infrastructure such as poles, netting, and irrigation tubing.

What was your initial response to crop, tree and infrastructure recovery?

Our response was determined by the perceived severity of damage in the various orchard blocks. Mostly, we did take a wait-and-see response. In our Gala block, which sustained a slow-cooker burn, we saw delayed tree mortalities 2 years post-fire, which meant the block will not return to full production. Much of our infrastructure and machinery losses were covered by our insurance policies, which meant we could replace them or get a payout fairly quickly.

Do you have any thoughts on replacing or recovering damaged orchard blocks? Which gave the fastest return to normal production?

Not particularly. It depends on the situation in each block. Some will recover and others will not.

What recovery success stories would you like to share?

The government grants have enabled us to replace damaged blocks with more modern orchards. We have new plant and machinery. Our orchard is now 100% netted and we have been able to establish some new varieties. The grants and insurance have been vital to us remaining in the industry.

What would you do differently?

The downside of the bushfire recovery grants was the time involved in the application and reporting processes. If this happens again, we would engage a professional to assist with the grant process.

Have you made any changes to orchard infrastructure or equipment to add resilience against fire?

We have removed a lot of flammable material from the orchard and around structures (Figure 51).

Do you have any advice for orchardists who might be confronted by future bushfires? Or any additional comments?

Expect some delayed tree mortality, particularly in blocks that had a slow-cooker burn.

It is essential to have insurance that is fit for purpose.

Engage with visiting government and industry representatives after the fire. It is important they have a clear understanding of the damage and financial impact.

Figure 51. This old *Pinus radiata* shelter belt adjacent to an apple orchard at Wyola was one of the main fuel sources for the fire in the orchard. Photo: Greg Mouat.

Cherries in Lobethal, SA

Grower	Robert (Bob) Barnard
Property name	Cherrytime Orchard
Property location	1917 Lobethal Rd, Lobethal, SA 5241
Primary crop	Cherry, hay, cattle
Irrigation type	Drip
Inter-row/tree line management	Under-tree spray and mid-row slash
Netting or cover system	Drape nets (50% netting installed on day of fire)

What was the predominant fire type?

Probably 50:50 (Figure 52). There was significant radiant heat, with fire attacking from three sides (blow-torch).

Figure 52. The orchard affected by both blowtorch and slow-cooker fire types. Photo: DEW.

Much of the longer-term tree damage came from embers landing within the block, which caused fire to creep up the rows (slow cooker effect).

The condition of the dripline was a good indicator of the damage (pipe was either deformed or completely combusted, leaving a black line on the soil surface).

Did you have any bushfire mitigation infrastructure or strategies before the 2019–20 fires?

Two strategies: one for the house and one for the orchard. The house plan relied on water tanks, fire pumps and decent hoses. I cleaned the gutters multiple times throughout the season.

For the orchard, I had the mid-row mowed and water tanks set up on the ute and trailer.

What did you do to prepare in the days before the fire?

Orchard floor management was up to date (50 mm of grass to keep it a little green).

The pumps were checked and the PTO spray cart was moved up near the house (snap decision on the day).

The tractor was moved to a low-lying (safe) area of the orchard.

We opened gates to help stock find their way to somewhere safe if need be.

We had to clean the gutters again (on the day of the fire) because gum trees had been raining leaves during the preceding two weeks.

On the day of the fire, it was only me who was available and I could not leave the house to manage the orchard. I just had to watch it burn.

Evacuate or stay and defend: would you choose differently next time?

I would probably do the same again, although maybe mowing a little more frequently, and I am working towards having a protective orchard sprinkler system in place.

The pathway to getting a crop has not really changed, so most of what I am working through is the same as in previous years.

The difference this year (2024–25) is that my full watering program is kicking in 6-8 weeks earlier than usual, and last year, it went for longer than usual.

It feels dryer now than it was during the millennium drought period.

What damage was sustained?

Complete crop loss and 50% loss of trees (sporadic through the block).

I lost my Silvan sprayer and a hay mower; the tractor is rapidly declining.

I also lost netting, many fence lines and some trellis posts, which has since made rows a bit ragged as they pulled the remaining trellis out of shape.

The hay shed effectively exploded!

What was the biggest challenge(s) immediately post-fire?

There were operational and psychological challenges.

Animal management and fencing were the immediate priorities.

There was no irrigation water until January 2021 (I could not find the replacement irrigation line I needed), so I am lucky that the root system could exploit moisture in a deep layer of clay.

We found that we could not sleep for a long time after the fire and kept waking at 2 am. This added to a level of fatigue that was a struggle moving into the COVID period. Particularly when managing staff at the orchard and offsite jobs.

What was your initial response to crop damage?

The crop was allowed to drop, as it was cooked.

What was your initial response to tree damage?

I removed melted netting off the trees (big job) and then started pruning out the dead wood. Anything that still had leaves was kept; anything black or charred was removed.

I pruned the trees 4 times within the first 14 months from the fire to redevelop the canopy (starting in February 2020).

I was prepared to remove my larger block (>1,000 trees) but ultimately only removed the worst 10%. I should have removed more (or possibly started again), as more than 30% of this block has

since died and been removed. The renovation strategy would not be practical for blocks greater than 5 ha. You just could not afford this level of inefficiency.

I removed a smaller block entirely because the damage was so bad.

I could not replant as quickly as I would have liked because tree and irrigation availability was limited.

What was your initial response to infrastructure damage?

I pulled out wires and posts (some wire could be reused), replaced sheds and netting and planned a new irrigation system.

Recovery vs replacement….do you have any observations on what gives the quickest return to production?

I think that if >25% of the orchard is burnt, then you would have to seriously consider replacement.

You must be realistic when planning accurate costings. It is an essential part of the recovery phase.

Also, it is important to take a breath before making decisions. While it feels like you need to quickly take action and try to fix the problem, there is probably value in waiting a little while. I may have made slightly different decisions if I had delayed my pruning.

What success stories do you have through the recovery phase?

I continuously misted the house and surrounding trees with my PTO spray cart and it made a big difference to the environment immediately around the house. The spray cart was fed with a hose connected to town water, which allowed me to continuously mist water as the worst of the fire swept through. It worked really well.

I also learned a lot more about tree response to stress and I am happy I got the burnt part of the orchard to survive, which is now returning to a level of stability.

PIRSA's Bushfire Recovery Grant was not big, but it did act as a motivator to get things done and work towards an agreed plan. It certainly helped me re-establish my orchard.

What would you do differently next time?

I would seriously consider if cherry growing is what I wanted to continue to do. If yes, then I need to:

- make a detailed plan for a 3–5 year timeline
- ensure an accurate budget of input costs and make a forecast of what profitability is expected over time as part of the plan; ask if this matches my long-term goals
- cost every item with contingencies
- discuss with a range of mentors/experts (PIRSA), family, professional body.

Have you made any changes to orchard infrastructure or equipment to add resilience against fire?

I have a plan to place a 'fire line' of overhead sprinklers across the north and west orchard boundaries. This will have 8-metre apart butterfly sprinklers fed from a 16,000-litre fire tank. Wet stubble is far less likely to ignite if embers fall upon it.

Would you change anything about the establishment of new orchard blocks or their seasonal management?

I would suggest larger 'cleared' headland areas.

Consider emergency overhead sprinkler systems with fire water storage.

Do you have any advice for other orchardists who might find themselves confronted by bushfire?

The immediate decision on the day of a fire is to ensure personal, family and worker safety.

I would not recommend to other people that they should stay and defend.

I suggest setting up a system that can operate without the need to stay.

Any additional comments

If you are in business, and you are not insured adequately… you are not in business. It is dangerous to underestimate when replacement prices keep going up.

If this fire had come through 10–20 years earlier, the orchard might have survived much better. I have been running it pretty lean for the last few years. It is now a little more ragged and drier. Possibly more susceptible.

A big impact on our orchard has been the change in input costs over the past 3 years. In reality, the current circumstances threaten the financial viability of every farm business. This is the most change we have seen in our business circumstances in our 40 years of farming.

Figure 53. Larger diameter trunks are more likely to retain vascular connection when exposed to flame around trunk (slow-cooker). Trees with large trunks have greater potential to recover canopy following exposure to slow-cooker fire than those with narrower trunks. Photo: SARDI, October 2024.

Apples and cherries in Lenswood, SA

Grower	Kym Green
Property name	Ellimatta Orchards
Property location	Coldstore Road, Lenswood, SA, 5240
Primary crop	Apples and cherries
Irrigation type	Inline dripper
Inter-row/tree line management	Grass clover inter-row and under tree mulch.
Netting or cover system	Mostly structured hail netting.

What was the predominant fire type?

Both external blow-torch and internal slow cooker (Figure 54). It was the perfect storm.

We have a strong focus on organics at this orchard and the healthy mix of cover crops had dried and provided fuel load for embers to combust. It was very difficult to chase and manage the spot fires that ultimately smouldered around the tree trunks.

The fire roared through quickly and effectively created its own wind. It had been so hot and dry through the preceding week that the cover crop combusted incredibly quickly. Embers landed, and fire immediately spread everywhere.

Figure 54. A slow-cooker fire-affected cherry block at Elimatta Orchards, Lenswood, SA. Photo: Susie Green.

Did you have any bushfire mitigation infrastructure or strategies before the 2019–20 fires?

The tanks and turkey nest dams were full, but there were no sprinklers to wet the inter-rows.

We hosed down the house and pump sheds before the fire arrived. We tried to manage with a tractor and spray cart but the fire would leap-frog rows, which made chasing spot fires incredibly difficult.

What did you do to prepare in the days before the fire?

We filled tanks and made sure the spray carts were ready. There was not much more we could be done at that point. I had 8 people working to save the property, but 20 probably would not have stopped the damage.

Evacuate or stay and defend: would you choose differently next time?

I would absolutely stay and defend again. I now have fire appliances available to fit to 2 tractors and my ute. I have also got hoses on the sheds.

What damage was sustained?

We managed to stop the fire from getting into the neighbour's place, but it damaged much of ours. We lost most of our 2019–20 cherry and apple crops from one property, with more than half of 4.5 ha being affected. More than 11,000 of our trees were burnt with varying degrees of survival.

In addition to crop and tree losses, we lost 2 tractors and associated spray plant. The drivers survived, but one of them was almost lost when the tractor's path was blocked by a fallen tree and he had to run through the burning scrub.

Other damage included irrigation laterals, drape nets, electrics to the bore pumps.

What was the biggest challenge(s) immediately post-fire?

Seeing generations of your family's efforts burnt. It was also really hard to face the fire, and the aftermath, without much help other than family and staff. You cannot count on the CFS (they are very busy) and while Lobethal's Bushfire Recovery Centre was helpful, it really felt like we had to manage the fire and recover alone.

I am really mindful that recovery and support has to be a conscious community effort, because it could be your place next time and we all need to help out.

What was your initial response to crop damage?

We allowed the damaged crop to fall naturally. No fruit was picked at all.

What was your initial response to tree damage?

Mostly watch and wait. The only pruning I did was to cut out the dead wood.

What was your initial response to infrastructure damage?

Get the irrigation back on and water the trees (20–25 mm poly with sprinklers to get things going quickly).

Recovery vs replacement….do you have any observations on what gives the quickest return to production?

If I was ten years younger, or had family coming through behind me, I would have been better off replacing the orchard. Succession planning definitely influenced my decision to retain trees and manage them through a recovery phase. It has taken a lot longer than I expected and I have had some gradual decline and slow tree death.

Maybe re-grafting early could have been better.

What success stories do you have through the recovery phase?

Hosing down the pump shed saved it and the headworks.

We also managed to save another shed with a lot of machinery in it; a dense mat of pine needles on the roof held water and slowed combustion.

Good comradery from outside of the district (support from the Governor, the Army, SA government research and, most importantly, regional friends).

We were glad that the damage was at the back of the block, so we were not reminded of it every day.

Overall, the recovery has been slow. It is very difficult to add a clean-up on top of running a business and a family.

What would you do differently next time?

Have more fire appliances on the districts farm utes as these are far more nimble than tractors, which are slow and often offer no protection.

Ensure there is good communication between farm ute volunteers.

Connect to CFS so we can quickly target spot fires. This type of system exists in the Yorke Peninsula where there is a CFS Farm Fire Unit registration program.

Go and help at the front before it reaches the irrigation districts.

Have you made any changes to orchard infrastructure or equipment to add resilience against fire?

We now have additional fire appliance equipment for tractors and utes and the packing shed now has a firefighting system.

Would you change anything about the establishment of new orchard blocks or their seasonal management?

Not really, although my stage of life is probably influencing this answer. I am committed to organic production and will continue to grow a healthy cover crop to nurture my soil. Perhaps this answer would be different if I had family coming behind me to take on the block when I retire.

Do you have any advice for other orchardists who might find themselves confronted by bushfire?

Make sure you have a good relationship with your neighbours and work together to sort out reliable communications during an emergency.

Irrigation headworks, power and delivery pipes need to be protected.

You cannot rely on town water, so have tanks and dams ready and bore pumps safely active.

Any additional comments

Be prepared as there is every chance you will be fighting the emergency on your own.

Figure 55. Narrow trunks are susceptible to loss of vascular connection from prolonged exposure to flame (slow-cooker). Recovery from variable levels of slow-cooker fire exposure can be sporadic. Photo: SARDI, October 2023, of Stella and Santina cherry, Lenswood SA.

Apples in Lenswood, SA

Grower	Robert Green
Property name	Oakleigh Orchards
Property location	Staffords Road, Lenswood, SA, 5240
Primary crop	Apples
Irrigation type	Drip
Inter-row/tree line management	Sprayed under tree and slashed mid-row
Netting or cover system	Trellis release

What was the predominant fire type?

>85% external blow torch (Figure 56) and <15% internal slow cooker.

We were badly affected by violent native scrub fire at the northern edge of property.

Did you have any bushfire mitigation infrastructure or strategies before the 2019–20 fires?

We had electric and diesel genset powered bore pumps were ready (and protected by their own sprinkler systems); spray tanks behind tractors (not adequate on the day); and hail netting partly protected the orchard when it interrupted embers falling to the orchard floor, but nothing could really protect us from the fire in neighbouring scrub and paddocks.

I have always had a standing policy of not throwing slashed mid-row clippings under the tree row after mid-December, but in 2019–20, the fire was early and some clippings were still there.

What did you do to prepare in the days before the fire?

We ensured tanks were filled and watered around the house, sheds, and pumps.

We started diesel generators so the mains were pressurised, but:

- One of these generators failed on the day of fire due to a faulty ignition switch.
- The other sucked molten netting into the air intake that then clogged up the radiator; it failed after 15 minutes.
- When the tanks on the top of the hill emptied, there was no water.
- Just goes to show that your best laid plans can still fail.

There was not a lot of time to do much as everything escalated so quickly.

Evacuate or stay and defend: would you choose differently next time?

My wife and kids left, but I would always stay and defend.

You really could not do much about the fire front that swept through, it was just too powerful. I knew from my experience with the CFS that much of the damage starts from creeping spot fires that follow the front. I managed to save a shed on the bottom property because I was at the right place at the right time.

What damage was sustained?

We lost around 5 ha of productive orchard (at ~$240 k/ha replacement value in 2019–20) plus 15 ha of grazing paddocks. We also lost small sheds, bin trailers, stock yards, irrigation and fence lines.

What was the biggest challenge(s) immediately post-fire?

Having to prioritise getting water back to the trees. It is very difficult to manage the repair of netting and fences when you are also trying to keep trees alive and manage the upcoming harvest operations in the undamaged areas.

You cannot rely on town electricity, it is often one of the first casualties in a fire.

Figure 56. Aerial image of a blow-torch affected apple block at Oakleigh Orchards. Note the area of melted netting that corresponded with the area of dead trees. Photo: DEW.

What was your initial response to crop damage?

Watch and wait. Why spend time and money managing ruined fruit (just let it drop naturally).

What was your initial response to tree damage?

Watch and wait. In higher value varieties, I eventually went through and snapped out dead wood before dormancy (so staff could see what was alive and dead).

What was your initial response to infrastructure damage?

The first priority was getting water to the trees. Needed to help them recover.

Recovery vs replacement….do you have any observations on what gives the quickest return to production?

Without a succession plan for the orchard (no family currently looking to take on the orchard), it was impossible for me to consider orchard replacement. I just was not confident at the time that establishing new orchards was a good investment for my situation.

For me, if I was going to push out a block, it was not coming back as an apple orchard.
This decision was purely economic and built around orchard age, historic production and marketability of the variety.

What success stories do you have through the recovery phase?

I was fortunate that one of my best blocks had rows that ran parallel to the fire front. It meant I could remove the worst of the fire-affected rows (four of them) and still have a complete valve unit, leaving relatively consistent tree health within the remaining rows. Blocks with rows running

perpendicular to the fire front (or those that had within the orchard) resulted in patchy rows and incomplete/inefficient valve units.

It is hard enough to make money when you have a complete row, let alone when it is patchy and slowly declining in health.

Fire prompted the removal of four blocks. I have focused on the varieties that are winning and otherwise turning poor performing blocks into paddocks to run stock.

What would you do differently next time?

I find myself second guessing sometimes. Maybe I should have renovated a couple of the blocks I have removed. Two of them could have been lucrative and I wil probably always wonder 'what if' I had renovated.

I also found myself reinstalling netting over some lower value 'commodity' blocks that maybe I should have targeted for removal.

I think I have been pretty good at basing my decisions on economics, but I still wonder 'what if'.

Have you made any changes to orchard infrastructure or equipment to add resilience against fire?

I have made minor changes such as making sure new fences are well clear of trees and pushing out potential fuel loads.

I would like to see a clear, well-managed break between the scrub and orchard land.

Even though the fire was 4–5 years ago, were still working through general repairs. It is too soon for me to have added any significant fire resilience equipment.

Also, it is unlikely that my family will follow me into the orchard and this means I do not want to invest too heavily into expensive fire resilience changes.

Would you change anything about the establishment of new orchard blocks or their seasonal management?

Drip irrigation was a real handicap as I could not wet the dry mid-row sward. If I was planting a new orchard, I would consider mini-sprinklers.

I have considered leaving a break unplanted, but that is a big price to pay for a rare and unpredictable fire. Setting up boundary fire protection (irrigation) would not have done anything for this fire. We really need the edge of the scrub to be further away. Fire intensity would be significantly lessened if intensity of front was further away.

Forest managers should be pushed hard to install a fuel free break along the edge of their scrub land.

Do you have any advice for other orchardists who might find themselves confronted by bushfire?

You really need to see the damage for what it is, not what you want it to be.

If you see missing bark on a fire-affected tree, then you are likely to be facing long term management issues and/or a slow tree death.

As hard as it is, you really must take the emotion out of your decisions. Pull out the pen and paper and run the economics.

Do not be stubborn; the economics of your orchard needs to drive your recovery decisions.

Any additional comments

Immediately after the fire, I thought the block was finished. I was really surprised when the buds started to move again and how many shoots were bursting within a month of the fire. It just goes to show that you do not want to get the bulldozer going in the first weeks following the fire.

Figure 57. Bushfire (blow-torch) affected Rockit™ apples pictured in January 2020 (left), May 2020 (middle) and October 2024 (right) in Lenswood SA. Remedial pruning was delayed until May 2020 to allow harvest operations to be completed elsewhere in the orchard. Poling and semi-poling pruning decisions were guided by the regrowth. Photo: SARDI.

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Bushfires in orchards: a guide to preparedness, response and recovery

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