Bushfires in apple orchards: observations from the 2019–20 season

Kevin Dodds

Bushfires in apple orchards: observations from the 2019–20 season

Kevin Dodds

Development Officer – Temperate Fruits
Department of Primary Industries
Tumut District Office
PO Box 3 TUMUT NSW 2720
M: 0427 918 315
P: 02 6941 1405
E: kevin.dodds@dpi.nsw.gov.au
W: www.dpi.nsw.gov.au

Document 20/1001. Jobtrack 17019.

ISBN 978-1-76058-423-9

Image acknowledgements

Unless otherwise stated, the images in this guide were taken by Kevin Dodds, NSW DPI.

Contents

Introduction

The 2019-20 bushfire season across south-eastern Australia was the worst on record. There was significant loss of life, millions of hectares of private and public land burnt, and thousands of dwellings and other structures destroyed.

New South Wales (NSW) apple-producing districts Batlow and Bilpin were severely affected, receiving extensive damage to orchards and infrastructure. Following the fires, it became apparent that information on fire damage to orchards and strategies for recovery was lacking.

This publication documents our observations of how the fires affected apple orchards. This information should help growers and industry stakeholders as they recover from these fires and prepare for similar future events.

Bushfires in apple orchards

Bushfires are a common seasonal feature for some Australian landscapes. Hot weather, dry fuel and strong winds combine with an ignition source to produce devastating fires. Several studies (e.g. Bradstock 2010; Yebra et al. 2020) identified fuel load and weather as the two main risk factors for bushfires. Increasing temperatures and drought could further increase the risk, especially for temperate forest regions in eastern Australia.

In NSW, temperate fruit orchards including apples, cherries and stone fruits are typically located in areas adjacent to native or planted temperate forests, native roadside vegetation strips and dryland pasture. The proximity of orchards to these high-risk fuel sources places them at increased risk of damage from severe fires. The bushfires that decimated many orchards at Batlow in the Southwest Slopes and Bilpin in the Blue Mountains west of Sydney in Summer 2019–2020 originated either in adjacent forest or dry pasture.

After the fires, it became evident that there is little information available to assist fruit growers with assessing the damage or strategies for orchard recovery. This document summarises initial observations and assessments made by NSW DPI staff and orchardists in the weeks following the bushfires. This should assist industry stakeholders with orchard planning and critical decision making in the likely case of similar fires in the future.

It is important to note that the observations reported in this publication are based on fires that affected apple orchards mid-season (late December and early January). The damage caused by fires at other times might be different and require other strategies for recovery.

Fuel sources

The amount and type of fuel available will influence fire intensity and duration. The damage to orchard trees and infrastructure was caused by fuel sources that were both internal and external to the affected orchard blocks.

Internal fuel sources included:

- dry grass in the under-tree drip zone or weed-free strip (Figure 1)
- dry mulch
- sawdust in orchard nursery stool beds (Figure 2)
- irrigation pipes and timber trellis posts
- bin storages and machinery sheds
- netting and other material stockpiles.

External fuel sources included:

- native vegetation strips on orchard boundaries (Figure 3)
- windbreaks, especially those of *Pinus radiata*
- adjacent bushland or dry pastures
- dry, heavily grassed fallow areas close to the orchard.

External native vegetation strips and under-tree dry matter were the two most important fuel sources resulting in damage to orchards, while dry sawdust in apple rootstock stool beds had the greatest impact in nurseries.

The fuel source also influenced the type of damage caused. Fires that were fuelled by external fuel sources were generally more intense, faster moving and appeared to have a 'blow-torch' effect on the trees. Fires that were fuelled by internal sources, e.g. spot fires starting on dry grass or mulch under the trees, were more likely to have a 'slow-cooker' effect on the trees.

We use the terms 'blow-torch' and 'slow-cooker' to identify the main fire types and their effects on the trees. However, it should be noted that the two fire types were not mutually exclusive and there were numerous examples of orchard blocks that were affected by both blow-torch and slow-cooker fires. For example, in some blocks the fire came from adjacent forest and had a blow-torch effect on the trees, but further in the orchard where trees had dry grass underneath or in the inter-row, a slow-cooker fire persisted beyond the reach of the blow-torch fire.

Figure 1. Internal fuels such as dry grass (unburnt, left) are important fuel sources in orchard blocks, resulting in significant fire damage to tree trunks and lower canopies (burnt, right). Photo taken 3 April 2020, 94 days post-fire.

Figure 2. Dry sawdust fires in fruit tree stool beds resulted in significant losses to new rootstock production across the Batlow district. Photo: Ian Cathels, Ardrossan Nurseries, 28 January 2020, 24 days post-fire.

Figure 3. A heavy fuel load of native vegetation on an orchard boundary.

Fire types

The 'blow-torch'

Most orchard tree damage (> 60%) was from direct flame and/or scorching caused by wind-driven heat that came from native vegetation strips or windbreaks adjacent to the orchards (Figure 4). These areas typically contained high fuel loads that produced significant wind-driven heat for a sustained period. The orchard rows closest to the fire source were the most severely affected and the reach of the blow-torch effect depended on factors including aspect, position on the slope and location relative to the prevailing wind.

The most severe blow-torch fires reached up to 15 or more rows (60+ metres) into the orchard with enough heat to kill or severely scorch entire rows of trees (Figure 5). In some situations, the heat alone was enough to completely kill trees up to 10 rows in from the boundary.

Fallow areas of dry pasture within or adjacent to orchards also resulted in burning (direct flame) and scorching (wind-driven heat) to orchard trees (Figure 6).

Figure 4. Burnt native vegetation on an orchard boundary. Photo taken 22 January 2020, 18 days post-fire.

Figure 5. External fuel sources such as roadside vegetation strips produced wind-driven heat, scorching adjacent orchard blocks. Photo taken 18 February 2020, 45 days post-fire.

Figure 6. Flame and heat from fallow areas of dry grass (left) within or adjacent to orchards damaged trees and netting. Photo taken 15 January 2020, 15 days post-fire.

Blow-torch fires typically resulted in well-defined areas of damage with a gradient of decreasing severity that moved away from the heat source into the orchard block. This uniformity means that in most cases, it is possible to define the distance into the block at which tree recovery is likely. However, the damage caused by the slow-cooker fires was much more variable from tree to tree, making it harder to predict tree survivability.

In blow-torch affected blocks, the heat appeared to travel a path of least resistance. Structured hail netting tended to trap and channel hot air. In one orchard, there was clear visual evidence of heat travelling down roadways between blocks, scorching the row ends and continuing through the open space between the upper tree canopies and the netting, scorching the treetops. In the latter situation, damage to treetops persisted for many rows further into the netted orchard than it did in the lower canopies.

The 'slow-cooker'

Spot fires occurred in many orchards where there was enough dry matter under the trees or in inter-rows to sustain the fire. Dry grass, weeds and/or mulch ignited throughout blocks and fire persisted along the tree rows assisted by wind (Figure 7). In orchards with a lot of dry grass under the trees, almost all rows were burnt and trees suffered substantial damage to trunk conductive tissues and scorching of the lower tree canopy. Drip irrigation tubing also ignited and burned along the tree row, sustaining the fire and causing some direct damage to tree trunks.

The intensity and persistence of the slow-cooker fires appeared to be associated primarily with the volume of fuel present and whether it was dry or green. Some low-intensity burns resulted in minimal canopy damage and an unknown level of trunk damage (Figure 8).

Figure 7. An example of the damage caused by an intense slow-cooker fire which resulted in substantial trunk damage and canopy scorching. Photo taken 28 February 2020, 58 days post-fire.

Figure 8. This orchard received a low-intensity slow-cooker burn, resulting in minimal canopy scorching. Photo taken 15 January 2020, 15 days post-fire.

Crop and tree observations

Between January and May 2020, we inspected orchard blocks and recorded the damage caused by the fires. The goal was to help inform recovery decisions and learn how to future-proof orchards against similar fires. We tried to capture as much information as possible in those initial months post-fire before the opportunity was lost.

Damage to fruit

At Batlow the main fire occurred on 4 January 2020, approximately 80 days after full bloom. Primary chemical and secondary hand thinning programs had been completed and fruit was about 40–50 mm diameter, depending on the variety. Signs of fire damage to fruit included:

- partial scorching on the side facing the heat source (Figure 9)
- overall browning and retention on the tree (Figure 10)
- overall browning and drop.

A lot of fruit without obvious damage was carried to maturity on trees with some degree of leaf scorching (Figure 11). The loss of photosynthetic capacity associated with leaf scorching will affect assimilate production, which is likely to cause some problems with fruit quality attributes and tree carbohydrate reserves (Han et al. 2016). Further research is required to properly understand the fruit quality and postharvest effects.

Figure 9. Partial fruit browning on the side facing the heat source. Photo taken 8 January 2020, 4 days post-fire.

Figure 10. In some situations, fire damaged fruit remained on the trees for the remainder of the season. Photo taken 9 April 2020, 96 days post-fire.

Figure 11. Some fruit on trees with leaf scorch did not have any obvious damage but is likely to suffer from quality and postharvest problems relating to storability and shelf-life. Photo taken 28 January 2020, 24 days post-fire.

Damage to conductive tissues

Single bark windows can mislead

In the first weeks after the fires, we cut small bark windows into tree trunks and branches to assess the damage (Figure 12). While this helped us determine the status of the phloem and xylem tissues at the site of the cut, further investigations revealed that single bark windows do not provide sufficient information to make accurate predictions about a tree's potential for recovery or survival.

Furthermore, the cuts need to be deep enough to penetrate the bark layer into the phloem and xylem, otherwise the assessor may only be viewing the damage to the bark and not to the more critical conductive tissues underneath. Figure 12 shows a bark window that is too shallow and has not reached the conductive tissue layers. From this example, it might appear that the brown side (right) of the cut is dead, but this is only the outer bark, and in this case, the underlying cambium was still alive. A notable observation on these mature trees was that the purple colouring of fire-affected bark (Figure 13, middle) does not necessarily equate to underlying cambium death. In many instances, conductive tissue underneath the purple bark appeared undamaged.

One indicator of underlying conductive tissue death was bark with a 'lizard skin' appearance (Figure 13). A tree with this unusual bark pattern was likely to have suffered phloem damage, which could lead to eventual death (Midgley et al. 2011). The cause of 'lizard skin' is unknown and it may take several weeks to months to be fully expressed in the damaged trees. We observed this most commonly in severe 'slow-cooker' affected trees.

Taking a closer look

To explore the limitations associated with single bark windows, we debarked some severely fire-affected trees in Batlow orchards. We started by debarking tree trunks at randomly selected heights and then debarking them completely to reveal the full extent of the damage (Figure 14). In this example, the phloem tissue was still alive at the top window, partially alive at the middle window and completely dead around 360° of the trunk at the base window. While this was very effective at showing the variability of conductive tissue damage caused by fire in mature apple orchards, unfortunately, debarking kills trees. Consequently, we sought to find non-destructive indicators of tree survival, beginning with debarking assessments and relating the results to other visual recovery indicators in the same trees.

Figure 12. Small bark windows can give localised information on conductive tissue damage but can be misleading because they do not represent the rest of the tree. Photo taken 15 January 2020, 15 days post-fire.

Figure 13. The rough, pimpled 'lizard skin' (top right) on the bark of an apple tree indicates underlying phloem tissue damage. The adjacent purple bark (middle) was not a reliable indicator of phloem tissue damage. Photo taken 23 April 2020, 113 days post-fire.

Figure 14. Debarking at randomly selected heights (top) and the same tree trunk fully debarked (bottom). This tree sustained phloem damage around 360° of the lower trunk. Photos taken 9 April 2020, 100 days post-fire.

Premature autumn colouring

On 9 April 2020, approximately 100 days after the Batlow fire, the owner of one of the worst affected slow-cooker orchards mentioned that he had observed premature autumn red colour in some of his trees. This colour change was apparent across all the fire-affected orchard blocks on this property and several varieties including Royal Gala, Pink Lady and Fuji. Some rows of very old vase-trained Granny Smith trees with large trunks did not exhibit the early colour change and we suspect that the large trunks provided the phloem with some protection from the fire. As the premature autumn colour developed, it became apparent that it did not develop in the usual uniform pattern typical of other seasons (Figure 15 and Figure 16).

Figure 15. Premature autumn colour in a block that was severely affected by a slow-cooker fire. Photo taken 23 April 2020, 111 days post-fire.

Figure 16. An aerial image of Royal Gala apple trees that were severely affected by a slow-cooker fire. Note the random distribution of trees with early autumn red colouring. Photo taken 29 May 2020, 149 days post-fire.

To determine if there was a link between the premature autumn colouring and conductive tissue damage, we debarked the lower 60–80 cm of the trunks of affected trees. From the small sample of trees (n=25), we found that 100% with premature red colouring had phloem ringbarking (Table 1). Trees with a green or yellow canopy were most likely to have maintained some phloem connection between the canopy and root system, albeit in some cases a limited connection.

Table 1. Early autumn canopy colour and phloem ringbarking status of selected Royal Gala and Pink Lady apple trees from a severely burnt orchard at Batlow. Data collected 23 April 2020, 111 days post-fire.

Variety	Canopy colour	Was the phloem ringbarked?	% of trunk radius with phloem damage at the worst point of injury
Royal Gala	Red	Yes	100
Royal Gala	Red	Yes	100
Royal Gala	Red	Yes	99
Royal Gala	Red	Yes	100
Royal Gala	Red	Yes	100
Pink Lady	Red	Yes	100
Pink Lady	Red	Yes	100
Pink Lady	Red	Yes	100
Pink Lady	Red	Yes	100
Pink Lady	Red	Yes	100
Royal Gala	Yellow	No	86
Royal Gala	Yellow	No	77
Royal Gala	Yellow	No	44
Royal Gala	Yellow	No	5
Royal Gala	Yellow	No	73
Pink Lady	Yellow	Yes	100
Royal Gala	Green	No	30
Royal Gala	Green	No	11
Royal Gala	Green	No	30
Royal Gala	Green	No	44
Royal Gala	Green	No	28
Pink Lady	Green	Yes	100
Pink Lady	Green	No	43
Pink Lady	Green	No	59
Pink Lady	Green	No	68

Note: while the premature autumn red colour seemed to be an indicator of phloem ringbarking in this orchard that received slow-cooker fire damage, a lack of similar symptoms in other orchards at Batlow, Bilpin or the Adelaide Hills means that we are unable to recommend using this as a reliable non-destructive diagnostic tool for all slow-cooker situations until further research is conducted. Readers should not assume that trees without this colouring will recover or survive. Many trees with yellow or green autumn canopies sustained significant damage to phloem tissues and the long-term prognosis for these trees is yet to be studied.

Post-fire growth response

In blocks that received blow-torch fire, the fire and heat intensity decreased on a gradient from the fire source towards the interior of the block. This heat gradient suggested that tree regrowth responses might follow the same pattern.

To investigate this, we studied a 12-year-old block of Pink Lady (Rosy Glow) apples on M9 rootstock that sustained severe blow-torch fire damage. Extending 12 rows in from the fire source, these trees had been pole-pruned by the grower 24 days post-fire, effectively cutting them back to their trunks. This provided an excellent opportunity to study and record post-fire, post-pruning regrowth responses on a gradient from the fire source.

Regrowth responses at 139 days post-fire were defined as:

- dead tree, no regrowth
- weak growth response, but no significant extension growth
- reasonable growth response, with one or more shoots > 30 cm long.

Figure 17 shows a typical tree for each of the defined regrowth responses along with the associated trunk debarking result for the prevailing fireside and a trunk cross-section at approximately 45 cm trunk height. Trees with shoot regrowth of around 30 cm sustained minimal trunk conductive tissue damage compared with those exhibiting weak regrowth.

We sampled 5 dead trees, 10 weak regrowth trees and 10 trees with reasonable regrowth and shoot(s) > 30 cm. While only small numbers of trees were assessed, early observations seem to confirm that trees with shoot regrowth of about 30 cm long sustained minimal trunk conductive tissue damage compared to those exhibiting less regrowth (Table 2).

Early observations indicate that shoot regrowth could be used as a non-destructive tool to estimate the potential for tree recovery, particularly if this is supported by a small number of debarking samples to calibrate the damage.

Table 2. Regrowth assessments from a block of Pink Lady apples that received severe blow-torch fire.

Regrowth class	Average trunk circumference (mm)	Average width of worst burn (mm)	% loss phloem
Dead tree (n=5)	239	239	100
Weak growth (n=10)	210	53	25
Reasonable growth (n=10)	201	6	3

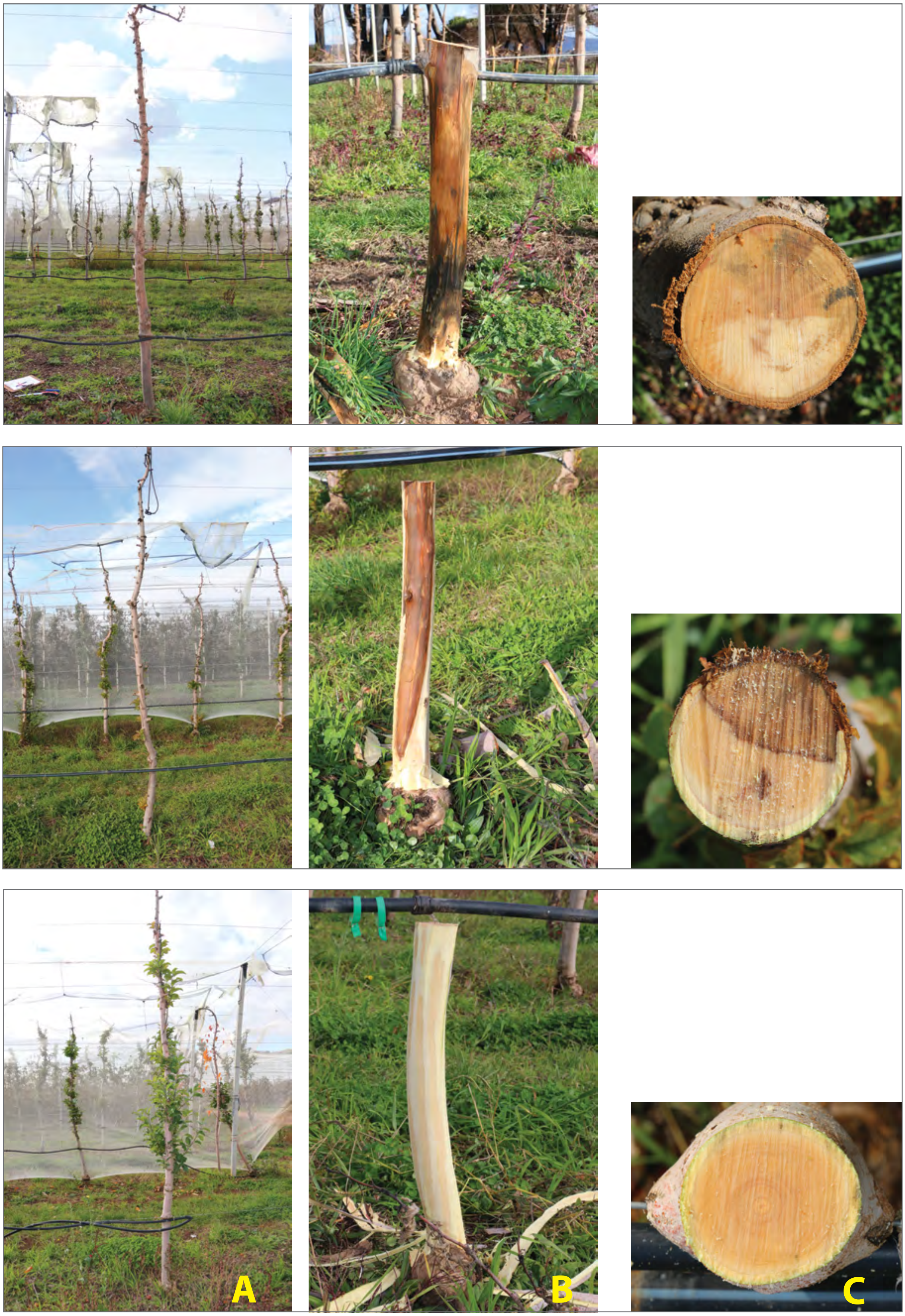

Figure 17. Tree regrowth (A), conductive tissue damage (B) and trunk cross-section (C) for three classes of tree regrowth in a severe blow-torch block. Dead tree (top), weak regrowth response (middle) and reasonable regrowth response (bottom). Photos taken 22 May 2020, 139 days post-fire.

New leaf growth might not mean tree survival

It was mid-season (December–January) for the apples at Bilpin and Batlow when they were burnt. Fruit size was approximately 40–50 mm diameter or BBCH phenological stage of 74 to 75 (Meier 1997). This meant there were approximately 4 to 5 months of the season remaining with suitable conditions for the scorched trees to regrow. Within two weeks of the fire, new foliage had grown on some trees (Figure 18) while others did not regrow at all. This prompted us to question whether new foliage growth after a fire would be a reliable indicator of tree survivability. From our observations, the answer is 'not always'.

During our debarking studies at sites that were affected by slow-cooker fire, we noticed many trees that had suffered 100% phloem ring-barking of the lower trunk. However, they continued to produce new foliage and grow fruit to maturity. This indicates the xylem tissue was still functioning to deliver water and nutrients to the canopy and crop, despite the severe damage received. Seeing this in the orchard might inspire a grower to think that their trees will recover, however tree survival from this amount of damage is unlikely. Complete loss of phloem connection prevents the tree from moving carbohydrates from the canopy to the root system, which is essential for tree survival.

Figure 18. Regrowth on a Red Fuji apple tree 15 days after a blow-torch fire (see Figure 4). Photo taken 15 January 2020.

Premature flowering

As trees with extensive scorching to leaves and shoots began to regrow, some of the next season's floral buds (that had initiated before the fire) burst into bloom prematurely (Figure 19). This effect was greatest on trees that suffered overall scorching from blow-torch fire and was evident in different varieties. This will likely have some effect on bloom density next season.

Figure 19. Some of next season's flower buds that had initiated before the fire opened prematurely as trees began to regrow. Photo taken 28 January 2020, 24 days post-fire.

Evidence of root system survival

Despite the extreme heat resulting in the death of all above ground tissues in some blow-torch and slow-cooker sites, we did observe evidence of root system survival. Many trees in the worst burnt areas produced suckers from the root systems. In most situations, root survival resulted in suckering even where the entire tree canopy was lost. The timing of this response varied from site to site, with some trees suckering within the first few weeks of the fire, while others took longer.

Figure 20. Suckering provided evidence of root system survival even where the heat was enough to destroy entire tree canopies. Photo taken 29 February 2020, 59 days post-fire.

Infrastructure damage

Hail netting

The most obvious damage to hail netting occurred on the edge of blocks hit with blow-torch fire (Figure 21 and Figure 22) or within blocks receiving slow-cooker fire where direct flame and the most intense heat was able to reach (Figure 23). Netting melted and became welded to tree canopies and trellis structures, making it very difficult to remove when cleaning up.

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 scenarios. In most cases where we observed melted or completely missing netting, the trees underneath were dead. While this was not quantified by any assessments, it was a common observation made by both DPI staff and growers.

When viewed from a distance, large areas of hail netting seemed to have escaped serious damage. However, closer inspection revealed that extensive areas of netting had been compromised by ember attack (Figure 24). It was not unusual to find ember holes in hail netting hundreds of meters away from the main fire. Even minor ember damage to structured high tension netting is concerning, as the ability for it to withstand future storms and the weight of hail is diminished.

Figure 21. Melted netting was closely associated with the occurrence of dead trees, particularly in blocks affected by a blow-torch fire. Photo taken 22 April 2020, 109 days post-fire.

Figure 22. Hail netting appeared to be an accurate indicator of severe tree damage or death. Most trees under melted netting did not recover. Photo taken 28 April 2020, 115 days post-fire.

Figure 23. Melted netting in an orchard that suffered a slow-cooker fire. These trees suffered severe damage to the trunk conductive tissues. Photo taken 10 January 2020, 6 days post-fire.

Figure 24. Ember attack caused extensive district-wide damage to hail netting, often reaching hundreds of metres away from the fire source. Photo taken 11 March 2020, 67 days post-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 25). 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 Bush Fire Recovery Information – CCA Timber factsheet prepared by NSW Government.

The loss of posts, end stays and cables caused danger as the integrity of trellis and netting systems was compromised and risk of collapse was high (Figure 26). 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 27).

Figure 25. Chemical ash residues from burnt treated pine poles presented a risk to stock and human health and required careful management.

Figure 26. Structural damage to timber strainer posts in a block with structured hail netting. Photo taken 10 January 2020, 6 days post-fire.

Figure 27. A harvest bin storage shed generated enough heat to soften and bend steel beams. Photo taken 10 January 2020, 6 days post-fire.

Irrigation systems

Significant damage to above-ground irrigation system components including polypipe, fittings, valves, filters, water tanks and pumps resulted from the fire (Figure 28 and Figure 29). Damage to power poles and supply lines caused the local electricity supply to be cut, further hampering efforts to re-establish irrigation systems. Polypipe 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 28. Damage to irrigation pumps hampered efforts to re-establish irrigation to the orchard following the fires. Photo taken 10 January 2020, 6 days post-fire.

Figure 29. Low-density polyethylene irrigation tubes that supply irrigation to trees via dripper or sprayer were extensively damaged. Photo taken 10 January 2020, 6 days post-fire.

Orchard machinery

Vehicles, tractors, sprayers, orchard implements, power ladders, forklifts and other heavy machinery were among those burnt in the 2019–20 fires. In some cases, the grower had taken reasonable steps to place the machinery in locations perceived to be lower risk of burning. However, the intensity of the fire and ember attack meant that few places were safe (Figure 30 and Figure 31). 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 30. Despite being placed in the centre of a dry dam, this orchard machinery was lost due to the intense fire and ember attack.

Figure 31. This excavator was parked in an open area but unfortunately was adjacent to a stack of timber harvest bins.

Priority tasks following a fire

Safety first

Fire can dramatically change your local area and orchard environment, creating many safety hazards. The priority before entering a fire-affected area is to seek advice on safe access and to comply with any directives made by bushfire and emergency response agencies. Road closures may be in place where there is damage to the road surface, electricity supplies or risk of falling infrastructure and trees.

When you are permitted access to your property, move carefully around your orchard and assess potential hazards. Prevent staff from entering high-risk areas until the hazards have been assessed. Be particularly aware of risks posed by damaged buildings, fallen power lines, large trees and damaged trellis structures. Clearly mark any hazards with fluorescent marking spray or barrier tape and provide staff with details of their location.

Restore cool storage power

Cool-stored fruit may be added to your losses if there is no power and no back-up power source. Urgent restoration of power to cool storages is vital. If power outages are widespread, (as they were at Batlow), diesel and petrol generators will be in very high demand. Using the time immediately after the fire when there is no safe access to your property to source any available emergency generators and fuel would be wise.

Restore irrigation

Bushfire season corresponds with peak orchard irrigation requirements. Getting your irrigation systems working as soon as possible after a fire is vital to minimise the effects of water stress on the undamaged portion of the crop.

In a large-scale fire, there will be many kilometres of damaged polypipe that will need replacing. Suppliers might not have enough stock of the required drip tube to facilitate a rapid fix. Stocking drip tube on-farm might be a good idea for recovery from future fires.

Fire-damaged pumps will need to be replaced and it may be some time before the electricity supply is re-established. At Batlow, some areas were without electricity for more than two weeks following the fire. Diesel or petrol generators and pumps will need to be employed to get pumps running sooner rather than later.

Supplementary fruit thinning

Delays to safe access and re-establishing irrigation systems might cause the recoverable portion of the crop to suffer some loss in growth, potentially resulting in reduced fruit size at harvest. Depending on the timing of the fire, additional crop thinning might help overcome this. At Batlow and Bilpin, many growers carried out post-fire secondary fruit thinning and this helped produce reasonable fruit size in blocks that would otherwise have struggled to reach the desired size. Reducing the crop load on fire-damaged trees is also likely to improve the rate at which trees can recover.

Re-establish protective netting

Full exclusion netting systems are designed to exclude vertebrate pests including birds, flying foxes and other animals. If fire damaged this netting, the remaining crop will no longer be protected, exposing it to potentially more losses. Therefore, re-establishing this netting system will be vital to protecting the surviving crop.

Sourcing materials and netting contractors might be challenging, especially after a large-scale fire. Maintaining a supply of materials needed to ensure rapid (even if temporary) repair to damaged netting would be advisable.

Resume crop protection programs

After a major fire, 2–3 weeks may pass before it is possible to re-establish access and resume crop protection programs. Consider the timing of the fire and the likely effect on your pest and disease management schedule. Pests such as codling moth and mites can cause significant damage in high-pressure blocks following an unplanned break in the monitoring and control program. Fire and heat are likely to have altered pest–predator dynamics in the orchard, so keep an eye out for elevated pest activity and new pests.

Disposing of damaged infrastructure and managing chemical hazards

Segregate fire damaged materials as they are removed from the orchard. This will aid in the disposal process. Key waste items that should be separated include polypipe, netting, wire and treated pine posts. Particular care should be taken when handling treated pine posts and their burnt residue (Anon. 2019). Fires expose chemicals and other hazards that can represent a risk to animal and human health. The NSW DPI Primefact titled 'Bushfire Recovery Managing Chemical Hazards' is a useful reference that highlights some of the risks and where to go for help.

Disposal procedures will depend on the nature and scale of the fire and damage caused. At Bilpin and Batlow, local councils and contractors were engaged by the state government to coordinate the waste management process.

Remember to look after yourself

Natural disasters like the 2019–20 bushfires are frightening, stressful, confronting and potentially overwhelming. It is important to make time to stop and consider your wellbeing. Chat with a family member, a friend, your GP or make contact with one of the many government run support agencies listed below.

It is important to remember that things will get better. At the time of writing, 12 months after the fires, many severely affected growers have commented that the post-fire support they received (including physical, emotional and financial support), has helped them to look to the future with renewed optimism and a desire to innovate.

BushfireHub https://www.dpi.nsw.gov.au/climate-and-emergencies/bushfires

Rural Recovery Support Service – Bushfires
The Rural Recovery Support Service is managed by the NSW DPI and funded by Resilience NSW. Its aim is to provide assistance to rural landholders and primary producers who have been affected by the recent bushfires. This service employs Recovery Officers who are a single point of contact for your recovery needs, providing information and referrals as required.

Visit the website https://www.dpi.nsw.gov.au/about-us/rural-support/rural-recovery-support-service to find your nearest Recovery Officer or make contact via email rural.recovery@dpi.nsw.gov.au or phone 0437 497 555.

Rural Resilience Program
The Rural Resilience team works with primary producers across regional and remote NSW to build personal and family resilience, which is an essential tool to withstand the challenges of rural life and farm based businesses. For further information or contact details of local Rural Resilience staff, visit www.dpi.nsw.gov.au/rrp

Mental health toolkit for the fires
The Australian National University has developed a free Community Trauma Toolkit containing resources to help support adults and children before, during and after bushfires.

Rural Adversity and Mental Health Program
For information about rural health and wellbeing and mental health resources visit www.crrmh.com.au

Contacts
Mental Health Line: 1800 011 511
Beyondblue: 1300 224 636
Mensline: 1300 789 978
Kids Helpline: 1800 55 1800

Strategies for the future

- Prepare a bushfire survival plan detailing strategies to protect yourself, your staff and your assets. The plan should consider whether you intend to leave early or stay and defend your property. Developing your bushfire survival plan will help ensure that you have given due consideration to safety and opportunities to mitigate risk and losses. For help with making your bushfire survival plan, see the Rural Fire Service website https://www.rfs.nsw.gov.au/resources/bush-fire-survival-plan

- Identify the potential fuel sources for fire surrounding and within your orchard; consider the potential fuel loads that might result in blow-torch and slow-cooker fires.
- Implement any strategies you can to mitigate the risks, for example:
  - keep under tree strips clear of dry matter that might fuel a slow-cooker burn
  - keep inter-rows green
  - in consultation with your neighbour and/or local council, develop a farm vegetation management plan. Be aware of the relevant regulations and recommendations regarding vegetation clearing, including protecting any locally significant threatened or endangered species. Be aware of the regulations relevant to your state. In NSW, allowable activities relating to rural infrastructure are administered by Local Land Services. To contact your local LLS office, visit the LLS website
  - in nurseries, keep sawdust in apple rootstock stool beds damp
  - establish fire breaks between boundaries and orchards
  - if possible, have bin sheds and material stockpiles away from orchards
  - consider using metal/steel trellis posts in preference to treated pine or hardwood posts
  - where overhead sprinkler systems are used for frost management, consider how they might be used during a fire
  - consider raising irrigation laterals higher above the ground to reduce potential damage from under-tree grass fires
  - identify areas that will provide the best possible refuge for essential orchard machinery; protecting assets such as tractors and sprayers will minimise any delays in returning to normal operations post-fire
  - clear any combustible material from around key fire-fighting assets such as pump sheds, supply lines and water tanks
  - consider the security of your on-farm water supply for fire-fighting; tanks and above ground fittings made from fire-resistant materials may help prevent sudden loss of water
  - improve on-farm fire-fighting capacity to include assets such as slip-on tank units for utility vehicles.
- Allow trees time to regrow. The regrowth response several months following the fire can be used in conjunction with destructive inspections to help you make decisions about the future of your fire-affected blocks. Removing scorched and dead branches from trees in blocks that were affected by blow-torch fire will make it easier to see and assess any shoot re-growth. However, there will be no return on this labour investment for trees that have been completely killed by the fire. Delaying your initial pruning response until the first signs of shoot regrowth are visible will help you to limit the amount of labour wasted on dead trees.
- Assess the damage to your trees, remembering that small bark windows can be misleading:
  - consider sacrificing some trees by debarking several in each block to determine the damage to conductive tissues. If this is done after the trees have had a chance to begin recovering, you may be able to relate the level of visual canopy recovery to the degree

of conductive tissue damage observed; this could give you a tool to help assess the remaining trees based on vegetative regrowth.

- As orchardists reflected on the 2019–20 fires, many who stayed to fight the fire commented that in hindsight, they had focused their fire-fighting capacity on protecting assets that were covered by insurance (such as sheds and machinery), while those that could not be insured (e.g. trees and some orchard infrastructure) were left largely unprotected. Next time a fire occurs, more fire-fighting efforts might be directed to orchard protection.

Opportunities for future research

Our observations of how fire affected apple orchards captured many insights that were not previously documented. These observations highlight opportunities for on-going research aimed at quantifying the damage and identifying effective recovery methods for affected orchards. Future research questions might include:

- how does a bushfire affect fruit quality and postharvest storability of the harvestable portion of the crop?
- are there any second year fruit quality and postharvest implications?
- is there a preferred post-fire canopy management strategy for tree and long-term crop recovery?
- how long until fire-affected trees return to full production?
- is premature autumn red colouring an indicator of phloem ringbarking?
- how much conductive tissue damage can a tree survive?
- is it possible to relate various post-fire tree growth responses to long-term tree survival? If so, what are the indicators that growers could use to support the decision to remove or recover trees?
- are there measurable effects on soil and root systems?
- are there measurable effects on pest and disease dynamics?

Summary

After the worst bushfires on record tore through the apple-producing districts of Batlow and Bilpin in 2019–20, we discovered that information specifically relating to orchard damage and strategies for recovery were lacking. The observations presented in this document show the damage to orchards at Batlow and Bilpin caused by the fires. It also includes some of the initial recovery signs and a few methods we tried to determine the likelihood of a tree surviving. It is hoped that these observations will highlight the main bushfire risks for apple orchards and inform grower decisions relating to orchard recovery and future risk mitigation. It is expected that these observations will also help inform ongoing research into the impact of bushfires on orchards and strategies for recovery.

References

Anon. 2019. Bush fire recovery information: copper chrome arsenate (CCA) timber – burnt timber and ash, https://www.emergency.nsw.gov.au/Documents/factsheets/IECU-fact-sheet-bush-fire-recovery-CCA-timber.pdf

Bradstock RA, Hammill K, Collins L and Price O. 2010. Effects of weather, fuel and terrain on fire severity in topographically diverse landscapes of south-eastern Australia. *Landscape Ecology*, 25: 607–619.

Clarke H. 2015. Climate change impacts on bushfire risk in NSW. Office of Environment and Heritage, Sydney.

Han JH, Han HH, Kwon YH, Jung JH, Ryu S-H, Do KR, Lee HC, Choi IM and Kim T-C. 2016. Effect of early defoliation on fruit yield, reserve accumulations and flower bud formation in 'Sinano Sweet' apple trees. *Protected Horticulture and Plant Factory*, 25: 133–137, https://doi.org/10.12791/ksbec.2016.25.2.133

Meier U. 1997. Growth stages of mono-and dicotyledonous plants. Blackwell Wissenschafts-Verlag, https://www.politicheagricole.it/flex/AppData/WebLive/Agrometeo/MIEPFY800/BBCHengl2001.pdf

Midgley J, Kruger L and Skelton R. 2011. How do fires kill plants? The hydraulic death hypothesis and *Cape Proteaceae* 'fire-resisters'. *South African Journal of Botany*, 77: 381-386.

NSW Department of Planning, Industry and Environment. 2020. Understanding the effects of the 2019–20 fires, https://www.environment.nsw.gov.au/topics/parks-reserves-and-protected-areas/fire/park-recovery-and-rehabilitation/recovering-from-2019-20-fires/understanding-the-impact-of-the-2019-20-fires

Richards L, Brew N and Smith L. 2020. 2019–20 Australian bushfires—frequently asked questions: a quick guide. Research Paper Series, Department of Parliamentary Services, https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp1920/Quick_Guides/AustralianBushfires

Warrian A and Kidston J. 2020. Bushfire recovery: managing chemical hazards. NSW DPI Primefact 1718, https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/1198606/bushfire-recovery-managing-chemical-hazards.pdf

Williams D, Schneider H, Grills A and James P. nd. Recovery from fire damage in fruit orchards. Agriculture Victoria, https://agriculture.vic.gov.au/crops-and-horticulture/fruit-and-nuts/orchard-management/recovery-from-fire-damage-in-fruit-orchards

Yebra M, van Dijk A and Cary G. 2020. Mapping bushfire hazard and impacts – final report. Bushfire and Natural Hazards CRC, Melbourne.

Acknowledgements

The author sincerely thanks those growers at Batlow and Bilpin who opened their properties up for assessment and for sharing their observations and stories. In particular we thank the Duffy family, Greg and Kristin Mouat and the Batlow Fruit Company Pty Ltd for allowing us early access to their orchards so we could capture many of the observations in this report. I would also like to thank Dr Amanda Warren-Smith for her guidance and editorial skills in producing this document.

Reviewed by Dr Bruno Holzapfel, Senior Research Scientist (Perennial Crop Physiology).

Bushfires in apple orchards: observations from the 2019–20 season