Greg Moore—Ring-barking and Girdling: How Much Vascular Connection Do You Need Between Roots and Crowns?

[00:00:12] **Jamie Vidich:** Hello and welcome to the ISA Conference Rewind video series. I'm Jamie Vidich, Director of Educational Products and Services at the International Society of Arboriculture. Today, we're excited to bring you a presentation by Dr. Greg Moore. Dr. Moore will discuss ring-barking, girdling, and the vascular connection between tree roots and crowns. This presentation was originally given at the 2022 ISA Virtual Conference, and the views are those of the presenter. If you're interested in tree physiology in general or arboricultural treatments for ring-barking and girdling in particular, I expect you will really find this presentation quite fascinating. Now, sit back and enjoy.

[00:01:02] **Greg Moore:** Good day to everyone at the ISA virtual conference in 2022. I'm delighted to be here online. Regret not being able to see people face to face, but I'm very keen to be talking about a topic that's interested me for many, many years, and that's "Ring-barking and Girdling of Trees: How Much Vascular Connection Do You Need Between the Roots and the Crown of the Tree?"

And before I begin, I want to make sure that we're talking the same language, that we have the terminology correct, and so, during this presentation, I'm going to use two terms: ring-barking and girdling, which are very often used in our industry as synonyms. So, people use them interchangeably, and some other terms as well, but I'm advocating for the use of the terms "ring-barking" and "girdling" to mean very specific and different things.

[00:02:00] So, you'll notice here, I've got a formal definition of what I mean by ring-barking, and that's a circumferential cut around the trunk of the tree, which removes a band of tissue to the depth of and including the cambium. It removes a band which contains cork and cork cambium, phloem tissues, and the cambium, and so has an immediate impact on the translocation of materials in the phloem tissues.

On the other hand, girdling is again a circumferential cut around the trunk of the tree which removes a band of tissue to the depth of the active or functional xylem tissues. Effectively, a deeper cut. And such a cut removes a band which contains the cork and cork cambium, phloem tissues, the cambium, and the current seasons active or functional xylem. Now, it takes out the growth ring if you like, and so, [00:03:00] it has an immediate impact on both the translocational and transpirational processes.

So, these are two terms that I hope you'll become familiar with over the course of this presentation. I hope those definitions are meaningful to you, and from my perspective, if we could use those in a technically precise way, it would save us a lot of confusion when it comes to describing what happens to trees. And that could be important, for example, if you're dealing with a report that ends up before a court of law.

Now, ring-barking and girdling can occur for a whole range of reasons, but most of us will assume that we're talking about human-caused ring-barking or girdling. And of course, this is very common. It was a common agricultural practice and still is in some parts of the world for killing off native vegetation to clear paddocks for farming. [00:04.00] Foresters killed selected trees with it. Orchardist killed selected branches, for example, to control vegetative growth or fruit size and yield. And, of course, then we have all the accidental human and unintended ring-barking and girdling from people putting wires and various things and ropes around the trunks of a tree, sometimes from poor staking, from mowers and what we call whipper snippers, or what you would call brush cutters in the United States. And then, we've got poor propagation and planting techniques which lead to the girdling of the lower parts of the trunk and root systems. And then there are those spectacular acts of vandalism or vehicle accident.

So, lots and lots of causes of ring-barking and girdling due to human activity, and some of these go back many, many decades and centuries indeed. So, what you see on your screen at the moment is an etching [00:05:00] of ring-barked—ring-barking trees—that was used as a very common practice here in Australia to clear very large swaths of land, and these are professional ring-barkers who are clearing land back in the 1800s.

Naturally-caused ring-barking or girdling also takes place, and very often it's by animals: grazing animals—perhaps horses; birds, we have birds here—cockatoos, which are very large parrots that can strip large slabs of bark off trees; tunneling insects getting under the bark and working their way through the bark and cambium tissues; and of course, various fungal diseases, such as collar rot, can all contribute to girdling and ring-barking. We can also get circling of roots, as I mentioned earlier, from poor nursery techniques, [00:06:00] but it can also happen naturally. And it may happen, for example, with seedlings that develop in crevices. Here in Australia, and I suspect in many parts of the US, particularly on the west coast, bushfires and wildfires in the last few years have certainly brought home to us the damage that fires can do to both forest trees and trees that are along roads and in peri-urban parts of towns and cities. And then we have rodents and other animals that can ring-bark. So, ring-barking and girdling, really quite common phenomena, very often because of human causes, but sometimes due to natural phenomena as well.

On the screen at the moment, I'm hoping that you can see the base of a large tree that fell over. This tree—24 meters tall, so a large tree—[00:07:00]been in the ground for well over a decade, and what you're looking at in this particular photograph is the base of the tree where the root system should be. There was no root system; the tree fell over.

And so, we excavated a number of these sites and here are two examples of trees that had been badly propagated that were very seriously suffering from circular and girdling root systems, were planted out badly, and, you can see in both of these instances, there is a very, very poor development of the root system, because the roots had circled the base of the tree and basically cut off the supply. In effect, they had ring-barked or girdled the tree. And you may ask: well, how could trees survive with such a limited connection? And you can see here, the connection between the one root [00:08:00] and the trunk of this tree is only a couple of centimeters across. And the answer is: they were growing in very good conditions for a number of years. All of the carbohydrate remained above the ground, so they grew very well until, of course, they started to fall over, because they had no roots and because they started to lack nutrients and water.

So, if you consider ring-barking and girdling as different phenomena, then we ought to look at the physiology of how these work, because they're quite different. So, when you look at ring-barking, the first thing you do is you remove the bark and cambium, it has an immediate impact on translocation and phloem tissue. And what happens is that water and nutrient transport continues because xylem tissues remain undamaged. So, the removal of [00:09:00] phloem tissues affects the transport of complex, organic molecules such as sugars, amino acids, and hormones, as well as other simpler substances dissolved in the phloem sap. Now, transport of these substances from roots to foliage and from stem above the region of the ring-bark stem is halted, but so too is transport from the foliage to the root system, especially of photosynthates and hormones. So, what we find is that the transport through the phloem tissues and its impact on tree physiology can also vary according to the season. So, we're looking at what's going on with the movement of a whole range of complex organic molecules from the root to the shoots, but also from the shoots to the roots, and this can be impacted by what's going on in different seasons.

[00:10:00] So, during periods of active growth, when photosynthetic activity is high, transport is predominantly basipetal. That means from foliage to roots. In deciduous trees coming out of dormancy in early spring, transport is predominantly acropetal (i.e., from root to shoot, as carbohydrate that was stored in the root is mobilized to facilitate bud burst and leaf production). So, what we find is that translocation and phloem transport is essentially a symplastic movement of substances through the interconnected cytoplasm of interconnected living cells.

Now, I've used the word interconnected there more than once, deliberately, so that you get the idea this is living material and materials are being transported through these connections of living cells. And we'll come back to this [00:11:00] and the symplastic and the apoplast in a few minutes time.

So, what usually happens when you ring-bark and girdling is the interruption to the flow of carbohydrates and a rapid depletion of carbohydrates. The most immediate effect of these changes in transport is that hormones synthesized in the root, no longer travel above the zone of ring-barking, and those produced by the foliage, no longer get to the root. In other words, you've started to disrupt the entire metabolism of the tree. So, over the longer term, what really happens, though, is the failure of the photosynthate to reach the root system, and that has very significant consequences that can ultimately kill the tree.

Then sometime after ring-barking, growth and [00:12:00] branch and trunk incremental increase may continue above the zone of ring-barking because you still got photosynthesis occurring, and you might actually find that the condition of the foliage above the ring-barked trunk improves and growth rates increase, because all the carbohydrate that's being produced in the foliage remains above the ring-bark section of the trunk. None reaches the root system. So, what usually happens is that the trunk above the ring-barked zone increases in girth. Often, there's a noticeable swelling above the cut, whereas, below the cut, growth virtually slows and ultimately ceases.

Immediately after ring-barking, most trees have sufficient carbohydrate reserves in their root cells to maintain an active cell metabolism and [00:13:00] root growth for a period of time, but as time passes, the reserves are gradually consumed, at which point, growth ceases and root cells start to starve and die because of lack of carbohydrate. Then soon as that happens, water and nutrient uptake is then affected, and the tree starts to shed foliage, becomes chlorotic, and finally, an often quite suddenly, the tree wilts as the plant above the zone of ring-barking dies.

So, what you find here is that quite often the ordinary person that sees a large, old, ring-barked tree thinks the tree is going to be okay, because nothing happens immediately. Water and nutrients are still moving because you haven't damaged the xylem tissues, but eventually, the root system starves, and [00:14:00] the tree will die. Large tree—this could take somewhere between 2-5 years.

Of course, if there are other environmental stresses such as drought or flooding or waterlogging, the decline of the tree will be accelerated, and things will happen faster. So, here you see some typical examples of when you've done, you've sort of ring-barked the tree, and you can see the swelling is illustrated in this slide here.

Now, if we go to the real world, here is a tree that's been planted in a street, and you can see that it's been ring-barked by the paving, and you can see that characteristic swelling that's starting to develop above where ring-barking cuts have been made. That tree, by the way, was removed shortly after I took this photograph, because it was doomed not to survive.

[00:15:00] You don't have to have full ring-barking of a plant for there to be significant issues with the transport system. And you can see here, large wounds and large patches of ring-barking on branches can also be an issue, but I'm tending to focus on ring-barking and girdling of the trunk.

The width and the depth of the cut affects the trees responses to ring-barking. So quite often, if someone ring-barks a tree or if an animal ring-barks a tree, and the band is only narrow—might only be 75 to 100 millimeters—a healthy, vigorous tree may grow over that without any problems at all and resume its normal growth cycle. But if you've got a very large depth or section of bark removed, then the tree doesn't have the reserves, the callus production isn't sufficiently fast enough, and that tree, then, is [00:16:00] effectively ring-barked or girdled as the case may be.

Now I said earlier that we would come back and consider both the symplast and apoplast and for those of you that are interested in how all of the physiology works, I remind you that when you are looking at a woody tree, you have the connections of the living cells—that is, all of the cytoplasm in all of the living cells and their connections and the little plasmodesmata that collect between cells or cell—and that's called the symplast, the living system, and the phloem tissues and phloem transport use that living system. We also have the xylem tissues – large hollow vessels or elements, as the case may be, depending on whether you've got conifers or angiosperm—and [00:17:00] these have no cytoplasm in them. They're effectively dead cells or physiologically inert, and they're connected to all the cell walls. And so, you've got a second system.

And the way I think of a tree is that you've actually got three things working at once. You've got all of the living stuff, called the symplast. You've got the xylem tissues and all of the cell walls and cell spaces that make up the apoplast. And very often, when we're talking about the anatomy of the tree, we're very conscious of what's going on in the phloem tissues—what the ordinary person would call the bark—or the xylem tissue—the ordinary person would call the wood—that we forget about all of the cell walls that are there as part of that apoplastic system, and you need to think about those when you're looking at trees that have been ring-barked or girdled.

[00:18:00] Now, if we come to girdling—and we've talked about ring-barking, which was the removal of the foam tissue and cambium—what happens there is quite dramatic, because it affects both the phloem tissue and transport through the xylem tissue in transpiration. And the effect, really, is that when you girdle and you've taken out the functional current season and active xylem, you've immediately interfered with the water and nutrient supply. And so, really what can happen if you've got a warm windy day, the effect of that girdling will be almost immediate, because wilting starts literally within minutes or within hours, and for most of the canopy and the trunk above the girdled cut, permanent wilting will be reached in somewhere between 24 and 48 hours, depending on the size of [00:19:00] the tree and the environmental conditions. So, girdling is a very effective method of killing plant tissues above the cut. The effects are immediate, and it's a very effective and efficient way of killing a tree.

So, of course, you've got the transport through phloem tissue. The transport of water and nutrients can be both symplastic and apoplastic, whereas in the phloem tissue, it's only symplastic. So, what we find here is that there is movement of materials through the cell walls and intercellular spaces, and this is quite important, because very often, if you're only thinking of functional xylem and phloem tissue, if you think of a large tree that had a cut made through it and obviously the xylem[00:20:00] and phloem tissues have been damaged, but if you stop the cut, then the tissue immediately above the cut often remains healthy, callus has produced, and you might say to yourself, where is the water and nutrients coming from? And the answer is: it's coming through all of those interconnected cell walls that are maintaining a water supply above the cut. So, that's one of the things that you may have wondered about.

The other thing I should point out is that, when we think about most woody trees, we think of the anatomy as being typical. In other words, you've got your xylem tissues, your growth rings, your cambium, and on the outside of that you've got your phloem tissues, but there are various species that have what we call anomalous secondary growth where you might get alternating rings of cambium, [00:21:00] xylem, phloem. And this happens, for example, in some species of the *Myrtaceae*, and of course, coming from Australia where eucalyptus are so common, we know that that does happen in some eucalyptus species. So, these anomalous anatomies make the response of the trees quite different from what you might expect, and sometimes, you have people who ring-barked the species, nothing seems to happen, because you've got this anomalous secondary growth. And in some species, it's not just rings, but you have lobes as well.

So, just a couple of important physiological and other responses to ring-barking or girdling. Some of these effects you probably know. If the width of the cut is narrow, then the tree may simply grow over. The cut will callus, and [00:22:00] that callus may differentiate in a matter of weeks to months, and it's almost as if nothing has happened. So, a healthy vigorous tree can often grow over 100 to 150 mm ring-barking or girdling, provided it has sufficient carbohydrate reserves. If the wounds are large, the tree will respond by producing callus at the margins of the cuts, and it's then just a matter of time as to whether there is sufficient callus produced in a reasonable time to bridge the gap and for normal tree growth to resume.

Spring, particularly early in the season, is typified by very fast responses to wounding and very rapid callus production. So, what this means is, if you've got ring-barking [00:23:00] or girdling of a tree—a healthy, vigorous tree—when that ring-barking or girdling is done can impact and affect the way the tree responds.

So, if you're looking at say vandalism of a tree, and they happen to vandalize the tree in perhaps late winter or early spring, then quite often the tree will respond by producing a massive, massive amount of callus and simply grow on, which you probably wouldn't expect. If the tree has dormant buds, such as axillary buds or epicormic buds, or what we call lignotuberous or basal burl buds, below the cuts, these will often be stimulated by either or both ring-barking or girdling, because you've interfered particularly with the auxin movement down from the foliage, and sometimes these buds will develop sufficiently fast and large enough, and they will then [00:24:00] supply a photosynthetic area that can feed the root system. So, you might find that if those shoots started up, then the tree has a good root system.

It still has all of its foliage above the cut, and the callus that might be produced over a period of time that could take months or even a couple of years. Those shoots can really enable a tree to recover. So, those shoots, if you like, epicormic, axillary, or lignotubers, or basal burl shoots can actually provide you with the way of seeing whether the tree is going to overcome the effects of damage from ring-barking or girdling. And if that happens, sometimes, even though the cut never grows over, the tree might survive for many years, a decade after it’s been ring-barked, because it's still getting carbohydrate from the shoots below the cut, feeding [00:25:00] the root system, so to speak. Usually what happens in those cases, though, is eventually environmental stresses such as drought, water-logging, or insect grazing bring the demise of the tree.

Just a couple of other points that I'd like to make in relation to this and to provide some examples, if you like, of work that we've done with these on ring-barking and girdling. You need to know where the ring-barking and girdling has occurred, you need to know to what depth, and you need to know whether and how much of the trunk or branch has been affected.

So, we know, for example, that trees have survived ring-barking and girdling to 50% of their trunk vascular tissues. And we know that in young trees of river red gum, [00:26:00] the common plane tree, and some of our Acacia species, they've survived from having ring-barking and girdling to 60%, 70%, 90%, or even 100% of their trunk. So, we know that some species, some woody weed species, are really hard to kill, and in your part of the world, for example, beech and popular, some maple species, have been reported to be very difficult to kill from ring-barking. We also know that as little as 10% vascular connection can be enough for trees to remain healthy provided the tree is growing in good conditions, is kept free of stress, pests, and diseases.

What other effects of ring-barking and girdling are quite interesting. So, quite often ring-barking causes an increasing [00:27:00] in fruiting and flowering, and that's sometimes used in horticulture. We've also found that what you can find is that the response to girdling and ring-barking usually leaves about 10% to 20% of the vascular connection. So, you don't ring-bark completely if you want to get some of these horticulture effects that allow higher levels of carbohydrate to remain in the canopy, better fruit production, more flowering, and so on. You don't go to all the way around the trunk or all the way around the branch to get those sorts of effects.

We decided to do some research on tree species that we commonly use in Melbourne, Australia, and these were the river red gum, the common plane tree, or the London plane, and what we call black wood, Acacia melanoxylon. [00:28:00] And we ring-bark these at 60, 75, 90, and 100 percent using the definitions of ring-barking and girdling. And we used different depths of cut, but what we found is that there was no difference, because the only treatment that killed the trees was 100 percent. All the specimens survived even 90 percent ring-barking or girdling. Now, this was probably because the experiment was conducted over a 13-week period. The plants didn't die, because the trees were young, vigorous, and they simply grew over the cuts. So, it shows you how resilient young trees can be, but in some other experiments we found that if you have a severe ring-barking, then you get slower bud burst in the following spring.

So, even if the tree doesn't die, [00:29:00] there is an impact. We also found that in all of these species, if you ring-barked seriously, then the number of fruit produced declined significantly, usually less than half, sometimes about a third of what would happen on a healthy tree. And we also found, of course, that in severe treatments, quite a number of branches were shed from the young trees, and if you went to the more extreme girdling and ring-barking, the greater the shedding was.

There are other more subtle effects that ring-barking and girdling have on these trees. So, for example, in undamaged controls, we found that the plants grew much more quickly. They had shoot tip extension double that of ring-barked trees. [00:30:00] The infection of psyllids on some of these species, which are little sap sucking insects, was much, much higher in ring-barked trees than in the controls. And we probably know why that was the case because the psyllids attacked the trees that were stress, because they were mobilizing sugars, whereas in the Acacias, which are affected by a leaf blight in Australia, the leaf blight didn't impact on the ring-barked trees, but it did on the controls that hadn't been ring-barked.

So, what you find there is that ring-barking and girdling had much more subtle effects on tree biology and physiology than just whether the tree lives or dies. And this makes you realize that there is a complex set of [00:31:00] physiological responses taking place. Even if the ring-barking or girdling is incomplete, the trees have been injured, and their response to pests, diseases, and stress will vary.

Now if you've got a ring-barked tree, is there anything you can do? And the answer is, yes, there's lots of things you can do. The first thing is, if you've got a situation where bark has been stripped or detached from a tree, put it back, put it back as quickly as you can, keeping the tissues moist and making sure the orientation of the bark that's been displaced is maintained. In other words, the section pointing up, remains point up. Just put it back, because there's a very good chance, depending on the season, that it will naturally graph. And this is particularly important, if you've got trees that have been damaged by vehicle accidents or by deliberate acts of vandalism.

There are a whole range of [00:32:00] horticultural techniques that you can see here. Bridge grafting where you place scion wood from the tree that's been damaged, you insert it under the bark, and you are attempting to graft a whole lot of sections. This is a technical operation. It's quite difficult. It can take time; it's quite costly, but for a valuable tree, it's well worth the while. So, bridge grafting does work. It can be seasonal, and it can be species dependent, but it's well worth the while if you've got an old or very significant tree.

Approach grafting is where you grow young seedlings around the trunk of the tree, usually if you can get them, the progeny of the tree itself, and you effectively graft the trunks of those young trees back into the old tree, and you're hoping that the graph will take, and you'll have root system, supplying water and other materials to the[00:33:00] part of the tree that remains above. It's quite technical. It doesn't look good and would only be done in very, very rare circumstances for a very valuable tree.

So, these techniques make you realized that if you're going to deal with a very old and significant tree, that's been seriously ring-barked, you know that these approaches are going to be expensive. They required quite a lot of skill, and you're going to require follow-up, often for months if not years, after you've made these corrective treatments.

So, as we conclude this presentation, I'm just wanting to make everyone think about what happens with ring-barking and girdling. Use the terms precisely. The fact that a tree has been ring-barked or girdled doesn't mean that it will necessarily die. Arboricultural treatments, [00:34:00] particularly if applied rapidly and within hours to replace bark and to provide good conditions for the tree, can really make a difference to whether the tree will survive ring-barking or girdling. If you've got good callus production and good conditions, that callus can grow very, very fast, and you may get a growing over, a girdle or ring-barked section of tree, in a matter of months.

We know that trees can survive with as little as 10 to 20% of vascular connection or even less if they're young and healthy. The “do nothing” option to the tree may be an appropriate response, because if those trees are young and vigorous and really producing lots of callus, then leave them alone. See what happens. That's good arboriculture.

The last thing I want to say is to point out that trees [00:35:00] really are amazingly resilient, and it really does come as a surprise that you might only need ten percent of vascular connection between roots and foliage to maintain a healthy tree for a number of decades.

I wish to acknowledge my colleague, Sarah Priestley, who did the work on some of those graft and trees, my students in the graduate certificate program, who were also very interested in this topic, and I also acknowledge the work of Dr. Erin Moore, linguist, for reading and helping with the PowerPoint and the transcript that I've been using to accompany this presentation.

Thank you for your attention. Hope you have enjoyed this session.

[00:36:00] **Outro**