Riley Rouse: Root Defects of Container-Grown Trees: Should You Remediate Before Planting?

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[00.00.00] **Rebekah Holtzclaw:** Hello and welcome to the ISA Conference Rewind Series. I'm Rebekah Holtzclaw, an editorial assistant at the International Society of Arboriculture. Today we are excited to bring you this presentation by Riley Rouse, research technician at Michigan State University. Riley will discuss root defects in container-grown trees. This presentation was originally given at the 2022 ISA Virtual Conference, and the views seen here are those of the presenter. If you are interested in root defects or pruning techniques, I believe this presentation will be interesting to you. Sit back and enjoy!

Riley Rouse: [00:00:54] Hi everyone, my name is Riley Rouse. I work with Dr. Bert Cregg at Michigan State University. I'm a research technician [00:01:00] in the tree physiology lab in the Horticulture Department. Today, we're going to be talking about root defects of container grown trees. I'm going to give a bit of background on a series of studies that our lab has conducted over the last 10 years, and then we're going to dive into our most recent trial that was established in 2021.

So, we know that trees provide a myriad of ecosystem services, especially in urban areas, of course, including stormwater mitigation, reducing the urban heat, island effect, and energy savings, things of that nature. And then, of course, ornamental trees also increase our property values compared to neighborhoods without trees, and there are several ways that green space can improve our physical and mental health.

We all know this, but we don't talk about often enough, what is the number one way that we can maximize those ecosystem benefits? Well, it's making sure that the trees that we plant survive and grow. A larger tree is going to ultimately provide more ecosystem services, [00:02:00] and we need our trees to grow, of course, and survive in order to do these things. So, we talk a lot about tree plantings. We have a lot of community groups willing to get out there and do large-scale tree plantings, but that's all in vain if we don't get our trees through the critical establishment period and they're able to survive long term in the landscape.

So, container production is a great opportunity for this container stock, because container production is increasing in the United States. Nurseries like container stock because they can pack a lot of trees close together in the nursery. It's efficient for shipping for them. And then the advantages for those of us plant beans are that the trees are lightweight and they have a longer transplant season compared to B and B stock. So, they are a great option for those large community tree planting events, but of course, they can come with some serious issues, which we've all seen before, namely circling and malformed root systems.

Root systems [00:03:00] can develop poor root architecture in response to growing in traditional nursery black plastic containers, and unfortunately, that's often cited down the road. If you're doing a

postmortem on why a tree failed, the root architecture is as often to blame as the tree decline or tree failure, because the trees are not allowed to extend laterally in the black plastic containers. They hit the side walls of the container and start to circle, and get what you see here on the left, which we've all seen before. And that really decreases the stability of the tree, and the imprint of the container can persist long after planting, especially if the trees are circling at a small container size in the nursery and nothing is done about it when the trees are up potted. You can see several imprints, and again, that imprint lasts long after planting and persists in the landscape, which can definitely become an issue more than just decreasing tree stability. [00:04:00] The circular roots can become stem girdling roots at the base of the tree, which can further decrease stability and can cause other roots, other issues: choking out the tree, compressing on that xylem there.

And I want to make clear that the roots that I'm talking about today, the techniques I'm talking about today are in response to the poor root architecture of a standard black plastic nursery container. Alternative containers are available in the nursery and that availability is increasing. Air pods or root pouches or any containers that do air pruning are becoming more readily available, but the majority of what we have available to us is still a standard black plastic nursery container.

So, what I'm going to be talking about today are approaches that landscapers and arborist can do at planting. If you get to the job site, you pull up the nursery container, and you have just a dense root system, [00:05:00] what approaches can you take at that point? But I do want to note that these alternative containers are available, and if you can get your hands on them and they're cost effective for you, they are a great thing that you can use.

So, not a ton of work has been noted in the literature of evaluating these different root techniques, but we do a lot of these intuitively, right? A lot of us, when we buy a flat of annuals, we pop out a little flower, and we see the roots at the bottom. We kind of break up that root system, or we butterfly it a little bit. That's something that we just do kind of naturally when you see a matted root system. So, there's a lot of anecdotal evidence, but not a ton of evidence-based research in the scientific literature. But there's a little bit.

So, one of the techniques that we want to talk about is slicing the roots or vertical scoring through the root system. Kind of a common practice, I would say, among arborists. Again, it's intuitive; it feels like [00:06:00] you are scoring through those circling roots. It feels like you're doing something when you take a box cutter or a saw and you slice through some of those outer circling roots, and it has been shown in some studies that it can disrupt those circling roots and ultimately improve your root egress into the soil. But then there have been other studies where there were no differences in root response compared to a tree that did not undergo the slicing technique. So, this is one of the techniques that we wanted to look at and be able to build on any types of recommendations for this practice.

Shaving is a technique that has gotten a lot more attention in the last 10, 15, 20 years. Namely, Dr. Ed Gilman at University of Florida has been looking at this pretty rigorously. Shaving the root balls—when I say that, I'm talking about removing the entire periphery of the root system, whether with a sharp spade or a handsaw, just taking off that entire outside [00:07:00] of the root system. And when you're doing that, again, it makes sense intuitively that you're removing a lot of those outer circling roots, and you're cutting off roots where new roots can initiate from. And this has been shown in Dr. Gilman's work, and then also in our lab, we have seen good responses of root systems to the shaving.

And like I said, just to go a little bit deeper into this, why this works is that when you cut a root, a new root initiates from right behind that cut point. So, the root system will callus, and then new roots grow from that point. And in theory, in hope, we hope that those roots would grow straight out. If you've cut it right before it starts to circle, roots will expand laterally from that point. So, that's why we like the shaving and it makes sense to us that it would work.

So, like I said, we have been looking at some of these techniques over the last 10 years. [00:08:00] In 2012, a trial was set up in our lab where two separate experiments— and I won't get into too many of the results—but two experiments looking at shaving Bloodgood London plane trees. We also looked at just manually teasing the root systems, so just taking our hands or a garden fork and just pulling those root systems out, another thing that we do intuitively. Teasing took a really long time. Great results. The root systems looked fabulous, but it takes a while. Shaving, we got just as good of results, and it's quick. You can take a pruning saw and just chop off the side of the root system and that bottom layer, you want to make sure you remove as well. And the plane trees, specifically, that we looked at in this study responded really well to the shaving, and we saw increased root growth and reduced root circling. After either two or four years in the landscape, we dug them up, looked at the root system, and these are the types of things that we saw there.

So, when you compare a shaved root system to [00:09:00] one of our controls, just visually you can see that the roots of the control treatment that did not receive any root remediation, the roots really remained within that original root ball imprint from the nursery container, even, again, two to four years in the landscape. Whereas the shaving, we had a really good explosion of outward root growth into the surrounding landscape which, again, improves our stability and, again, just visually, it goes that's a root system we like to see right there on the right. So, we had great success with the shaving and wanted to continue to look at that practice.

Around this time, also 5 to 10 years ago, bare-rooting has been gaining in popularity and has been talked about a lot. Different practitioners have been kind of advocating this approach. So, when I'm talking about bare-rooting container trees—you know, different from bare-root stock where trees are lifted in the nursery and [00:10:00] shipped out with no soil or media around the root systems—bare-rooting as a technique is taking a container tree and removing all of the soilless media or container media to really get into the interior of the root system and be able to manually root prune and cut out any malformed roots.

So, here's a good photo of a bare-rooted container tree where we've removed all the root systems. So, the proponents of this method have really been saying that bare-rooting is really the only means to reveal and remediate any root defects that are on the interior of a root system, which again, makes sense. Some of these other techniques, we're really only getting into the outer circling roots. Whereas with bare-rooting, you can get all the way through the interior by kind of digging through there, and then anything that's on the interior, you can go ahead and remove or straighten out manually, whatever you want to do.

But again, this is one of those techniques [00:11:00] that's been talked about a lot. There's a lot of great anecdotal evidence but not necessarily any evidence-based research for the practice. So, we wanted to kind of take a look and be able to build some guidelines and some framework around this recommendation by just noting if there are species differences or differences in timing when you should be doing this.

So, this led into our study in 2018 where we looked at a few different species. We looked at the London plane tree again—because we had good results with that in the previous study—tulip trees, and red maple. So, we went ahead and used those three common urban species, and we looked at differences. We did shaving, and then we also did bare-rooting, and what we found was that trees really responded differently, species responded differently to these techniques. The London plane trees continued to be very hardy, whereas the tulip trees were extremely sensitive to the method [00:12:00] and had a lot of mortality actually when they underwent root remediation. They were extremely sensitive to that. So, we began to learn that there were some species differences in these techniques, and we wanted to begin to kind of build on that framework once again.

So, just some quick results from that study. This is looking at the plane trees once again. You can see the control on the left there. Roots continued to circle within that original nursery imprint. Shaving had a great response, outward growth of the root systems. And then the bare-rooted trees: they're good-looking root systems. We have outward root growth and decreases in root defects, but, at that point, we were really reducing the root tissue ratio and maybe to a point where that was, again, too much stress for some of the more sensitive species. So, we wanted to continue to build on our framework, and [00:13:00] that takes us into our most recent 2021 study where we wanted to continue to look at these techniques and continue to look at different species.

So, the study objectives throughout all of these trials really have been to evaluate these different methods. In the 2021 study, that's bare-rooting, vertical slicing, and shaving. Evaluate these methods of remediating root balls at planting to correct any root defects of container grown trees. And again, we wanted to build our framework in terms of species recommendations, and then demonstrate the effect of the techniques on eventually root egress and establishment of the containers trees.

So, in thinking about what species we wanted to use in this most recent study, we're diving into this bulletin by Nina Bassuk at Cornell. She's done a ton of great work with bare-root stock and planting bare-root stock in urban areas, and she has this great guide where she has listed [00:14:00] species that are difficult to transplant as bare-root stock. And one of the trees that we see on there is the tulip tree. Like we said, we did find that those trees, the tulip trees, were extremely sensitive to bare-rooting, as our technique of bare-rooting.

So, we decided to pick a couple of other species off of this difficult to transplant list and run with that and see if this bare-root method guide from Cornell could be translated to the bare-rooting method of root remediation. So, this go-round in 2021, we compare these other three species—tulip tree, *Ostrya*, *Carpinus*—to our London plane tree where we have seen that those are quite hardy and don't mind their roots being messed with too much honestly. Whatever we do to them, they respond either positively or no different from the control. So, no negative impacts have been shown, whereas with the tulip trees, [00:15:00] we have seen mortality and other negative impacts of some of the root remediation.

So, these are the species we looked at, and we planted 136 trees. They're grown in our pot-in-pot nursery on campus. So, we know that they’re plenty root bound when we go to plant. And again, the treatments were controlled, shave, bare-root, and slice. And then we also wanted to look at compensatory pruning, because in the previous trials, we saw a lot of dieback and responses of the trees where they're trying to regain the root-to-shoot ratio as mentioned, kind of a lot of dieback in response to root removal.

So, we wanted to take a look at compensatory pruning and see if we could preemptively kind of go ahead and take care of some of that, so the trees wouldn't necessarily have the dieback, which is obviously not aesthetic when you want to plant these in urban areas or for customers.

[00:16:00] So, like I said in earlier trials, trees had gone ahead and reduced their leaf area by having leaf scorch, flushing out with smaller leaves, or having significant dieback. So, we wanted to take compensatory pruning, look at compensatory pruning, as a pre-emptive way to kind of remediate any of these issues in the landscape. So, we're able to do this based on the pipe model theory from DaVinci where we can find that leaf area is proportional to cross-sectional branch area. So, we're able to measure each branch coming off the tree, look at the caliper of each branch, and then we can go ahead and determine what branches need to be removed in order to take off. We went with 1/3 crown removal. So, that's how we went about the compensatory pruning treatment.

So, like I said, this is kind of a buzzword these days, but previously, compensatory pruning was a common practice [00:17:00], you know, within the last century. It just kind of went out of fashion, because it was shown that there was really no benefit to the practice and maybe some negative impacts. Shigo had noted that there was possibility for carbohydrate reserves to be removed when you're removing the stems, and of course, you're reducing carbohydrate production when you're taking off leaf surface area.

So, that's why I kind of went out of practice, where we just saw no real benefit. But there were some other studies that showed when trees were under moisture stress, the compensatory pruning treatments may actually improve plant water relations in those studies. So, that's kind of what we were hoping. That's what we wanted to take a look at.

So, this is our compensatory pruning treatment. Like I said, trees were measured. All the caliper of each branch were measured, [00:18:00] and the dormant pruning was done in the dormant season. Our other treatments included, of course, control, where there were no root modifications whatsoever. The nursery container was removed, and no matter how pot bound that tree was, it was plunked right into the landscape.

So, the bare-rooting treatment: we went about doing this using the stream of water from a garden hose—not necessarily a high-pressure garden hose, just a standard hose—where we took the water, aimed it at the root system, and used that to kind of blast away any of the container media that was within the root system. So, after the media was removed, we went ahead and manually root pruned any circling or malformed roots just with hand pruners, cutting it right before, you know, the kink or the circling began. And so, what you end up with, what you see on the right there, is a tulip tree that has been bare-rooted and is going to go in the ground looking like that.

Our other two treatments were the shaving and slicing. So, for shaving, again, [00:19:00] we just use a saw to remove the entire periphery of the root system—about three centimeters on each side—and then we also take off three centimeters on the bottom where a lot of those roots get matted. That's the slicing—shaving treatment, excuse me. And then slicing, we just did vertical scores with a saw. Six scores, pretty deep, all around the root system, in order to kind of break up some of those interior roof defects.

So, after all of that, the planting is done, and we mulch all of the trees. I want to note that we do monitor soil moisture throughout the growing season, and we irrigate during the first growing season if it's necessary, looking at soil moisture and then, you know, upcoming weather. So, then you're left with an installation that you can go ahead and start taking some data on.

One of the first things that we note after planting is generally, like I said, some dieback in [00:20:00] response to these treatments. This is the rating system that we use: zero to four. You know, how scorched are the trees really? Zero being no score, no dieback, trees are happy and healthy. A four: dead. A three pretty much just wishes it were dead. So, keep that in mind as we look at the ratings here.

So, about a month after planting, the bare-rooting resulted in pretty severe dieback for all of our difficult to transplant species. So, the *Carpinus*, *Liriodendron*, *Ostrya*—that's lumped together as our difficult to transplant species compared to the *Platanus*, the plane trees. And bare-rooting is really where we saw the most effect. The shaving, slicing, none of those species really had negative impacts in response to that treatment, whereas the bare-rooting, almost immediately following planting, we do see just severe dieback. Depending on species, the level of severity varies, but significant [00:21:00] compared to the other treatments.

And this time, we also went ahead and looked at crown density, and we were able to do this using a free software called ImageJ. We take photos of each tree, two photos from different angles, and we average our results there. We're able to upload these photos, and the software can pick out the area that's green, so that's our, you know, our leaf area. And then, we go ahead and manually draw an outline of, you know, if the tree was full, where the green would be, if that makes any sense. And then we can go ahead and divide out those numbers to ultimately get our crown density.

So, what we saw here for crown density—really, once again, the bare-rooting reduced the crown density—but bringing the pruning treatment in here, the pruning, though it didn't, you know, statistically help anything, had a really good response. [00:22:00] The trees that were already pruned had a much denser crown compared to those that, you know, had to kind of address their own leaf area and dieback that way as opposed to where we already took off a third of the crown. Those trees looked a lot better than those that weren't pruned. So, that was an interesting finding.

The bare-rooting also reduced survival of the difficult to transplant species. Not super surprising when you have all of that dieback. It's a quick response if the trees can adjust and kind of maintain throughout that first growing season or if they just can't get through that initial transplant shock. They're going to have mortality. And so, this is looking after the first two years, actually; there's a negative impact of the bare-rooting.

The growth, however—other than the C*arpinus* trees in the bare-rooting treatment—[00:23:00] there were no differences in caliper growth over the first two growing seasons, and there were no differences at all in height growth over the two growing seasons for any of the species in any of the root treatments. So, this doesn't look that groundbreaking, but it's actually, kind of, a situation where no news is good news, right? So, there are no differences when you compare a tree in the slicing treatment compared to a control tree which is a good thing, because we're not negatively impacting the tree. So, pretty much what we want to see here.

And then getting into it a little bit, here, we're looking at average predawn shoot water potential, and these are throughout the first two growing seasons. So, here, I pulled out the *Carpinus* trees as an example to take a look at the moisture stress that the trees undergo, but the other species followed a similar moisture regime here. So, for those that aren't quite as familiar, [00:24:00] plant water potential is a measure of how tightly water is being held in the xylem due to that capillary tension in the tree. So, what we can do is apply pressure to shoot or a leaf in order to, kind of, try to pull that water out. If you need to apply more and more pressure, which gives us a lower number here, that's because the tree is really fighting to hold on to what little water it has, because it's moisture stressed to some degree and doesn't have a lot of excess water to spare. Whereas if you don't have to apply much pressure and water comes right out, that's a well-watered tree or less stressed tree, because it has water that it can freely dispose of essentially.

So, like I said, this was looking at the differences in root treatments for the *Carpinus* trees, and the big takeaway, if you take a look at 2021 here, is that the initial moisture stress hits the trees immediately after planting. So, a month after planting, on the June 2021 date across the four treatments at the top row there, [00:25:00] that's where we see some of the differences. Even the controlled trees are showing a bit of moisture stress. The bare-root trees showing the most, kind of, getting close to a critical level of moisture stress under that, you know, month after planting, but after that, as we move into the end of the first growing season, say August of 2021, if the trees hadn't died, now our sample size is shifting a little bit here, if the trees hadn't died, those that survived were really able to recover and get through that transplant shock and then they're performing at the same level of the control trees, so there's no differences being shown in water potential values across treatments. And then in 2022, no differences whatsoever. Again, the trees that were able to survive are indicating no moisture stress, at least compared to the control.

So, that's an interesting finding, showing that the trees that are able to achieve a functional equilibrium through, [00:26:00] again, scorch or dieback or flushing with smaller leaves are just kind of shutting down their conductance. Those trees that got through that initial transplant shock were able to thrive after that point. So, we've got to baby our trees a little bit at the beginning, and then, after that, they should be performing well after the first, at least first, growing season.

And I do want to say that, you know, in this case, bare-rooting did remove more roots than the shaving treatments. We measure, collect all the roots that we take off when we do these treatments to see, you know, is it how much we're taking off that's having this effect? So, in this case, bare-rooting removed more roots than the shaving treatment, but in other studies, the 2018 study, shaving took off more than bare-rooting, and bare-rooting was stressful to the trees.

[00:27:00] So, we like to make sure that, or just keep track of the roots that we removed to see is it the amount of biomass that's removed or something else. So, we do keep track of that there. And then we're not there yet, but in the next one to three years, we'll go ahead and do a whole tree harvest where we cut down the top of the tree. We measure the biomass of the leaves and the trunk, and then we take a tree spade, come in, excavate the root system, and we can really see the important stuff which is how the root systems look.

So, in doing that, we have kind of a systematic way that we monitor or measure root egress and percent of circling roots and all that, and I kept the picture on the right there to show how crazy we get when we are looking at hundreds and hundreds of roots over the course of months. But that's going to be the

ultimate goal when we really see the effect of these treatments, right? Because it's interesting to know what's going on when the trees are in the landscape, [00:28:00] how do they look above ground, because that's important to our clients, but we haven't really tested the effects of the root treatment until we look at the roots. So, that's going to come in the next few years.

Like I said overall, some observations that we've seen over the course of these trials are that shaving and, at this point slicing, those have shown to have relatively little, if any, negative impact on at least the species that we have tested on their survival or growth, whereas bare-rooting has been extremely stressful on a number of difficult to transplant species that we've looked at. So, that's one to be a little bit more cautious with and maybe not be super aggressive with, and at this point, compensatory pruning did not affect survival or growth, which again, no news is good news. And it actually might offset some of the negative impacts of root pruning. Like I said, we're getting the [00:29:00] more dense crown and no negative impact on moisture stress.

So, if you're interested in trying some of these techniques, I would say avoid species on that list of known to be difficult to transplant species, and then definitely perform these treatments when the trees are dormant. You know, we can plant container trees all throughout the growing season, but it's not a good idea to perform these treatments in the heat of summer, depending on where you live. If you want to try things out, I would try them on the tail end of the season.

And then moving forward. You know we've been doing this, like I said, for 10 years. We have a handful of different studies that we are learning from, but what do we want to look at in the future? We want to continue trialing treatments with even more species, because like I said, we have a lot of good anecdotal evidence that some of these things are successful for different people, for the root system remediation, but we need to continue to build the evidence-based recommendations. [00:30:00] And then, again, for most of our work, we've dug the trees after only two to four years in the landscape or ultimately, you know, we want to have root harvests down the road 5 to 10 years to see, you know, compare the differences to see if circling roots reform or if the root systems continue to extend laterally and look good after that long. So, we do have subsets of these trees that we don't excavate where we can come in and look at them in a little bit of a more long-term sense. And then of course, we can look at the stuff in the landscape, and we can make observations, but it's really important, next steps, are going to be really diving deeper into why certain species respond better. You know, we see these species differences, but you know, why is it that some of these trees are categorized as difficult to transplant? They might be difficult to transplant for different reasons. So, that might be factors related to root growth potential, [00:31:00] root carbohydrate status, desiccation tolerance. Those things really need to be explored in order to continue to build a framework for the shade trees. Especially for the bare-rooting technique, where once you've removed that container substrate, you're working with the bare root plants, you're impacting an awful lot of fine roots, you're packing hydraulic conduction.

Those are just some of the things that we want to continue to look at as we continue this work in the future.

I don't do this alone. I have a lot of financial help, help in the field, mentors, all of that, campus resources. I need to acknowledge those folks, and I'm looking forward to talking with y'all in the Q & A during this session, so thank you so much.