A Consumer's Guide to Statistics in Research

By Susan D. Day

This is second in a series of reader-friendly articles about understanding statistics used in research. The first article appeared in our December 2006 issue.

Cause and effect?

Picture this: You are walking down the street under a leafy, vaulted canopy of American elms. The sunlight sparkles through the graceful, drooping boughs. It is 1970 in a small midwestern U.S. town, and Dutch elm disease is wending its path of death and destruction through your neighborhood.

Now imagine this: You are from another planet and totally ignorant of our ways here on earth—just visiting from the next solar system, perhaps. As you walk down the street, you see big orange Xs on some of the trees. A few days later, you see those same trees being cut down. You think there is something interesting about the orange Xs and decide to do a research study. You number every tree in the town (it's a *very* small town) and note whether it has an orange X. Then, after one month, you check on every tree and note down which ones have been removed because they are dead or dying.

"Hmmm . . . ," you say. "Ninety-nine percent of the trees with Xs were removed, but only five percent of the trees without Xs were removed. I think I'm on to something here."

You go to the village forester to inform her that a new disease you are calling "Orange X" is killing their trees and that you would like to undertake research to determine how to prevent it.

Now imagine you are yourself again. Clearly there was a flaw in the logic you followed as an interplanetary traveler. After all, you know what spray paint is! Thank goodness you came down to earth before saying you've discovered "Orange X" disease. There are, it seems, some benefits to not being from another solar system.

In all seriousness, however, this is a classic case of confusing a *causal relationship* with an *association*. If there is a causal relationship, then Orange X causes trees to become dead or dying. If there is an association, then trees that are dead or dying tend to also be the trees with Orange X.

Is there a better way to study this phenomenon? Perhaps a completely randomized designed experiment like the one we described in the previous article (December 2006) would be the way to go. Plant out a number of similar trees and randomly select half to "inoculate" with Orange X (using a can of spray paint). Determine which ones are dead or dying the next month. Then use statistical tests to determine the likelihood that death or dying is due to chance or other factors or is due to the inoculation treatment.

Okay, but let's suppose that the question you are interested in relates to 200-year-old oak trees. Suddenly that option is out of the question. You cannot find a field of 200-year-old oak trees to work with (you need replications, remember?). Even if you find them, you can bet nobody wants you to inoculate half of them with a potentially fatal disease! If it's a root problem you want to study, you might also want them to be far enough apart so their root systems don't overlap. Now we really are on another planet!

How to work with associations is a problem scientists tackle all the time. Associations consistently crop up in newspaper headlines—especially about medical or behavioral research. For example, we might read that kids who watch a lot of television score ten points lower on reading tests than kids who watch little or no television. This is almost certainly an *association.* Television habits couldn't have been assigned randomly to children—they were just recorded. Saying that watching television *causes* low reading scores, or that low reading scores *cause* children to watch more television, is an unsupported conclusion. Perhaps children who watch more television also have parents who own fewer books—maybe that is a real "cause" of their low reading scores.

Researchers often try to "control" for such factors. For example, they might divide the children into groups by parents' book ownership level and then see how the association holds up in each group. If it's just as strong, we have eliminated one potential source of bias. There are many possible answers behind the data, and, as good consumers of research, it is best to be critical and skeptical (always in a friendly way, of course!).

Researchers don't work in a vacuum, naturally. By thoroughly understanding the system being studied, evidence for theories can be strengthened or weakened. For example, we have a clear understanding of the role of spray paint in marking trees, so we don't even consider it as a possible "cause" of tree death. A medical researcher may understand that a particular tissue is involved in causing a certain disease. If a study later shows that substance Z, known to cause that tissue to malfunction, is associated with having that disease, the three facts together make better evidence for causation than the association alone.

The same thing occurs with tree research. Just like humans, trees are complex. We must always think of the evidence behind a particular conclusion and keep our minds open to alternate interpretations. Statistics are just one part of a complex research process that helps us understand how things work.

By the way, how many replications does an experiment need?

I said I'd get back to replication. How many replications should there be in an experiment? How many is enough? Just like studies that look at association, many factors are weighed in the balance when the number of replications for an experiment is determined.

In an ideal world, we analyze the variation in the data we are going to measure, decide how large of a difference we wish to detect, decide how certain we need to be of the research results (is it life or death?), specify the design of the experiment and the statistical analysis method to be used, and then calculate the required number of replications.

In tree research, it is rarely that straightforward. We have constraints—and lots of them. How do we know the variation if we've never studied this question before? How much space do we have to plant trees? How much money do we have to buy trees, containers, or a million other things? How long does it take to collect the data? If it needs to be collected all on the same day—then we have to be able to collect it in one day. If the trees are already existing, then the only way to increase the number of replications is to reduce the number of treatments. Suffice it to say, most researchers would like to have more replications than they do.

An absolute minimum is two replications—conventional statistical analysis cannot be performed with fewer than two. But trees are highly variable organisms. Although research can be performed with two replications, the resulting evidence probably won't be very conclusive, unless the effect you are measuring is extraordinarily strong and variation is very low. The more replications, the more likely you will be able to detect the effects of a treatment.

For much arboriculture research looking at physiological issues with trees, five to twelve replications are typical. But time and money are real limitations, so the number of replications is always a trade-off with other factors.

Is that really a replication?

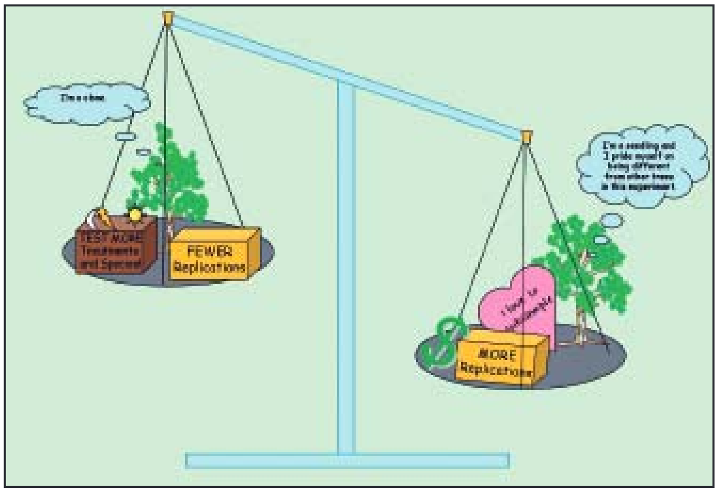
A replication should be an independent and unbiased example of a treatment. For example, let's say you treat several patches of soil under one tree with super compost and then study the root growth in each patch. The roots are all attached to the same tree, so the patches are not independent examples. They are not replications. Likewise, if you have ten seedlings in a pot and apply fertilizer to the pot, these are not ten replications. That doesn't mean they have no benefit. They are subsamples. If there is a lot of variability from seedling to seedling, averaging the size of ten seedlings reduces the unexplained variation in your data—part of the key to good results.

Obviously, trees have to be cared for now. We can't wait for every answer to be available. But just as it is for medical doctors, the best tree care professionals keep up with the latest developments in their profession. Hey! That's why you're reading *Arborist News*, right?

Next time: *Statistical error—What is it and what are the risks involved?*

Susan D. Day is a research assistant professor in urban forestry at Virginia Tech, Blacksburg, Virginia, and a member of ISA's Science and Research Committee. Dr. Day can be reached at sdd@vt.edu.

Research described in this article is a work of fiction (thank goodness!). No relation to real studies, places, persons, or events is implied or intended.



How many replications should an experiment have? There is no one answer. Many factors have to be weighed to determine what will give you the best information with the tools you have available.

JUST FOR FUN

Just for Fun Answer (puzzle on page 26)