GROWING KNOWLEDGE

Series content is coordinated by Dr. Lloyd Nackley, associate professor of nursery production and greenhouse management at Oregon State University in Corvallis, Oregon.

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Smarter air blast spraying

Dr. Heping Zhu stands beside an early "Doc Ock" prototype of the Intelligent Sprayer System during field testing. With its conspicuous collection of hoses, wires, sensors, and controls, the experimental system helped demonstrate the potential for precision spraying in specialty crops. PHOTO COURTESY OF OREGON STATE UNIVERSITY

What nearly two decades of intelligent sprayer research have taught us

BY LLOYD NACKLEY

One of my earliest field experiments after arriving at Oregon State University found me walking nursery rows with two people who knew far more about pest management than I did: nursery IPM specialist Robin Rosetta and plant pathologist Jay Pscheidt.

We were setting out small pieces of yellow water-sensitive paper — tucking them deep inside branches, behind leaves, and into the difficult places where insects might hide or fungal diseases might develop. When spray droplets hit the cards, yellow turned to dark blue, giving us a simple way to see whether the spray had reached its target.

The cards were simple. The machine coming down the row was anything but. Hoses and wires seemed to emerge from everywhere. It was a research prototype, and it looked like one. Somewhere along the way, we started calling it Doc Ock, because to us it resembled the many-armed Spider-Man villain Doctor Octopus.

But behind that ungainly machine was an elegant idea. Instead of driving through a nursery spraying every plant and every empty space at the same rate, what if the sprayer could actually see the crop in front of it? Could it recognize a large tree from a small one, adjust for differences in canopy density, and shut individual nozzles off when there was nothing there to spray?

From 'What if?' to 'You can buy one'

The Intelligent Sprayer project began in 2009 under the leadership of USDA »

The Red Robin, one of two Intelligent Sprayer research platforms developed and operated by Oregon State University, during field trials at a commercial Oregon nursery. Long-term partnerships with growers have been instrumental in moving intelligent spraying from experimental prototypes to practical commercial adoption. PHOTO COURTESY OF OREGON STATE UNIVERSITY

Agricultural Research Service Agricultural Engineer Dr. Heping Zhu. Zhu and a large group of university, industry, and grower collaborators were trying to bring precision agriculture to specialty crops, where the targets can be remarkably complicated.

Think about a nursery row over the course of a growing season. A recently planted tree may have only a small canopy. A few months later, that same tree may be substantially larger. One cultivar may be narrow and upright while the next is broad and dense. There may be gaps between plants, missing trees, or large differences in foliage from the bottom to the top of the canopy.

A conventional air-blast sprayer doesn't recognize any of those differences. Once calibrated, it applies according to the settings we give it.

The intelligent sprayer system added another source of information: the plant itself. Using LiDAR (light detection and ranging), the system scans the crop as the tractor moves down the row. Those measurements describe the size, shape, and density of the canopy. The control system then uses that information to adjust individual nozzles in real time. More canopy can receive more spray. Smaller canopies receive less. When there is a gap between plants, nozzles can shut off.

Today, that explanation doesn't sound especially futuristic. Nearly two decades ago, it did. Looking through old issues of *Digger* now is a little like flipping through a family photo album. The equipment changes. The questions change. Some familiar faces disappear and new ones arrive. But you can watch the idea mature almost year by year.

In November 2012, Robin, Heping, Sam Doane, and Derek Wells introduced *Digger* readers to the technology with a wonderfully simple question: What if a sprayer could "sense" when a plant was present?

A year later, *Digger* announced that a new version had arrived in Oregon. The earlier ultrasonic sensors had given way to more precise laser sensing, and prototypes were being tested in commercial nurseries, including Hans Nelson & Sons and J. Frank Schmidt & Son.

By 2015, Robin was writing about whether intelligent spraying could pass a much more important test: could we reduce pesticide use without sacrificing pest control? In 2017, the Oregon Association of Nurseries was calling the technology a potential "game changer." And then, in 2018, came the headline researchers developing agricultural technology hope someday to see: *Smart sprayer becomes commercially available.*

In six years of *Digger* stories, the question had gone from "*What if*?" to "*You can buy one*."

Learning to spray less

One of the deceptively simple ideas behind intelligent spraying is that not every gallon leaving a sprayer is doing useful work.

Growers aren't spraying air, soil, or the gaps between trees because they want to. Those losses are partly a consequence of trying to deliver enough pesticide into complicated plant canopies to protect the crop. And using less material isn't an accomplishment if the result is more insects, more disease, or an unmarketable plant.

So the real question was never simply whether intelligent spraying could reduce spray volume. It was whether we could spray less and still grow the same healthy crop.

Answering that required years of experiments across different crops, pests, diseases, canopy sizes, and production systems. It also required commercial nurseries willing to let researchers bring prototypes

USDA-ARS researchers fine-tune a newer generation of the Intelligent Sprayer System, retrofitted onto a conventional air-blast sprayer. The retrofit uses LiDAR technology to detect plant canopies and control individual nozzles, adjusting spray applications as the sprayer moves through the crop. PHOTO COURTESY OF OREGON STATE UNIVERSITY

onto their farms and find out whether an idea that worked on paper could survive the messiness of actual production.

Dan and Jesse Nelson at Hans Nelson & Sons have been among the project's longest-standing Oregon partners. Their nursery became a place where prototypes could be tested, adjusted, demonstrated, and tested again. Many other Oregon growers have participated over the years as well, providing something researchers can't reproduce at an experiment station: the complicated reality of a working nursery.

Gradually, the evidence accumulated. Across specialty crops, intelligent spraying has maintained effective pest and disease control while substantially reducing spray volume and off-target losses.

In our work, variable-rate spraying applied 67–74% less volume in orchard systems and 61–80% less in vineyards than conventional applications. Other research has documented reductions in airborne drift of up to 87% and ground losses of up to 90%.

Those numbers are impressive, but I think the more intuitive way to understand the technology is that more of what is sprayed is being directed toward the target rather than the spaces around it.

Efficiency becomes economics

Eventually, every promising agricultural technology runs into another important question:

Does it pay? An economic analysis from Ohio provided one useful example. Researchers comparing conventional constant-rate spraying with retrofitted variable-rate spraying in apple orchards estimated annual savings of approximately \$574–\$708 per acre.

Those estimates didn't include the potential value of reduced drift, ground losses, or fuel use. At the scale of a commercial operation, those savings can add up quickly.

At North Willamette Research and Extention Center, Bruce Sorte, Oregon State University economist, took the thought experiment one step further and asked what relatively modest production savings could mean across Oregon agriculture. Crops potentially suited to variable-rate spraying account for more than \$1.75 billion in sales in our seven-county region.

In one economic scenario, we assumed only a 5% reduction in production costs, adoption on half of applicable production, and reinvestment of those savings back into the operations. The potential regional economic impact exceeded \$77 million.

That doesn't mean intelligent sprayers have already put \$77 million into growers' pockets. Rather, it demonstrates something more useful: even relatively small improvements in efficiency become consequential when multiplied across a large specialty crop industry.

And the savings aren't only measured in dollars.

Less material leaving the sprayer means less potential for drift, less pesticide reaching the ground, less carrier water being hauled through the field, and less wasted product. The economic and environmental benefits aren't competing outcomes. In this case, they come from the same basic idea: put the material where the plant is.

The project grew more than a sprayer

Maybe the easiest way for me to appreciate how much time has passed isn't to look at the equipment at all. It's to look at the people.

Robin and Jay, who were beside me during those early Oregon experiments, have since retired. Brent Warneke joined our program as an M.S. student and has » since earned his Ph.D. Brian Hill arrived as an M.S. student and went on to spend five years with us as a research assistant. Dr. Melissa Scherr brought her expertise as a postdoctoral entomologist and is now teaching at Linn-Benton Community College.

The same thing has happened across the larger collaboration. At the University of Tennessee, professor Amy Fulcher has continued advancing intelligent spraying while training another generation of researchers, including M.S. graduate Lauren Fessler Mathews.

At USDA-ARS, Adam Clark continues the engineering work alongside Heping Zhu, whose leadership has kept researchers, growers, universities, and industry partners working on the same problem across crops and across the country.

Somewhere along the way, a project designed to develop an intelligent sprayer also developed next-generation scientists. That's an important part of the return from sustained agricultural research, even if it doesn't fit neatly into a graph of pesticide savings.

Federal investment, through the USDA-ARS *Integration of Intelligent Spray Technology into IPM Programs in Specialty Crop Production* (USDA-ARS Project Number 58-5082-2-010) provided more than equipment. It has also supported graduate students, postdoctoral researchers, experiments, Extension demonstrations, grower partnerships, and years of accumulated knowledge about how precision spraying actually works.

When 'innovative' becomes ordinary

Today, intelligent spraying has entered a very different phase. Commercial systems are demonstrated at agricultural expos. Smart Apply Systems and equipment dealers such as Papé Machinery bring systems directly to growers, and Oregon State continues to evaluate and demonstrate the technology.

The crops have expanded too. Intelligent spraying systems have been tested and adopted in nurseries, apples, grapes, citrus, pecans, and other specialty crops.

Here in Oregon, we're seeing growing interest in young hazelnut orchards, where small developing canopies separated by considerable empty space make the logic of variable-rate spraying particularly easy to see.

Oregon State University researchers tuck yellow water-sensitive spray cards deep within the canopy of nursery shade trees. The cards change colour when struck by spray droplets, allowing researchers to evaluate whether applications reach difficult areas where insects and plant pathogens may be found. PHOTO COURTESY OF OREGON STATE UNIVERSITY

Some larger orchard and vineyard operations now run fleets of intelligent sprayer systems. Perhaps that's the clearest evidence of how far the idea has come.

Nearly 20 years ago, researchers were asking whether a sprayer could detect a plant. A decade ago, I was standing in an Oregon nursery with Robin and Jay, tucking yellow cards behind maple leaves while an ungainly prototype covered in hoses and wires worked its way toward us.

Today, growers can walk into an agricultural equipment demonstration and watch a commercial version do essentially what those early researchers imagined.

That doesn't happen just because someone has a good idea. Agricultural innovation is slower and more communal than that. It takes engineers willing to build prototypes, growers willing to test them, scientists willing to repeat experiments, students willing to spend long days collecting data, public agencies willing to sustain research, and eventually commercial partners willing to turn a promising technology into equipment that has to work on Monday morning when a grower needs to spray.

In 2012, a *Digger* article like this one asked whether a sprayer could sense the plant in front of it and apply only what was needed. Nearly two decades of research have moved us beyond that question. Today, intelligent sprayer systems are working in commercial nurseries, orchards, and vineyards, and we're asking what else those sensors can tell us.

Can the same LiDAR that guides a spray application also count trees, measure their growth, and help growers make better irrigation and fertilizer decisions? Can we combine information about the crop and soil to manage individual blocks more precisely? And, increasingly, can autonomous tractors do some of this work while keeping people farther away from pesticide applications?

Twenty years ago, Dr. Zhu and others set out to build a more intelligent sprayer system. Today, we're asking whether the intelligence riding through the nursery can help us manage even more than spraying.

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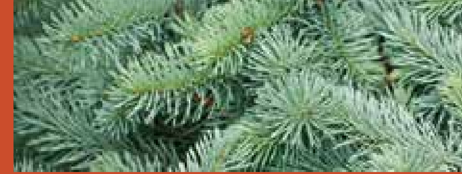
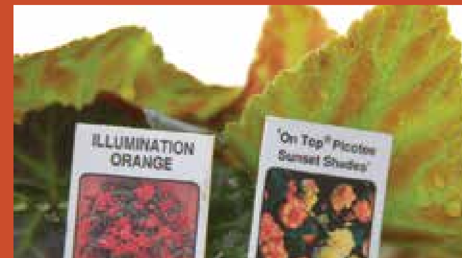

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