How Computers are Being Used to Hack Grapes

BY STACY BROOKS

Left: Dr. Bruce Reisch, professor at Cornell AgriTech's Horticulture Section, School of Integrative Plant Science / Right: Dr. Avinash "Avi" Karn, computational biologist, and Dr. Fred Gouker, project manager, at Cornell AgriTech

It's a familiar sight at universities and oenology institutions across the country: rows of grape vines that represent years of work, each with the hope to change the wine industry for the better.

At first glance, it doesn't seem like grape-breeding techniques have changed much over the centuries. Breeders fertilize one vine with the pollen of another, hoping to create offspring that will resist disease and produce quality grapes.

But behind the scenes, grape-breeding research relies increasingly on computers that analyze genetic data. The hope is that this will increase the rate at which new grape varieties are developed and ensure the vitality of the winemaking industry.

"I use the analogy of 23andme when I try to explain what we are doing," says Dr. Dario Cantu, associate professor of viticulture and enology at University of California, Davis. "All these companies that give your ancestry and your likelihood of getting sick from some diseases—I think that's what we're doing, using similar tools as these companies to quickly understand genes in Italian grapes."

Dr. Cantu uses computers to analyze the genetic makeup of wine grape cultivars to understand the differences responsible for various characteristics. Breeders can then attempt to combine desirable traits to create original varieties that may be more resistant to disease and drought, and offer new, unique flavors.

"I'm not a breeder myself," says Dr. Cantu. "I collaborate with Andy Walker [a fellow faculty member at UC-Davis]. He's the breeder. We complement each other in the sense that he's the traditional breeder and I'm the computer guy, so I help him understand the genetics of some of the traits he's interested in.

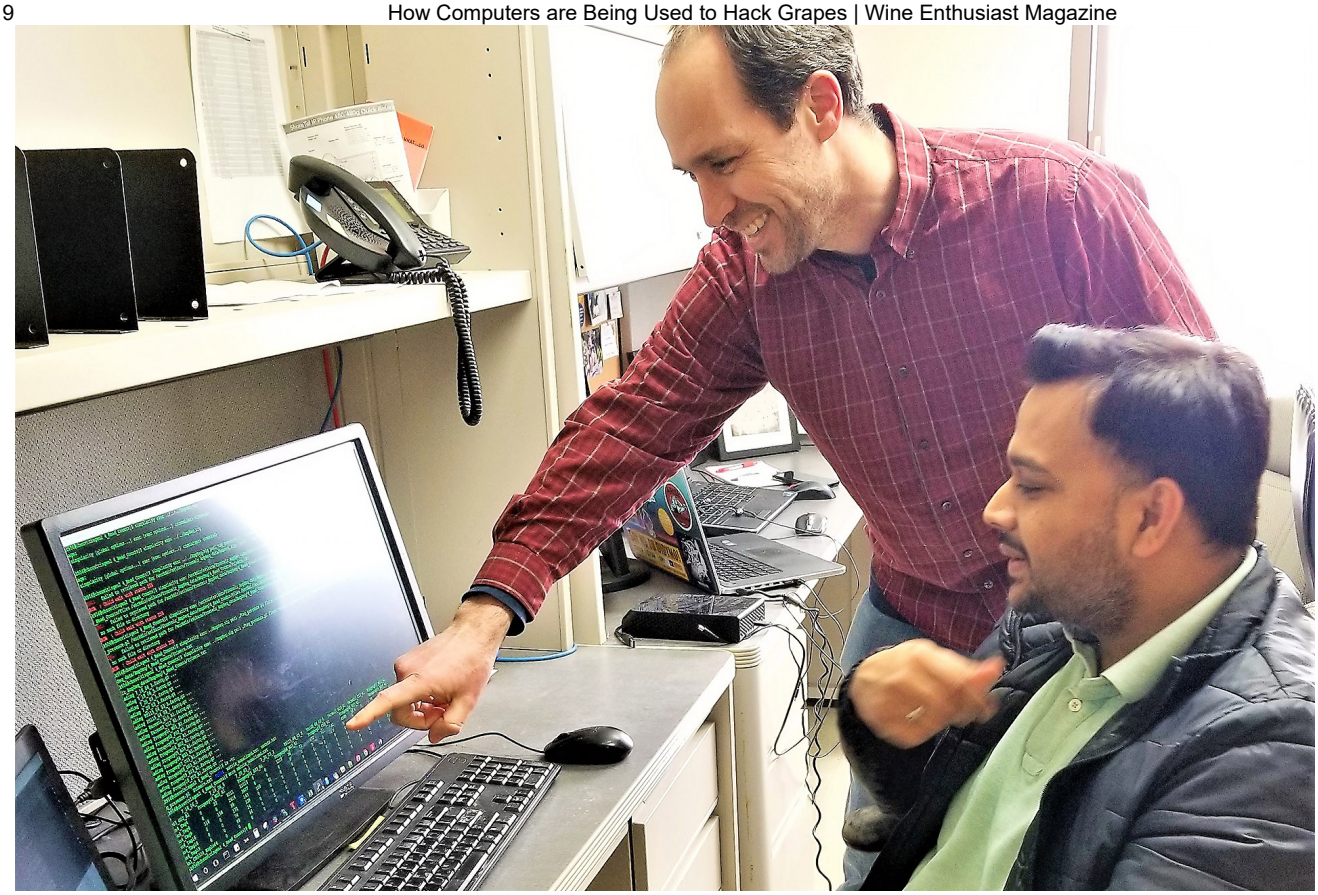
"So what Andy does is screen natural populations of wild grapes for disease resistance —to powdery mildew, etc.—and then he tries to introduce those traits into cultivated varieties. I help him understand the genetic basis of those traits."

Making grapes the old-fashioned way

Traditionally, a breeder would select two parent plants with desirable traits, or phenotypes. For example, one parent might have large grapes, but poor disease tolerance, while the other may have smaller grapes, but be resistant to powdery mildew. In this instance, by crossing these plants, breeders would seek an offspring that possessed the desirable traits of large berries and disease resistance.

Once the breeder has used the pollen from the male parent to fertilize the female parent, the resulting seeds are planted. It will take four to six years for the plants to bear fruit and be evaluated.

The catch? It's not guaranteed that any of the offspring will inherit the desired trait. Potentially, years of work could literally prove fruitless.



Dr. Lance Cadle-Davidson (standing) and Dr. Avi Karn, analyzing large scale genetic data for favorable grape traits

Giving nature an upgrade

Marker-assisted breeding is a way in which computers are used in grape research, a central part of the VitisGen2 Project. This method uses DNA data to help breeders choose which grape seedlings to keep. The goal is to develop plants with better-tasting grapes that are more disease and pest resistant.

"In grapevine breeding programs, we have so much data," says Dr. Avinash Karn, a postdoctoral research associate of computational biology and quantitative genetics at Cornell University. "There's genetic data, which includes DNA sequencing data, and phenotype data. Phenotype data can be [physical traits like] disease resistance, fruit quality or adaptations like cold tolerance."

Karn says that high computing power is crucial to analyze the staggering volume of information generated from a program like VitisGen2.

Marker-assisted breeding seeks to streamline the breeding process. First, researchers collect phenotype and genetic data for specific grape vines. The information is put into a database, and researchers use tools to determine which genetic sequence, or marker, is associated with a particular trait. Then, by looking for that marker in a plant's DNA, they can determine if it possesses the desired quality.

Karn compares the process to skimming through a book and looking for a few key words instead of reading the entire text.

Once the desired trait has been identified, breeders make a cross using conventional techniques and plant the resulting seeds. Instead of waiting several years until the vine bears fruit, breeders can see if the vines carry the desired gene within months.

Once the seedlings are a few months old, the leaf tissue can be analyzed to see if the plant inherited a particular DNA marker. If it does, the breeder can continue to grow the vine. If not, it can be discarded.

"[Marker-assisted selection] will help the breeder save time, money and space," says Karn. "That's the big difference, in using all this information and analyzing it, over any conventional [breeding] method."

What does the future hold?

How will computer-assisted grape breeding affect wine consumers? Karn says that vines that are resistant to diseases or better adapted to a changing climate will ensure that winemakers have the grapes they need to meet increasing consumer demand.

"I would say the work we do is definitely going to help the [grape] breeders, by saving time and money and [helping them in] making more efficient decisions," says Karn. "They are going to be able to deliver a better product, which will help produce better quality wine."

Dr. Cantu says that in addition to the development of new grape varieties, it's important to understand the genetic material of existing, but lesser-known, cultivars.

"We talk a lot about how climate change will ruin viticulture and winemaking, but we can explore the available cultivars," he says. "There are thousands of them out there. There are [some] that have been adapted to be cultivated in very hot and dry climates, like southern Italy or southern Spain. They are much better adapted to the environment we're facing now, and maybe even more to the one we're facing in the future.

"What we find on our shelves will have different names and different labels. But it may be even better than what we have right now."

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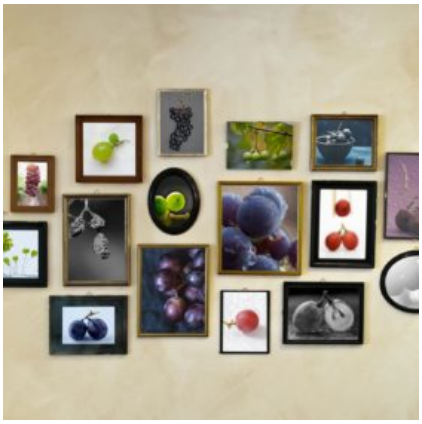

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