Rethinking Water

Canada's farm country is vastly different from California's, especially when it comes to climate and water shortages. But California offers a lesson to anyone in the business of farming: when water is in short supply, you need to innovate.

NAPA, Calif. – As he gazes over the ordered rows of grape vines framed by a postcard-perfect view of the famed Napa Valley, Benoit Touquette talks of depriving his grapes of water.

"We want to be on the edge – this is where we want to play," says the transplanted French winemaker. "Too much stress is not good, but it is not good to have too little (stress) either."

In California, virtually every farmer constantly worries about not having enough water. So to talk of deliberately depriving (albeit temporarily) plants of water is more than a bit unusual. But on Hartwell Estate and 31 other vineyard locations in the Napa Valley, winemakers like Touquette are exploring an uncharted frontier – trying to discover a way to "train" their grapevines to use water more effectively.

Their explorations may one day change the way we think of water use in agriculture.

For the moment, the focus is almost entirely on grape vines and inducing short periods of water stress in order to produce smaller but more flavourful grapes. Elite wineries such as Hartwell (which sells most of its wines for more than $100 a bottle), have been the first to invest in the sophisticated technology it takes to manipulate their vines by first restricting and then providing the right amount of water at just the right moments. But research is also underway on using the technology on olive trees and, if successful, will likely be expanded to other perennials. It's too early to say if it might yield lessons for irrigated annuals, much less field crops, but it seems certain to at least challenge the current beliefs about how all plants use, and misuse, water.

The heart of that technology is a water-measuring device called a sap flow sensor. Developed by two other young Frenchmen who emigrated to California, the device essentially consists of temperature-sensitive sensors embedded in a small heating sleeve that wraps around a section of a vine. By measuring temperature changes at both ends of the sleeve, the sensors determine how much water, or sap, is flowing through the vine. This data is then wirelessly transmitted on a nearly continuous basis to a computer. The computer combines that information with up-to-the-second weather data and then uses complex algorithms to determine transpiration rate and, hence, the precise degree of water stress that vine is undergoing at that moment. Depending on vineyard uniformity, a set of four sensors can be enough to give you an extremely accurate profile, on a near-continual basis, of a vineyard up to 30 acres in size.

At first glance, this may seem like just a technological step up from soil moisture meters and other methods for telling when a plant is thirsty. But there's much more going on here.

Let's say there's a heat wave, and temperatures have soared past the 40-degree mark – which is not uncommon on the steep, rocky slopes of the extinct volcano where high-end wineries such as Hartwell have carved out international reputations for fine wines. In such conditions, you would normally take a look at the thermometer or take a few soil moisture readings and say, 'These plants must be frying in this heat. Turn on the irrigation pumps.'

But then what? How much water should you put on? A little bit today and then some more in few days? A good soaking? Maybe just a bit every day?

A temperature-sensitive sensor measures the transpiration rate of the vine and wirelessly transmits that information in real time to a nearby computer. Complex algorithms use that data and current weather info to precisely measure water stress. Depending on how uniform the vineyard is, four sensors can profile up to 30 acres of grapes.

Graphics courtesy of Fruition Sciences.

These are vital questions in this arid valley, where vineyards collect runoff during the winter rains and store it in reservoirs. Typically, they'll capture enough to put on between 100 and 200 millimetres of water per acre the following summer. Once that's gone, there's no more.

So being able to get, as they say in California, "more crop per drop" is something every grower in this state agonizes over all the time. Sensor technology is opening a door that has, until now, been firmly nailed shut.

"This is a big shift in the way we think," says Thibaut Scholasch, co-founder of Fruition Sciences, which developed the algorithms and combined it with sap flow sensors to create this new technology.

"With this, we can now think of the plant as a sensor itself. So instead of having soil sensors or thermometers or relative humidity sensors and using them to guess how the plant is doing, we use the plant itself to measure how the environment is affecting it.

"So now we can ask questions that we could never imagine before, such as: What happens to the vine on a hot afternoon and what are the consequences in terms of yield and quality? This is a big step forward."

To put it another way: Right now our understanding of how a plant uses water is quite primitive. We know a severe lack of water causes plants to wither and divert all their resources to staying alive, rather than producing a bountiful harvest. At the other extreme, we know plants don't make smart choices when water is in abundance. They will ignore fruit development in favour of vegetative growth – a 'choice' that will put them in even worse trouble if the supply of water abruptly dries up.

"For plants, water is addictive – the more water you give a plant, the more water it needs," says Scholasch. "Using a sensor to monitor a vine's water use allows you to train a plant to use less water. So you can break this vicious cycle."

Vicious isn't a bad choice of words to describe Touquette's introduction to California viticulture.

A rising young star in the winemaking world, Touquette was recruited by Hartwell in 2007 and arrived in Napa in time to lose 40% of his first crop because of a lack of water.

"In a heat wave, I can lose my grapes in three or four days – it was crazy," says the 33-year-old.

Touquette believed there was a better way – the way of science. He and his crew first dug a bunch of nine-foot-deep test pits so he could see what the vines' roots were up to. He found they only penetrated five feet down – instead of the normal eight – because of a highly acidic band of soil. To lower the pH in that band, he applied 20 tonnes of lime per acre on the 23-acre vineyard. He also changed the pruning methods, selecting straighter offshoots so that fewer bends in the vine would constrict water flow and encourage an overhead canopy of leaves to shade the grape clusters.

But Touquette wanted to go further.

"I believe we are wasting water because we don't know what the plants need," he says. "This is why I wanted to monitor the sap in the vine."

Precise readings of transpiration rates can tell you a lot. Transpiration takes place when tiny pores on a plant's leaves, called stomata, open so it can take in air carbon dioxide and emit oxygen (it needs the carbon dioxide from the air for photosynthesis, which produces oxygen as a by-product). But along with the oxygen, water vapour also escapes, or transpires, from the plant. Measuring the rate of water vapour emissions gives a very accurate picture of what the plant is up to on a biological level.

What Touquette found was that his vines' water conservation abilities aren't that great, at least in the short term. Give them a little bit of water and they open up their stomata in order to inhale the CO2 they need to produce foliage. That, of course, sharply pushes up transpiration rates and sends a signal to the roots to suck up every droplet of moisture that has just been applied. If moisture is limited – say, if only a few millimetres of irrigation water have been applied – the soil rapidly dries out again.

"So very quickly the vines would find themselves in distress again and they would freak out, and begin to shut everything down," says Touquette.

"The plant (initially) acts as though it has lots of water when it doesn't. Then it goes to the other extreme and you end up with raisins unless you apply more water right away."

The surprise was that – under the right circumstances – vines could actually break out of this rollercoaster of initially soaking up water as if the supply was endless and then flipping into a dying-of-thirst mode.

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Replacing instinct with science

Benoit Touquette next to a weather station/wireless transmitter for a sap-flow sensor.

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When Touquette gave the vines a really good soaking, they would first go growth crazy, then 'freak out' when moisture immediately next to the roots was depleted, and finally take a middle road of moderate leaf, stem and fruit growth combined with root growth to go after the remaining soil moisture.

"When we put more water on, the plants go through this pattern," says Touquette. "They first use too much water and freak out on the third day. But then they recover and begin to regulate themselves."

Napa Valley grape growers typically dole out their water 10 millimetres at a time, which means, you can make 12 or 15 such 'withdrawals' from your 'water bank' each growing season. Deciding to put on two or three times that amount takes guts and is not a bet you'd make unless you knew it would pay off. The sensor technology gives him that confidence, says Touquette, adding it also allows him to develop a site-specific irrigation plan that precisely varies watering according to slope and orientation to the sun.

"Before, I would be praying," he says. "Now I know what is going on, what the vines can handle, and how to apply my water to get the most benefit.

"Some say, 'It's going to be 104 degrees Fahrenheit and so I'm going to put on 10 millimeters of water' And I'll say, 'No, this is the worst thing you can do.'"

On yield alone, he can point to impressive results. In 2007, grape yields at Hartwell averaged 1.7 tonnes an acre. In 2009 – another dry year – the harvest rose to 2.8 tonnes per acre.

Word is catching on. Hartwell was one of the first Napa Valley vineyards using Fruition Sciences system. Now there are 32 systems installed in the valley, along with one in another winery south of San Francisco and two in France.

"Napa will lead the way," says Touquette. "It is a new approach, a scientific approach. No longer do you just have to go on instinct."

Useful links:

fruitionsciences.com – Includes details on how the sensor system works and news articles in both English and French.

hartwellvineyards.com – website of Hartwell Estate.

If Touquette has his way, the breakout will come next year with the release of the first vintages produced with the new technology. Improved yields and water efficiency are important, but the big prize in Napa is better grapes.

While he doesn't want raisins, Touquette's water rationing can be used to produce smaller grapes with more concentrated flavour. Hartwell has a good standing among wine connoisseurs, but it's not in the most elite leagues – yet. The young winemaker believes that will change, beginning with his 2011 vintages.

"I know what it (sensor technology) has allowed me to do in this vineyard," he says. "I know that between 2006 and now, it is like night and day. It has changed that much."

"Better wine is made from water-deprived vines," says Scholasch, a winemaker himself before starting Fruition Sciences. "With this technology, we can ensure we are constantly optimizing the level of water deprivation."

Like his compatriot, Scholasch speaks of grape vines as if they are almost sentient. He says scientific estimates based on temperature and evaporation rates greatly overestimate the amount of water a vineyard actually needs.

"The real measurements (taken in vineyards like Hartwell) are 20% to 25% below what classic scientific model would predict," he says. "A plant is much smarter than we have traditionally thought. Yes, its water needs are determined by the sun and temperature, but it can also regulate how much water it uses to conserve more water."

"We are showing this is true for vineyards and there is a high probability that this is true for many other perennial crops."

How far it goes beyond that is anyone's guess. But 8,000 years after ancient Mesopotamians invented irrigation, we've found a brand new way to measure its effectiveness.