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Soil mapping in the Napa Valley as related to vineyard establishment and management.

Soil mapping in the Napa Valley as related to vineyard establishment and management.

The focus of this issue is on vineyard management. See pages 4–15, 31–38, and 40–43.
Managing soil quality in Mid-Atlantic vineyards

By Gill Giese, viticulture instructor
Surry Community College, Dobson, NC

Soil is derived from a parent material (rocks of various geologic origins) that is in turn impacted by climate (temperature, water, ice, wind, etc.), time, organisms, geography, and human activity. For some viticulturists, soil is the growing medium that provides anchorage, water storage, and nutrients. To others, it provides more and may be referred to as terroir.

Terroir, originally a French term in wine, coffee, and tea, is used to describe special characteristics that geography bestowed upon these products. Loosely translated as “a sense of place,” it is the sum of the effects that the local environment has had on the manufacture of the product. Terroir is the basis of the French wine Appellation d’Origine Contrôlée (AOC) system that has been the model for appellation laws across the globe. This model assumes that the land on which grapes are grown imparts unique qualities to the wine that is specific to that region. Some of the most important factors influencing grape composition and the resulting wine quality depend on a soil’s characteristics and properties, the cultivar/rootstock combination being grown, and the climate both are exposed to. In broad terms, terroir may be described as the combination of climate, topography, and soils; and, some would argue, the human interaction or management of all three. The word terroir is used easily by some and is overused and underdefined by others.

Grapevines can thrive in “poor soil” that others would describe as part of a “good or high quality terroir.” Much of viticulture is concerned with defining exactly what a “poor soil” or “good terroir” is since these are typically associated with some of the “best” or “quality” (place of production, aroma, bouquet, balance, personality, and character) wines. These terms are somewhat subjective, but they tend to influence price. Or maybe price influences perception of quality!

This article is concerned with the soil as a growing medium for wine grapes in the eastern United States and seeks to introduce how a vineyard soil should be sustainably managed to produce the grape crop required for the desired quality and style of wine desired.

What do grapes need?

Let’s review the nature of grapevines and their soil requirements:
The grapevine is a long-lived perennial woody liana (30–50 year commercial life).

Grapevines are deep rooted and will explore most of the soil available.

Soil water and nutrients drive vine vigor, which influences vine balance (relative amount of vegetation and fruit) and berry yield and composition.

Soil pests and diseases that can affect vines include nematodes, phylloxera, and downy mildew spores.

Famous regional soils include chalk in Champagne and Chablis and schist in Mosel. But the ability of specific cultivars to perform on specific soils is mainly circumstantial.

Soils are characterized within three parameters: physical, chemical, and biological.

The physical character of soils includes its structure, drainage characteristics, and water-holding capacity. Vines on soils that drain adequately in 24 hours will not be as adversely affected by heavy rains or drought as those that are on soils that are very shallow or less well drained. Both of the latter soil scenarios can promote berry cracking and, consequently, increased incidence of bunch rot. Diversion ditches, drain tiles, and deep ripping may improve drainage.

Chemical factors impact nutrient management for a soil. Are adequate nutrients present and available to support vine growth? Are there excessive levels of nutrients that could cause possible toxicities?

The biological character of a soil includes organic turnover and some nutrients. A soil’s biological status will impact water infiltration rate, general tilth, and the biodiversity that is required for sustained yield and vine life.

Some wine and vine properties that are often related to soil properties and can be measured include: vine survival and growth, vine balance, berry composition, and wine flavor, quality, and price. To what degree does soil influence each of these? The connection to price and quality is a distant one. In contrast, soil properties do have a direct connection to vine survival and growth, which in turn, affects berry composition and flavor.

Soil water relations affect vine survival, growth, and berry composition. The amount of available water and percentage of air that impacts soil drainage and consequent root growth will affect berry composition. Toxic substances in soils—heavy metals, high magnesium level, too much salinity, etc.—will play a role in vine health.

Other considerations include bulk density and soil porosity, the bacterial activity in the soil that leads to fertility, and the effects of pH. Water retention of a soil is important in dry-grown vineyards and is improved by increased organic matter and mulching.

Soil is a reservoir for water. Soil water is necessary to sustain plants between rainfall or irrigation events. By holding water for future use, the soil buffers the plant–root environment against periods of water deficit. In the eastern U.S., excessive soil available water that leads to excessive vegetative vine vigor is a common problem. However, in areas where vines remove more water than is supplied by precipitation, the amount of water held by the soil and available to vines may be critical.

Available water capacity increases with increasingly fine-textured soils. Coarse-textured soils (sandy soils) have a lower field capacity due to the high percentage of large pores subject to free drainage. The field capacity of fine-textured soils is greater due to their small pores that hold water against free drainage. Compared with a well-aggregated loam or silt loam soil, available water of clay soils tends to be lower since these soils generally have a greater matric potential (essentially holding
the water more tightly in comparison with sandier soils) and increased permanent wilting point.

**Rootstock choice is a critical decision**

The root louse phylloxera is the primary reason that *Vitis vinifera*, the traditional European wine grape, is grafted to rootstocks. These rootstocks are derived from several *Vitis* species native to North America and possess various degrees of resistance or tolerance to phylloxera. Phylloxera is assumed to occur in any potential vineyard soil and can devastate a planting of *Vitis vinifera*. Rootstocks are the foundation that serve as biological and physical support and interface between one’s soil and scion variety. Since no rootstock is perfectly suited to a given variety and soil, the best choice when choosing a rootstock is to avoid a bad choice. To do this, one should consider the following:

- soil borne pests: phylloxera and nematodes;
- potential vigor of vines;
- site climate;
- scion variety (its compatibility with the rootstock, possible latent viruses that may express themselves with some rootstocks and not others, etc.);
- soil type and conditions (fertility, pH, drainage, etc.);
- desired yield and quality;
- training and vine spacing; and
- water availability and irrigation regime (drought tolerance of the rootstock).

Rootstocks perform differently depending on the scion variety, cultural practices, and environmental conditions. One can select several rootstocks to manage this variability in different sections across a given vineyard. The impact of soil type on rootstock choice is dictated by salinity, acidity, limestone, and climate. Salinity in soils is typically not a concern to East Coast growers. High rainfall and humid conditions, for the most part, prevent high salinity buildup in eastern soils. Excessive vine vigor due to ample rainfall, deep soils, and humid growing conditions is common in East Coast vineyards. Although no rootstock will control scion vigor completely, there are relative differences in the amount of vigor a rootstock will impart to a scion. Growers typically select less-vigor-inducing rootstocks. If the region in which a given variety is being grown is at its cool limit, then a short-season rootstock should not be used.

Systematic research over time on which rootstock performs best under East Coast conditions is currently lacking. However, there are some rootstocks that are more commonly used. State viticulturists or private consultants can provide more insight and advice on a rootstock choice for a particular site.

**Soil testing for vineyards**

Factors routinely tested in a submitted soil sample include:

1. **Soil class:** mineral, mineral organic, or organic.
2. **Humic matter percentage (HM%):** organic matter that has decomposed to humic and fulvic acid. The HM% can affect herbicide and lime rates.
3. **Weight per unit volume (W/V):** impacts soil texture. Sands can be compacted and weigh about 1.5 g/cm³ while silt and clay loams weigh about 1.0 g/cm³.
4. **Cation exchange capacity (CEC):** indicates the extent to which a soil can hold and exchange basic cations such as Ca, Mg, and K. CEC will vary with pH, organic matter content, and soil texture (clay will have a higher CEC compared with sandier soils). A soil with a high CEC can prevent leaching of nutrients, but they may be so

Photo by Bob Nichols (USDA-NRCS).
tightly held as to be unavailable to plants.

5. Base saturation percentage (BS%): the portion of the CEC occupied primarily by the nutrient cations Ca, Mg, and K. High base saturation percentages are desirable since this indicates a ready supply of nutrients.

6. Exchangeable acidity (Ac): indicates the portion of the CEC occupied by acidity factors such as hydrogen and aluminum. This should increase as pH decreases.

7. pH (hydrogen ion concentration): an index of active acidity in a soil. This scale ranges from 1 to 14, with 7 being neutral. Most soils will be in the range of 3–8. Weather, cultural practices, and additions of lime and fertilizer cause pH to fluctuate.

Seasonal management decisions such as tillage, application of fertilizer and organic matter, or cover cropping can alter soil characteristics. Soil is often manipulated in order to initiate changes in vine growth. Growers till soil to manage weeds, incorporate lime, seed cover crops, and add fertilizer and/or apply irrigation. These activities impact soil structure; especially if compaction is caused by farm machinery.

To understand the effects of vineyard management on soil quality, one must first measure soil quality factors and interpret numerical data and physical evaluation against a reference. Soil pH and mineral nutrient levels are important for vine health and productivity; however, those topics are well covered in existing literature. Guidelines for optimum lime and fertilizer applications have been established.

Other soil factors

Less frequently analyzed numerical measures are: CEC, soil organic matter (SOM), soil texture and bulk density, and soil microbial activity (SMA). Soil texture, pH, and SOM all influence the CEC. The texture, or percentage of sand, silt, and clay content of a soil, does not change within the lifetime of a vineyard, provided erosion does not occur. Thus, a one-time measurement of soil texture is sufficient. A clay soil will have a relatively higher CEC compared with a sand or silt soil because the structure of clay offers more surface area than does silt or sand. Practices that increase organic matter content or soil pH will increase CEC. Tracking soil CEC over time is useful for understanding changes in soil quality with respect to nutrient availability. This track record is generally available since the CEC is almost always included in a standard soil analysis.

The typical SOM of vineyards in the Mid-Atlantic falls within the range of about 2 to 6% and is most commonly measured by oxidation of carbon. Organic matter is a mixture of living organisms (roots and microorganisms), dead organisms (plant/root debris and dead microorganisms), and humus, which is a well-decomposed form of SOM. Humus consists of large, complex, and stable organic molecules that are resistant to further decomposition. Humus is very important to soil quality. Its complex structure holds more water, nutrients, and chemicals compared with clay and strengthens the soil structure.

A fertilizer regime that simply adds specific cations (i.e., Ca, Mg, and K) may, in the long term, be less efficient than an approach that retains nutrients in the organo-mineral complex of the soil. Nutrients associated with clay minerals or humus are less likely to become leached or eroded from surface soil. Enhancement of nutrient availability is ensured by maintaining a near neutral soil pH (about 6.0–6.4). The humus component of SOM indirectly affects nutrient availability by binding more strongly with aluminum and other heavy metals than with macronutrients, which will increase nutrient availability even if soil pH does not change.
The physical soil characteristic of bulk density is measured from intact cores of soil. Intact, “undisturbed” soil cores retain their natural structure and the volume of the soil composed of air space. Once bulk density is determined, soil porosity can be calculated; soil porosity impacts the soil’s water infiltration rate and drainage qualities.

Drainage is the most important physical soil quality factor associated with vineyards. It is recommended that a vineyard have soil that is well to excessively drained. The surface drainage of a vineyard soil will depend largely on the degree of slope on which it occurs. Vineyards should be planted on sloping sites of 7–20%. Internal soil drainage depends on soil pore size. Large pores will drain excess soil moisture more rapidly than will small pores. As water drains from soil, pore space is filled by air, and roots commence growth. If bulk density increases over time due to compaction, this air space will be decreased. Additionally, continuous cultivation of soil may decrease the number of large pores, leading to decreased water drainage and root growth. Management practices that encourage earthworms and fungi in soil, decrease soil compaction, and increase the growth of roots are important for sustaining bulk density.

The SMA, especially in the vine row, plays an important role in decomposing organic matter into humus, providing nutrients, and improving soil structure. Some land grant college and state laboratories will perform specific analyses to determine quantities of soil organisms that affect plant health; most notably, plant pathogenic nematodes. Analyses of the total mass of organisms in the soil, or “soil biomass,” encompass activity of bacteria, fungi, yeast, actinomycetes, and many other microorganisms that contribute to nutrient cycling whereas analyses of specific organisms measure functional groups, such as nitrogen-fixing bacteria. SMA analysis results are not easily interpreted, and there is no standardized guideline for reference levels of microbial activity of soils. A list of laboratories that provide SMA analysis is available online from the National Sustainable Agricultural Information Service (ATTRA) at: http://attra.ncat.org/attra-pub/soil-lab.html.

**Long-term soil monitoring**

Changes in soil quality occur over many years. Only the most extreme events, such as massive erosion, are measurable within a shorter time frame. A soil proposed for a new vineyard may be below its potential quality due to previous land management. It may be desired to improve a highly weathered, mineralized soil and increase (rather than maintain) a soil pH and organic matter, and thus increase its CEC and SMA. A soil that has been farmed intensively with ample amendments over time may contribute to excessive vine vigor, and this should be considered when making variety, rootstock, cover crop, and trellis decisions. Records of soil quality factors enable a grower to rate soil management practices and determine if long-term soil quality objectives are being met.

There are many soil management options for vineyards. The effects of erosion, loss of organic matter, and compaction are frequently difficult to overcome and should be avoided by good management practices. Soil characteristics and management practices should not be considered individually. Successful management of a quality vineyard depends on the understanding of one’s soils and the selection of practices that favor both soil conservation and successful, long-term production of quality fruit.

**Further reading**


Managing nematodes in vineyards

Plant-parasitic nematodes are a major economic problem in every major grape production region in the world. The soil roundworms feed upon the roots, stressing the plant and reducing root growth, which may ultimately reduce fruit yields or make the plant more susceptible to other infections.

Many growers already know that nematodes can be associated with sandier soils. But Dr. Andrew Walker, professor, geneticist, and Louis P. Martini Endowed Chair in Viticulture in the Department of Viticulture and Enology at the University of California–Davis (UC-Davis), cautions growers not to rely on this assumption. He spoke at a UC-Davis Cooperative Extension conference last fall on current pest issues in vineyard health.

Walker pointed out that nematodes can be found in soils of all textures, including silty and clay soils. The real reason for nematode occurrence in a particular area, he explained, has to do with their spread within and between fields with agricultural crops and equipment. Where we farm determines where nematode infestations end up, and they’re often brought in with plant material and nursery stocks.

There are generally two types of grape-parasitic nematodes: ecto- and endoparasitic. Ectoparasitic nematodes feed from the outside of the root system and include ring nematodes and dagger nematodes.

“Ring nematode is a classic case of a nematode that could be eliminated with even a few years of fallow,” Walker said. “It’s not a very persistent nematode, but we see major damage from it because we pull [vines] in the fall and we plant in the spring. If we pulled in the fall and waited a spring or two, we’d have no ring nematode problems.” But populations remain high in the soil because of continuous planting.

Walker explained that the problem is especially severe because “there is very limited resistance [of grape rootstocks] to this nematode.” His research program is developing rootstocks that could better resist ring and other nematodes without the need for fumigants or nematicides.

“If we’re not going to fallow vineyards, even for a year, we need better forms of ring resistance. Because as you pull those vineyards, you’ll typically find very high populations, and you’re not really giving the chance for those populations to drop before replanting.” So it’s a critical issue for rootstock research in the future.

“We could get by with lots of nematicides. They’re very effective at knocking those populations back and allowing those vines to establish, ▶

[continued on page 12]
Managing fungal diseases in vineyards

Growers have to deal with a variety of pests. This article describes current research on several important fungal diseases of grapes: powdery mildew, summer bunch rot, and Botrytis bunch rot.

Powdery mildew

Powdery mildew is one of the most damaging diseases of grapes and affects vineyards worldwide. The fungus that causes it (Erysiphe necator, formerly Uncinula necator) can infect all green tissues. “Whether that tissue is berries or shoots or leaves, it’ll grow on all of that,” said Steve Vasquez, viticulture farm adviser for the University of California–Davis (UC-Davis) Cooperative Extension in Fresno County, CA. He spoke at a UC-Davis Cooperative Extension conference last fall on current pest issues in vineyard health.

The fungus has both an asexual and a sexual stage. Growers who see signs in the spring on shoots or leaves are actually seeing the continuation of the previous year’s infection. The fungus survives the winter as dormant mycelium (vegetative bodies) in buds or as chasmothecia (spore-producing bodies) on the vine’s bark. It then re-emerges in the spring by one of two methods. Within the bud, the strands can grow until budbreak, when they cover the shoots. These infected shoots are known as “flag shoots.” The second possible method takes place on the bark, where the chasmothecia release spores after spring rains. Spores then disperse by wind and land onto leaves, starting a new cycle of infection.

Powdery mildew can spread very quickly when the temperatures are optimal, between 70 and 85°F, according to Vasquez. Under the optimal conditions of these temperatures and high humidity, a single spore can germinate, infect the plant, and produce a new colony and a new crop of spores in five days. Higher temperatures (over 90°F) are too hot for powdery mildew and tend to prevent disease from spreading. Because the risk of berry infection is particularly high when weather is mildly warm and moist, focusing spray programs during these periods may be important to prevent berry infection.

Symptoms

The most obvious symptom is a whitish or grayish powdery appearance on the leaves or shoots. Early berries are more susceptible than later berries to spore infection. Early infection of clusters leads to small or split berries, gray or brown patches, and poor yield. “With respect to berries, once they get up to about 12° Brix, the powdery mildew is not able to invade the actual berry itself,” Vasquez said. But as berries develop, affected fruit often cracks, leaving the fruit vulnerable to secondary infection by other fungi. “It really transitions it from the powdery mildew being a problem to Botrytis and the sour-rot fungi being a problem,” he said.

Management

It is important to remember that infection can persist and that shoots and canes can become infected at any time. Vasquez recommended looking at canes at the end of the season: “This is a really good indicator of what type of program you’ve had that season. People who feel they’ve been having problems, the first thing I do is go out during the dormant season and see what kind of scarring is on those canes.” Symptoms during the dormant season can indicate an infection that will recur in the spring.

[continued on page 14]
but if you don’t want to use nematocides or fumigants, it’s going to be a problem,” he added.

The dagger nematode, another ectoparasite, is “about the largest parasitic nematode that exists on grape,” Walker said. “It causes by itself very severe damage to root systems. It is very aggressive in feeding on roots.” The pest is especially harmful because it can serve as a vector for the grape fanleaf virus, which causes fanleaf degeneration disease. The nematode injects the virus into the plant as it is feeding on the roots.

Endoparasitic nematodes, in contrast to their ectoparasitic counterparts, feed within the root. A prominent example is the root-knot nematode, which causes the characteristic symptom of nodules (knots or galls) on the roots, thus impairing root function.

“And then there’s a group that spend part of their time outside the root and part of their time inside the root. Citrus nematode and root-lesion nematode are in that category,” Walker said. Some grape varieties, such as Zinfandel and Pinot Noir, may be more susceptible to these types of nematodes. Citrus and root-lesion nematode are spotty in geographic distribution but can cause serious problems where they do occur.

Walker said he would rank root-lesion nematode in California towards the bottom in terms of incidence but towards the top in terms of intensity. He said it could be avoided completely by fallow or by rotation with other non-susceptible crops. Symptoms of root-lesion nematode include a browning discoloration to the root, root lesions, and dying roots.

Soil sampling can help determine which species of nematodes are present and in what quantities. Sampling before establishing a vineyard may be especially helpful, since nematodes can infest previous crops and linger in the soil. So before planting a vineyard, it is especially important to know the cropping history. Said Walker, “It would be a serious mistake, for instance, to pull an apple orchard and plant a vineyard right away without regarding root-knot nematode and root-lesion nematode,” which particularly like apples.

One thing to keep in mind is that nematode populations within a vineyard are usually not uniform. Some areas of the vineyard may be more heavily infested than others. Nematode infestations are “patchy,” according to Walker. They tend to spread out from infected spots in irregular patches or radial areas. He
said growers and consultants should make sure that scouting and soil-sampling protocols cover different areas within the vineyard to reflect this potential in-field variability.

Knowing which types of nematodes are present can help inform choice of rootstock. Different rootstocks perform differently against nematodes. Walker rated Ramsey rootstocks at the top of the list of broad nematode resistance and Freedom, Harmony, and Schwarzmann in the upper tier. He characterized St. George as being “miserable” at nematode resistance.

Rotation of rootstocks from year to year is a good idea. “I wouldn’t follow Schwarzmann with Schwarzmann. I wouldn’t replant with the same parentage group and would not use them over and over again.” Grape rootstock choice should be made in conjunction with other factors specific to your region and varieties, such as resistance to the insect phylloxera, drought tolerance, and lime (pH) tolerance.

Several preplant fumigants and postplant nematicides exist on the market. Be sure to check with your state viticulturist for updates on their application to your problem species and your area’s rules and regulations for application. A major challenge to chemical control is that more than one, even all, of these nematode species can be present, causing cumulative damage to the rootstock. No chemical product or rootstock choice is going to provide perfect resistance to nematodes. Walker noted that it is important to test new rootstocks for their ability to naturally resist multiple types of nematodes and other diseases that often exist simultaneously.

Finally, Walker recommended new ways of thinking among viticulturists about fallowing and crop rotation to help prevent nematode and other diseases from building up. Fallowing for one or more years can be an effective method to decrease nematode populations in soil but is generally considered economically unfeasible for many grape growers. If it isn’t feasible, he said crop rotation can be practiced.

“We do it in every other form of agriculture. We don’t do it in viticulture, but we need to do it in viticulture. And we need to rotate amongst rootstock types. We need to avoid replanting the same parentage groups back in the same soil time after time as we replant vineyards. And, of course, these are long-term plans. They’re 20-year sort of plans, but they need to be factored in to the equation.”
some extent. In California, researchers have developed the powdery mildew risk index, a computer model that uses local temperature and humidity data to predict the timing of outbreaks and the best times to use fungicides. The risk assessment index can help growers determine when to apply products to control powdery mildew before it becomes serious. Check with local specialists to determine if this tool has been developed for use in your area.

A good preventative chemical program for powdery mildew, Vasquez said, will involve starting at the right time and using the right mix of materials. “We’re really fortunate with respect to powdery mildew because there are so many products for it. We’re up to about 24 different types of fungicides … all products that work well.” Fungicides come in several different “classes,” which correspond to differing modes of action of the pesticides. Common classes include DMI compounds (demethylation inhibitors), such as Rubigan, Rally, and Procure; strobilurins, such as Abound, Sovran, and Flint; the biofungicides AQ10, Serenade, and Sonata; quinoline compounds (Quinte); and natural sulfur and copper.

“The DMIs and the strobilurins are highly susceptible to becoming resistant from powdery mildew,” Vasquez cautioned. “You wouldn’t want to use Flint for your first spray and then follow it up by Sovran, and then follow it up by Abound.” He stressed the importance of alternating pesticides from different classes to make sure that you don’t get resistance buildup. Additionally, it is best to save the most effective materials for the critical periods. “The name of the game is coverage,” Vasquez said. “If you’re not getting good coverage, you’re going to end up with problems. Whatever your product is, you really need to think about having high enough rates…. Spray cards are a great way to see what kind of [coverage] you have or to make sure your machinery is working properly. They start out yellow, and as more water gets put on them, they turn blue…. So it really gives you a good idea of how your spray rig is working.”

Proper timing is also crucial and depends on not only your local region but also the grower’s variety: “If you have Rubires, you may not have to go in there early in the spring to spray them because they’re a little more tolerant of powdery mildew. But an early springtime program for Chardonnay makes good sense.”

Finally, don’t forget about leaves and vines. Good control of leaf disease throughout the season significantly reduces disease pressure the following year by limiting the number of the spore-producing structures (chlamydothecia) that form, overwinter, and initiate infection in the spring.

Conversely, high disease levels the previous year increase early-season disease pressure, and so if a grower has had a bad infection the previous year, extra early-season sprays may be necessary the following year.

**Bunch rots**

Bunch rots are fungal diseases that cause rot of ripening fruit. Those important to grape growers include *Botrytis* bunch rot and summer bunch rot.

**Botrytis bunch rot**

*Botrytis* bunch rot is caused by a single species of fungus, *Botrytis cinerea*. Tight-clustered grape varieties tend to be more susceptible due to the pressure growing berries exert on their neighbors. In addition, any injury to the berry during ripening can promote infection by the fungus, making prevention of injury important for prevention of bunch rots.

“When the sugars start seeping out,” Vasquez explains, “this is a good point of infection for *Botrytis*.” Some forms of injury that promote susceptibility to *Botrytis* include powdery mildew growth, punctures made by feeding insects or birds, or improper handling.

Sometimes symptoms do not appear until later in the season. Although growers may not see signs in early berries, “latent infections are probably some of the worst,” Vasquez said. If infections are not treated early, the fungus can spread to intact, ripe berries before harvest. It also can overwinter in berry mummies left on the ground or hanging on the vine and return in the spring to infect shoots and leaves, as well as new blossoms. “You end up losing shoots,” Vasquez said. “And when you lose shoots you lose fruit.”

Management strategies can be either cultural or chemical. Excellent control of *Botrytis* can be achieved with good canopy management strategies, including the removal of debris and basal leaves. “The debris in the flower clusters themselves are really good sources for *Botrytis* to grow and cause problems, Vasquez noted. “So one of the easiest ways to get rid of that is to go through and leaf pull—that helps remove a lot of that debris.” In addition, removal of infected material during the dormant season can help prevent flare-ups the following spring.

There are a variety of well-established fungicides for *Botrytis* management at various points in the growing season. One new trend is the use of plant growth regulators. Vasquez said a lot of growers will use gibberellic acid to “help open up the berry cluster so it’s not so
tight,” thus preventing berry split and Botrytis infection.

“Organic growers don’t have a lot of options,” Vasquez said. “They certainly don’t have the arsenal of fungicides that a conventional grower would use.” Vasquez and colleagues are exploring organic sprays that might help, such as peracetic acid, which looks like a promising alternative to fungicides for delaying rot.

Good control of Botrytis has a major secondary benefit as well, since it can help prevent infection by other fungi such as summer rot fungi.

**Summer bunch rot**

Summer bunch rot is another fungal fruit-rotting disease of ripening grapes. Summer bunch rots are a concern not only because of yield losses, but because of the potential for the fungi to produce a toxic chemical, ochratoxin, that persists in mature grapes and has been classified as a possible human carcinogen.

Summer bunch rot is especially prevalent during prolonged periods of warm, wet weather. Infection is initially caused by any one of a variety of different kinds of fungi that enter a cracked or injured berry and cause it to rot and spread. Botrytis could be the initial culprit as well as a variety of other fungi such as Aspergillus or Rhizopus species. It usually begins in one or a few berries but then rapidly spreads to the entire cluster and can destroy most or all of the cluster. Because of its speedy spread, crop damage can be extensive, Vasquez said.

As berry rot progresses, other pathogenic species are often attracted to the rotting berries, including other fungi, acetic acid bacteria, yeast, and vinegar flies. For this reason, in its more advanced stages, it is also known as sour rot, from the characteristic vinegar smell of acetic acid produced by the active bacteria that often occur. Fruit may leak and appear wet.

Controlling summer bunch rot becomes increasingly difficult in later stages of infection, in part because many different species can become involved. Susceptibility also increases as clusters mature, making early treatment essential.

“Summer bunch rot is a real challenge in terms of products to manage it because a lot of these fungal species have different growth temperatures, and they like different environments,” Vasquez said, adding that you really don’t know if you have just one species or many, or which types of fungi are present. “And some chemicals that are registered for use don’t work on all [types of fungi]. So it’s always been a challenge for growers.”

Because fungicide application is not always successful against summer bunch rots, Vasquez emphasized cultural management strategies to prevent their occurrence. “The two [management strategies] that you really have control over are managing irrigation and managing fertilizer.”

Good canopy management is also important. Controlling humidity within the canopy can be achieved by leaf removal. “Leaf removal is a big help,” Vasquez admitted, “and it’s a pretty easy strategy to implement. Open up that canopy [and] allow the air to move around.” Another management strategy for summer bunch rot is to reduce mechanical injury to fruit during ripening. Fruit thinning and/or shoot thinning may be necessary as well.

Also, by managing your powdery mildew and Botrytis bunch rot, you can really minimize the types of sour rot that you get. If a grower can prevent an opening for infection by a bunch rot species, later season woes can be avoided.

Vasquez mentioned that he is seeing more summer bunch rot problems nowadays, especially in the raisin industry. He believes this is the result of changes in industry practices, which are moving toward more expansive trellising systems. These systems produce more fruit than the old methods but also increase moisture and humidity—“a perfect environment for these fungi,” he said.

In summary, managing fungal diseases requires good timing of strategies, the right mix of chemical and cultural prevention techniques, and good monitoring. Vasquez also stressed the importance of region-specific information. He has noticed that grape growers who see a new problem in their vineyard often reference information outside of their state, which may not be very helpful; therefore Vasquez recommended sticking with state-specific recommendations when possible.
New Research

Diversified, low-input cropping systems can help reduce dependence on fossil energy

By James Giese, director of science communications; jgiese@sciencesocieties.org

Conventional agricultural production systems rely heavily on fossil energy, but emerging uncertainties regarding its future availability and prices point to the need to better understand the energy efficiencies of different cropping systems. To address this need, Matt Liebman, Michael Cruse, and their colleagues at Iowa State University conducted a six-year study to compare the energy use of a conventionally managed corn–soybean system (a two-year rotation) with two low-input cropping systems that used more diverse rotations and manure, but substantially lower quantities of nitrogen fertilizer and herbicides.

The two low-input systems, which use lower levels of purchased inputs such as fertilizer and fuel, consisted of a three-year rotation of corn–soybean–small grain/red clover and a four-year rotation of corn–soybean–small grain/alfalfa–alfalfa. Depending on how fossil energy costs were assigned to manure, the two low-input systems used between 23 and 56% less fossil energy than the conventional system.

Lower inputs, similar yields

From 2003 to 2008, nitrogen fertilizer inputs were reduced 66% in the three-year rotation system and 78% in the four-year rotation system compared with the two-year system. Herbicide use was reduced by an average of 80% in the three-year system and 85% in the four-year system. Despite these reductions in inputs, corn and soybean yields in the low-input three- and four-year systems matched or exceeded levels obtained from the conventionally managed two-year system. Crop yields in all of the experimental systems were similar to, or greater than, mean yields of commercial farms in the surrounding county in all years of the experiment.

According to Liebman, the two-year corn–soybean rotation is typical of cash grain systems in the region of Iowa that was studied. The three- and four-year rotations are representative of low-input cropping systems in the region that are integrated with cattle production through the feeding of crops to livestock and the application of manure to crop fields.

“Iowa has a long history of mixed-crop and livestock farming, although these operations do require more management and labor,” Liebman says. “If fossil energy costs rise steeply, we may see more of them again.”

Manure

The researchers used two approaches for evaluating the energy and economic costs of manure. In one approach, manure was considered a waste product of a livestock operation, and its only energy cost was the energy used for its application. Similarly, for a low-economic-cost
scenario, manure was regarded as free except for application costs (labor, tractor fuel, and machinery depreciation).

The second approach included both the energy costs of manure application and manure nutrients assessed as if they required the same amounts of energy used to produce commercial fertilizers. Similarly, for a high-economic-cost scenario, the cost of manure was set as the application costs plus the cost of nutrients within the manure set at commercial fertilizer prices.

When considering manure as a low-cost economic input, the researchers found that the monetary return to land and management was similar for all systems, averaging $249 per acre. Using commercial fertilizer prices for manure nutrients reduced returns by $38 per acre for the three-year rotation and $28 per acre for the four-year rotation.

The researchers noted that the real energy and economic costs are likely to lie between the low and high extremes they analyzed and will vary depending on market conditions and the configuration and management of the livestock operation generating the manure.

Fossil energy

On a fossil energy input basis, the low-input systems required lower inputs than the conventional two-year rotation, using from 23 to 56% less fossil energy in comparison. Grain handling, and more specifically grain drying, accounted for proportionally the largest or second largest fossil energy input for all system analyses. The conventional two-year system used substantially more fossil energy in the form of fertilizers and pesticides than the low-input systems.

According to the researchers, reducing consumption of energy for grain drying is challenging in northern latitudes, where both farm size and climate conditions reduce the amount of time farmers can leave corn plants in the field to dry grain with solar energy. However, growing corn less frequently within a rotation sequence can decrease fossil energy requirements for drying grain.

Efficiency ratios, including crop energy output and economic return per unit of fossil energy invested, were significantly higher in the low-input four-year rotation than in the conventional system. Most of the variability observed among systems in energy use efficiency was due to differences in fossil energy input values, not in outputs from the systems, since productivity of the systems was essentially equal. For the high-energy manure scenario, the difference between the conventional and low-energy systems in fossil energy input was reduced, and consequently differences in efficiency ratios were also reduced. The incorporation of alfalfa into the four-year rotation was important: in all economic analyses, the four-year rotation was significantly more efficient in energy use than the two-year rotation, while the three-year rotation was not.

Labor

In this study, labor inputs followed an opposite trend to that seen for fossil energy inputs, with the four-year rotation having the largest input and the two-year rotation having the smallest input. Compared with the two-year rotation, which required 41 minutes per acre per year, the three-year rotation required 54% more labor, while the four-year rotation required 91% more labor. However, the incorporation of small-grain crops (triticale and oat) and alfalfa into the low-input rotation systems placed much of the extra time investment into parts of the year that did not overlap with peak activities associated with corn and soybean production.

The researchers suggest that historically low energy prices during the 20th century, along with relatively high wages in the United States, have contributed to widespread adoption of energy-intensive farming practices. The team’s analysis shows that the conventional two-year rotation system widely used in the central U.S. (corn–soybean) relies on fossil energy to reduce labor requirements while allowing net economic returns to remain constant. This allows greater wage rates for the producer. But the researchers claim that diversified low-input systems can provide greater returns per unit of fossil energy invested, even though overall returns to land are similar to the conventional system.

Looking ahead

In coming years, if demands from ethanol plants or overseas markets increase the price of corn grain faster than input costs rise or if commercial-scale production of biofuels from corn stover becomes economically viable, Midwestern cropping systems might become less diverse and more focused on corn. Alternatively, if fossil energy prices rise significantly without concomitant increases in crop value, diversified low-input cropping systems, such as those described in this study, may become preferable to conventional cropping systems and used more widely.

The research team, funded by the Leopold Center for Sustainable Agriculture and the USDA, is expanding its activities with measurements of effects of the different cropping systems on water quality, greenhouse gas emissions, and soil carbon and nitrogen dynamics. It will also investigate the economic consequences of integrating crop and livestock production in different ways.

“*It’s hard to predict the exact details of what the future will bring us,*” Liebman admits. “*But results of this study show that we do have options for maintaining high farm productivity and profitability while substantially reducing our dependence on fossil energy.*”

Pioneer unveils latest seed technology research

By James Giese, director of science communications; jgiese@sciencesocieties.org

In late February, Pioneer Hi-Bred International hosted a media event at its headquarters in Johnston, IA where the company showcased its latest research in seed technology.

Frank Ross, Pioneer vice president, North America, discussed some of the challenges farmers faced last year, including the difficult growing and harvest conditions. Corn experienced its slowest harvest pace in 25 years while soybean harvest was the fourth slowest in that time period. There was a general decline in farm revenue while growers faced higher input costs and an economy that was weak globally. Despite the challenges, Ross said that Pioneer seeds performed well.

“In corn, across 85,000 comparisons, we averaged a 1.7 bu/acre advantage, and our triple-stacked traits were at parity,” Ross said. He said that the company’s new Y Series soybean seeds did well, with almost 8 million acres planted in 2009 and enough product to plant up to 20 million acres this year. There were 31 new varieties offered last year across all maturities, and the company will be offering 26 additional varieties this year across all maturities.

“We plan to hire more agronomists for increased interaction with our customers and to do more test plots for increased product knowledge,” Ross said. “We are looking for greater field input about customer demands.”

During the media event, a variety of researchers and field agronomists gave presentations on some research areas that Pioneer is actively pursuing.

Drought stress

Drought stress is responsible for more lost bushels of corn yield than any other cause, costing farmers in the U.S. more than $3 billion annually, according to Dan Uppena, senior marketing manager, and Jeff Schussler, senior research manager. Among the corn-growing states of the Midwest, severe drought conditions are common in the Great Plains states from Texas to North Dakota, but all states have some drought-stressed areas nearly every year. In fact, every corn field is likely to experience some limitation of available soil moisture during the growing season that reduces yield, even when corn yield approaches 200 bu/acre.

“Drought tolerance is a complex trait with multiple genes involved,” Schussler said, “and multiple solutions are required.”

Breeding corn for drought tolerance is complicated by many factors including different growing cycles year to year, different levels of drought severity, differences in soil-water holding capacity, trade-offs from heat vs. drought, and other factors such as disease and insect infestations. In the near term, the company is researching molecular breeding tools to enhance native trait drought tolerance performance. In the mid- to long-term, it is investigating transgenic and native drought tolerance incorporated into germplasm.

Schussler said that the long-term genetic improvement of drought tolerance in corn involves understanding its genetics and physiology and using molecular-enhanced breeding. Pioneer has used this technology over the last few years to improve hybrid performance for a number of traits including disease resistance and stalk and root strength. Schussler said that they have developed some drought-tolerant hybrids using molecular breeding and have been testing them in the High Plains region, where yields are significantly limited by water every year. So far, the results have been positive.

“We’re looking for introduction as early as 2010 or 2011 for a couple of these hybrids. Last year, over a set of these locations and in California, we had about a 5% yield advantage compared with a dozen commercial checks including ours and some of our competitors, so we felt that was a good first step,” Schussler said.

High-oleic soybean oil

John Muenzenberger, business manager for specialty oils at Pioneer, and Susan Knowlton, research manager for ag biotechnology at DuPont, presented the latest developments with Pioneer’s high-oleic soybean, called Plenish. It is a soybean that has been genetically engineered to be high in oleic acid. It has a fatty acid profile of greater than 75% oleic and around 3% linolenic acid.

“This oil is a soy-based trans fat solution with lower saturated fat than alternative oils,” Muenzenberger said. “It has higher heat stability for frying, improved shelf life, and may have applications as a renewable, environmentally friendly option to petroleum-based biolubricants.”

The company says the Plenish soybeans will be Pioneer Y Series varieties, and yields are on par with commercial products. It is currently being grown under contract for ongoing field and oil testing in 2010 and 2011, with commercialization anticipated in 2012, upon full regulatory approval and field testing.
“We have product-testing agreements in place with major oil processors, food companies, and industrial users,” Knowlton said.

High-oleic soybean oil also is an attractive option for food companies because of the existing production infrastructure for soybeans and soybean oil. Soybeans are grown on more acres in North America than any other oilseed crop. Testing results show this oil has more than 20% less saturated fatty acid including 40% less palmitic acid than commodity soybean oil and 75% less saturated fat than palm oil.

The trait received Canadian regulatory approval in May 2009. The U.S. Food and Drug Administration completed its review in 2009, and the USDA is in the process of reviewing the trait. Regulatory submissions for the trait are planned or have been completed in key soybean-importing countries around the world.

**Refuge strategy**

In North America, growers planting triple-stacked products are required to plant a refuge (20% in the North, 50% in the South) to reduce resistance concerns. The U.S. Environmental Protection Agency (EPA) requires that growers planting Bt corn follow an approved insect resistance management plan, including the planting of refuge acres. Planting a biotech corn refuge helps decrease the natural selection pressures that can lead to insect resistance. These refuge acres ensure that rare resistant insects that feed on insect-protected varieties of corn will mate with susceptible insects and slow the development of resistance. However, even with the use of insecticides, these refuge acres are at risk of yield loss and require more time to plant and manage.

Pioneer’s strategy for dealing with this issue is called Optimum AcreMax 1 Insect Protection. The company claims it is the first “in-the-bag” seed refuge system and will eliminate the need for farmers to plant separate corn borer and corn rootworm refuges.

“We are still hoping to get approval for the use of this system for 2010,” said Bill Belzer, senior marketing manager.

Another trait that Pioneer is exploring is corn nitrogen use efficiency, providing increased yields through improved uptake, storage, and mobilization of nitrogen. The company is using its Accelerated Yield Technology (AYT) to drive faster selection of leads and doubling year-over-year testing scale. The company has multiple leads in evaluation, and early testing of leads shows double-digit yield increases in reduced-nitrogen environments.

**Molecular marker technology**

John F. Soper, senior research director, described how Pioneer is developing new hybrids with advanced molecular marker technology. This process includes phenotypic evaluation, trait enhancement, and molecular marker techniques and involves selecting parents and making crosses, developing new “inbreds,” testing and characterizing yields for agronomic and disease traits, and finally, commercialization.

“We are constantly accelerating the rate of genetic improvement,” Soper said. The company does this by increasing the number of development/testing cycles per year, identifying new ways to create inbreds faster, intensifying phenotypic screening, and utilizing the company’s accelerated yield technology program to identify progeny with favorable gene combinations.

Why are more cycles per year important? Because developing finished inbreds requires 6–10 growing cycles/seasons, and thorough yield testing requires three to five seasons. Any process that shortens that allows new products to come to market faster.
Canada East
Fungicides boost yield and quality in spring wheat

By Brian Hall, edible beans and canola pest specialist, Ontario Ministry of Agriculture, Food, and Rural Affairs, Stratford, ON, Canada

In humid climate regions such as Ontario, Canada, Fusarium head blight (FHB or scab) is one of the most serious economic diseases of wheat because of its potentially devastating effect on both yield and quality. Proline (prothioconazole; Bayer CropScience) is one of the most effective fungicides to date for the protection and suppression of FHB in wheat. In 2008–2009, small-plot research and field strip trials were carried out in Ontario to evaluate the effectiveness of Proline fungicide for FHB suppression in spring wheat.

Methods

Field strip trial experiments were established at 11 sites in 2008 and 28 sites in 2009 across a wide geographic area of Ontario. Project co-operators were asked to apply Proline fungicide in a block in a field planted to a single wheat variety. The fungicide was applied within the time period from when at least 75% of the wheat heads on the main stem are fully emerged to when 50% of the heads on the main stem are in flower.

The small-plot research trial was conducted in 2009 at Kemptville Campus, University of Guelph, in eastern Ontario. Two rates of Proline fungicide (128 and 170 mL/acre) were compared with an untreated check. Treatments were replicated eight times and applied at day 0 (75% heads fully emerged).

Results

In both 2008 and 2009, temperatures were moderate, and rainfall was above average at flowering, conditions favorable for leaf diseases and FHB infection. Tables 1 and 2 present the results of the on-farm strip trials. The yield improvement from Proline fungicide treatment was higher in 2008 than 2009. In both years, there was a similar reduction in visual Fusarium damaged kernels (FDK) and deoxynivalenol (DON), commonly referred to as vomitoxin.

In 2009, the FDK level was 6.2% in the untreated vs. 3.9% in the fungicide-treated wheat, a 2.2% reduction. Approximately one-third of the grain samples were improved enough in 2009 to make food grade (grade 3 or better). In 2008, the level of Fusarium was higher, and although the fungicide reduced the level of FDK (8.2% FDK in fungicide treated), the reduction was not enough to improve the grade. In 2009, the DON levels were low in many of the samples and would be acceptable to many millers, even though the FDK was above the 1 to 1.5% required for grades 1 to 3.

Results of the small-plot research trial are presented in Table 3. The yield improvement from fungicide was 7 bu/acre (11.7%), and FDK was lowered by 5.45 percentage points, or 35%. However, the reduction in FDK was not enough for any of the treated samples to make food grade.

The fungicide treatment in the small plot improved yield and quality more than the field strip trials. This may have been due to the greater wheat stand uniformity due to use of the proper nozzle configuration (backwards-forward orientation) in the small-plot trial. Earlier research has shown that for proper spray coverage, the backwards-forward nozzles or Turbo FloodJet nozzles (TeeJet Technologies) alternating along the boom at 15° below horizontal are required.

For more information, contact Scott Banks, OMAFRA, at Scott.Banks@ontario.ca.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yield (bu/acre)</th>
<th>Percent FDK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated check</td>
<td>60.08b†</td>
<td>15.47</td>
</tr>
<tr>
<td>Proline low rate</td>
<td>66.41a</td>
<td>10.50</td>
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<tr>
<td>Proline high rate</td>
<td>67.75a</td>
<td>9.54</td>
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</tbody>
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† Means in a column followed by the same letter are not significantly different. *p* = 0.1; *cv* = 4.70.
Southern
Mr. farmer, do you want a $6 haircut?

By John Fontane, Louisiana CCA board

A recent television ad depicts a new haircut business opening across from an established barber. A display outside the new business reads, “We offer $6 haircuts.” The established barber counters with his own sign, which reads, “We fix $6 haircuts.” The new store soon goes out of business.

Just like the person going to get a haircut, farmers will be faced with many decisions this crop season. What varieties do I plant? What analysis and rate of fertilizer should I apply and when? Which herbicide program should I select? What is the best fungicide and when should I apply it? Do I really need to apply an insecticide and how much?

The end result of these and other cropping decisions, with a little help from Mother Nature, will have a huge impact on the yield and profitability of their crop. Many of these decisions cannot be reversed or corrected. And when they are corrected, they are very costly. Farmers should not be making these decisions alone or without access to good information.

Agriculture is an ever-changing environment. It is important for farmers to keep abreast of new varieties, pesticides, updated nutrient management information, and other cultural practices. Most farmers in Louisiana depend on the sales reps (both ag retail and manufacturer) and the LSU AgCenter to assist with their cropping decisions. The knowledge and experience of the person assisting with those cropping decisions is critical.

CCAs are professionals who are required to pass two extensive exams and maintain 40 hours of continuing education every two years. These 40 hours must include at least five hours in each of the following categories: nutrient management, integrated pest management, crop management, and soil and water conservation. Keeping up with these CEU requirements is not an easy task. While many dealer representatives attend educational meetings throughout the state, only CCAs are required to certify their hours. The Louisiana CCA board in conjunction with ICCA guidelines determine which meetings meet the certification criteria.

And just as important as continuing education, CCAs are required to sign an ethics agreement to ensure their integrity and profess that they put the farmer’s best interest first. In Louisiana, there are more than 80 CCAs available to help farmers with cropping decisions.

Farmers want to know they are getting the best agronomic advice available. They should be able to concentrate on their many other daily decisions and not be overburdened with agronomic decisions. Just as they depend on a mechanic to fix their tractor, a banker to keep up with their finances, and a doctor to treat their ailments, they should depend on a professional crop adviser to assist them with decisions in the field.

Farmers should make sure they have someone they can depend on to assist them with their agronomic decisions. Anyone can quote prices and repeat recommendations from a book, but only a professional can offer the experience, knowledge, education, and reliability that the farmer deserves. A CCA is that professional.

A CCA cannot always fix a $6 haircut. What he/she will do is advise the farmer not to get one in the first place.

For more information about the Louisiana CCA program, visit at www.louisianacca.org.

[continued on page 23]
The American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA) along with the International Certified Crop Adviser (ICCA) program recently conducted a comprehensive survey of the agronomic, crop, soil, and environmental science professions. The survey looked at salaries, titles, benefits packages, job functions, location, and tenure. More than 2,000 individuals—members, certified professionals, and those not affiliated with our organizations—contributed to this very detailed compensation review.

Before I review some of the data, I’d like to first thank everyone who participated in the survey. Your involvement will greatly help us promote the professions. If you have not yet contributed, you can still do so. The survey will remain open and continually collect data and update the results. The more people we have involved, the better the data will be. To contribute, go to: https://acscompsurvey.enetrix.com.

We would like to encourage all who work in the agronomic, crop, soil, and environmental science professions to participate so that we can all gain valuable insights from the data.

Those who contribute will receive a free summary of the data. All you have to do is go to the same website listed above, log in, and follow the instructions. You will also have the option to purchase the full report, and as a contributor, you will be able to do so at a greatly reduced price.

The survey and reports were conducted and created through a partnership with enetrix, a division of Gallup. Within the report, you may request data based on the following parameters, allowing you to...
Agronomy

In the United States, an agronomist averaging just over 12 years of experience with no budget or supervisory responsibility has an average total compensation of $63,133. This includes both a base salary and bonus plan. Typical benefits packages include health insurance, retirement plan, a car allowance, and cell phone allowance. Canadian agronomists report similar information with a slightly lower total compensation of $60,793. The average age is 42 in the U.S. while in Canada it is 36. That might be part of the reason why the compensation is slightly lower in Canada—less experience.

Many agronomy positions in the private sector have a sales component in their responsibilities. If you take the same position but add sales to it, the total compensation rises by 22%. Considering the state of the economy in the last year or so, survey participants were asked if they were unemployed in the last 12 months, and only 2% of the agronomists stated that they were. That is much better than the general unemployment figures in North America.

Soils

Looking at a soil science position in the United States, the average years of experience is 15.2, and the average age is 45 years. The total compensation with no responsibility for budget or supervision was reported as $69,921 including salary and bonus plans. Typical benefits packages include health insurance, retirement plans, bonus options, car allowances, and cell phone allowances.

Now if we take the same position but add consulting to the title, the total compensation declines to $56,194, but the average years of experience also drops to 12.6, so less experience may be contributing to the lower compensation package.

Soil scientists reported a higher rate of unemployment for the last 12 months at 7%. This corresponds to what we were hearing from members and CPSS/Cs during this time; many who worked in soils positions related to construction saw a decline in work while those connected to agriculture were not hit as hard by the economic slowdown.

That is just a brief overview of the data. There are many more ways to segregate it, and the more parameters you select, the more defined it becomes. To get more details, please visit the website listed above where you can customize your search and pull out the specific data that you are interested in.

The Societies have done salary surveys in the past, but this was more in depth than prior surveys and was the first one that included all aspects of the professions. We will continue to refine the survey to better define the results. This data will help those making employment decisions whether as a career choice or trying to fill a key position. It will also be valuable for promoting the professions to the next generation or those changing careers.

If you have not yet participated, please go to the website and do so. Thanks again to those who have contributed.
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Comparing the effects of subsurface drip and overhead irrigation on boll distribution in cotton

Unlike most field crops, cotton is unique in that vegetative and reproductive growth occurs simultaneously through most of its growth cycle. Fruiting occurs at different times on different parts of the plant. Cotton can produce fruit on multiple nodes and fruited positions (Fig. 1). Fruiting begins near the base of the plant, usually between mainstem nodes 5 and 7 and continues on additional vertical nodes up the plant, as well as on additional horizontal fruited positions at each node. Vegetative branches can also form on the cotton plant. These branches act like secondary stems and can produce their own fruit.

The accepted axiom of vertical and horizontal flowering intervals is three days between vertical nodes and six days between horizontal positions, based on previous research. Therefore, timing and fruit location (both vertical and horizontal position of the fruit on the plant) have been used interchangeably to describe boll distribution. Because of the delays between vertical and horizontal flowering, the duration of flowering in cotton can range from 25 to 30 days, during which the plant may be subjected to different environmental conditions, water availability, and biotic factors. Any of these factors can affect flowering and fruited on a particular part of the plant, since the plant may concurrently have fruited structures that range from developing squares to large bolls. In addition, cotton can compensate for the loss of fruited structures early in the season by increased vegetative growth and increased fruit production later in the season.

Recently, researchers measured a 2.1 to 2.7 average day delay between flowering of first-position fruit on adjacent nodes and a 3.2 to 4.4 day delay between fruited positions on individual fruited branches, but noted that flowering interval depends on temperature, node, and cultivar. Because fruit forms from the bottom of the plant upward, early-season fruit forms lower on the plant, and late-season fruit forms near the top of the plant.

Water and crop production

Water is a limiting factor in crop production. Georgia cotton requires about 18 inches of appropriately timed water to maximize yields, less than the 22 inches of rainfall received on average during the growing season. The shallow, coarse-textured soils of the Coastal Plain and erratic rainfall patterns give opportunities for episodic drought, and moisture deficit from these drought periods can decrease yields and affect crop characteristics including increased fruit abortion and decreased flowering.

Irrigation water is commonly applied with overhead sprinkler systems such as center pivots, which have dominated cotton irrigation methods in Georgia and are used for about half of the cotton acreage in the state. Overhead irrigation water can negatively affect cotton pollination, reducing pollination and increasing fruit abortion. A group of researchers observed a 65% overall decrease in flower retention due to overhead sprinkler applications.

Subsurface drip irrigation (SSD) research has gained interest in the Cotton Belt as a method for increasing yield with limited irrigation. In the humid southeastern United States, research has demonstrated that irrigation from SSD tube placements in alternate furrows could provide positive cotton yield effects over rainfed cotton. Research has shown SSD-irrigated cotton to consistently perform as well or better than cotton under overhead irrigation.

In a recent issue of *Agronomy Journal* (Agron. J. 101:1336–1344) researchers evaluated the plant boll distribution of cotton grown under overhead sprinkler irrigation, two SSD irrigation regimes, and a nonirrigated control in the humid climate of South Georgia.

Studies were conducted in 2004 and 2005 at the C.M. Stripling Irrigation Research Park in Mitchell County, GA.
Earn 1 CEU in Soil & Water Management

Cotton cultivar DP 488 BG/RR was planted in all environments (different locations and years) in rows carefully spaced on May 5 and April 20 at Stripling in 2004 and 2005, respectively, and on May 15 at Lang in 2005. Drip tape was installed only in the SSD plots.

Fertility, weed control, and insect monitoring and control were based on University of Georgia Cooperative Extension Service guidelines. Mepiquat chloride was applied three times during each season at a constant rate for all treatments for cotton growth management. To ensure successful emergence of all treatments, all plots received overhead irrigation as needed to promote emergence.

In 2004, harvest aids (ethephon plus cyclanilide and thidiazuron) were applied when all plots reached at least 70% open bolls, 127 days from planting, and cotton was harvested at 141 days from planting. Due to potential differences in maturity between irrigation treatments recognized in 2004, harvest aids were applied in 2005 when cotton in each irrigation treatment averaged four mainstem fruiting branch nodes above the uppermost fruiting position with an open boll. At Stripling in 2005, differences in cotton maturity were minimal between irrigation treatments; therefore, the entire study was defoliated at 140 days from planting and harvested at 161 days from planting. At Lang during 2005, cotton in the irrigation treatments was defoliated at different times (between 122 and 129 days from planting), and cotton in the study was harvested at 148 days from planting.

The experimental design was four irrigation treatments in a randomized complete block design with four replications. The four irrigation treatments were (i) overhead sprinkler irrigation (Overhead), (ii) nonirrigated (Nonirrigated), (iii) SSD irrigation matching overhead sprinkler irrigation application (SSD Matched), and (iv) SSD irrigation based on soil moisture (SSD Fed).

The sensors were placed in two replicate plots of each treatment in 2004 and all four replicate plots of each treatment in 2005. Treatments were irrigated when half of the replicate plots had water potentials drier than the trigger point. The rainfall and irrigation amounts for the treatments are shown in Fig. 2.

Data collection and statistical analysis

Two rows in the center of each irrigation plot were designated for data collection and harvest. Before machine harvest, a portion of one harvest row was removed for plant mapping. Before plant collection, the selected section of row was examined to make certain that there were minimal skips and minimal plants with excessive vegetative branches due to in-season terminal bud damage. The plants were clipped at ground level, and the plants for each plot were wrapped together in butcher paper that was stapled closed around the plants. The bundles were carefully transported to a sealed storage facility, where they were stored until plant mapping was complete.

Plant mapping was completed within 4 to 12 weeks after the plants were removed from the field. Bolls were individually harvested, and seed cotton was placed in a grid box compartment that corresponded to the vertical mainstem node and horizontal fruiting position. Total number of bolls and total seed cotton mass were recorded for each node and fruiting position, and bolls produced by vegetative branches were placed in a separate compartment. The removed fruit was weighed by node and position to measure boll mass by node and position.

Cotton bolls produced on fruiting positions greater than three were rare and were combined with the third-position bolls when observed. Bolls produced by vegetative branches were placed in a separate compartment to minimize the confounding influence. Some bolls came off during harvest, transport, and storage. Special care was taken to minimize these losses, and the lost cotton in each bundle was measured.

Because of the large quantities of nodes and fruiting positions of the plants and the inherent complexity of

Fig. 2. Rainfall and irrigation amounts from 30 to 120 days after planting. Vertical dashed lines represent date of first flower for each study.
the number of points being analyzed, statistical analysis was difficult. To simplify the analysis, boll number differences between treatments by node and position were correlated with boll mass differences using regression analysis to determine how much of the variation in boll mass between treatments could be attributed to differences in boll number.

Boll fraction was calculated at each node as the ratio of boll number at each node to the total boll number for the fruiting position. Therefore, all of the nodes were pooled for each fruiting position, and the fraction of each node in relation to this sum was calculated. This measurement gives the relative contribution of each node to the total yield by position. The relative boll fraction of each treatment was compared with the Overhead irrigation treatment, calculated as the difference in boll fraction at a given node and position.

Boll number and mass by fruiting node and position

Differences in boll mass and boll number per node per plant between treatments were determined to be very closely related. Nearly all (95%) of the variation in boll mass differences was explained by differences in boll number. This suggests that nearly all of the differences in cumulative boll mass at nodes and positions were due to differences in boll number rather than differences in boll size. Unless otherwise indicated, differences in total boll mass between treatments at a given node and position followed the same pattern as differences in boll number.

There was no significant treatment effect on the amount of lost cotton in any of the environments (data not shown), and boll rot was not observed to a significant degree in any of the treatments or environments. Lost cotton averaged 3.0 ± 0.3% (standard error) of sample weight over the study period, with the 2004 samples averaging slightly more (3.9 ± 0.5%) than the 2005 samples. No treatment or replicate effect of cotton loss was observed by year or location. This suggests that differences observed in fruiting nodes were due to actual differences in fruit production and not to losses related to the harvest method.

Vegetative boll number and yield did not show a significant treatment, replicate, or environment effect and so were not included in this analysis. Vegetative branches were not determined to be significant contributors to plant response to irrigation. Changes in maturity and boll distribution can affect the final outcome of the crop. Increased fruit produced lower on the plant can decrease the effective days until maturity, if maturity is defined as the time it takes for a sufficient portion of the plant to be harvested. Increased determinacy due to SSD application can decrease the fruiting time of the plant, since fewer fruiting nodes and less second- and third-position fruit will be formed.

Cotton SSD irrigation is viewed as a more efficient system for water application, since surface losses are negligible. The increased efficiency extends to plant growth as well. The SSD system results in plants with more fruit near the base of the plant and less compensating growth higher in the plant. The difference in fruit load by node and position on the plant can change the maturity and growth dynamics of the plant, resulting in a more determinate plant.

Irrigation method had a significant impact on boll distribution on the plants, with the overhead irrigation treatment consistently having less cotton near the bottom of the plant.
and more cotton near the top than either of the SSD methods. The authors of this study conclude that SSD irrigation decreases early-season fruit loss, resulting in heavier carbohydrate sinks and decreasing overall growth and upper boll filling on the crop.

May–June 2010

Self-Study Quiz

Comparing the effects of subsurface drip and overhead irrigation on boll distribution in cotton (no. SS 04045)

1. Unlike most field crops, cotton is unique in that vegetative and reproductive growth occurs simultaneously through most of its growth cycle. How does fruiting occur?
   - a. Fruiting occurs early at the top of the plant.
   - b. Fruiting occurs at different times on different parts of the plant.
   - c. Fruiting occurs at all times on different parts of the plant.
   - d. Fruiting occurs continuously on all parts of the plant.

2. Georgia cotton requires about 18 inches of appropriately timed water to maximize yields, and
   - a. this is less than the 22 inches of rainfall received on average during the growing season.
   - b. this is more than the 12 inches of rainfall that usually reaches Georgia cotton.
   - c. thus the 65 inches or so of early-season rainfall that the state typically receives is adequate.
   - d. most of this is supplied by SSD irrigation in the state.

3. Overhead irrigation water can reduce pollination and increase fruit abortion. A group of researchers observed a
   - a. 65% overall decrease in flower retention due to overhead sprinkler applications.
   - b. 80% decrease in flower retention caused by overhead sprinklers.
   - c. 20% decrease in flower retention caused by spotty overhead application.
   - d. 30% decrease in flower retention caused by overhead application.

4. To ensure successful emergence of all treatments, all plots received overhead irrigation
   - a. early in the season prior to emergence.
   - b. as needed to promote emergence.
   - c. later to augment treatment plans.
   - d. only during boll filling.

5. According to the article, research has shown SSD-irrigated cotton to
   - a. consistently perform as well or better than cotton under overhead irrigation.
   - b. consistently perform about the same as cotton under overhead irrigation.
   - c. sometimes perform worse than cotton under overhead irrigation.
   - d. perform nearly as well as cotton under overhead irrigation.

6. Total number of bolls and total seed cotton mass were recorded for each node and fruiting position, and bolls produced by vegetative branches were placed in a separate compartment. The removed fruit was weighed
   - a. by node and position to measure boll mass by node and position.
   - b. en masse to measure total boll weight.
   - c. by vegetative branch only.
   - d. by fruiting node only.

7. Nearly all (95%) of the variation in boll mass differences was explained by differences in boll number. This suggests that nearly all of the differences in cumulative boll mass at nodes and positions were due to:
- a. differences in boll placement.
- b. differences in boll number.
- c. differences in size of individual bolls.
- d. differences in seed content.

8. Increased determinacy due to SSD application can decrease the fruiting time of the plant, since:
- a. more fruiting nodes and fewer second- and third-position fruit will form.
- b. fewer fruiting nodes and fewer second- and third-position fruit will be formed.
- c. fruit nodes will remain unchanged in number.
- d. second- and third-position fruit will be increased.

9. Cotton SSD irrigation is viewed as a more efficient system for water application, since surface losses are negligible. The increased efficiency extends to plant growth as well. The SSD system results in plants with more fruit:
- a. near the base of the plant and less compensating growth higher in the plant.
- b. at the top of the plant where it is easier to pick.
- c. in the three- to five-node area where it is protected from the sun.
- d. everywhere on the plant.

10. SSD irrigation decreases early-season fruit loss, resulting in heavier carbohydrate sinks and:
- a. increasing plant growth and number of bolls.
- b. decreasing overall growth and upper boll filling.
- c. decreasing lower growth and boll size.
- d. shorter plants and smaller bolls.

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SELF-STUDY QUIZ REGISTRATION FORM

Name: ________________________________
Address: ________________________________  City: ________________________________
State/province: ________________________________  Zip: ________________________________  CCA certification no.: ________________________________

☐ $20 check payable to the American Society of Agronomy enclosed.

☐ Please charge my credit card (see below)

Credit card no.: ________________________________  Name on card: ________________________________

Type of card: ☐ Mastercard  ☐ Visa  ☐ Discover  ☐ Am. Express  Expiration date: ________________________________

Signature as it appears on the Code of Ethics: ________________________________

I certify that I alone completed this CEU quiz and recognize that an ethics violation may revoke my CCA status.

This quiz issued May 2010 expires May 2013

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SELF-STUDY QUIZ EVALUATION FORM

Rating Scale: 1 = Poor  5 = Excellent

Information presented will be useful in my daily crop-advising activities: 1 2 3 4 5

Information was organized and logical: 1 2 3 4 5

Graphics/tables (if applicable) were appropriate and enhanced my learning: 1 2 3 4 5

I was stimulated to think how to use and apply the information presented: 1 2 3 4 5

This article addressed the stated competency area and performance objective(s): 1 2 3 4 5

Briefly explain any “1” ratings: ________________________________________________________________

Topics you would like to see addressed in future self-study materials: ____________________________________________________________
Vineyard nutrient needs vary with rootstocks and soils

By Jean-Jacques Lambert, assistant research soil scientist, Department of Viticulture and Enology, University of California–Davis; Michael A. Anderson, staff research associate, Department of Viticulture and Enology, University of California–Davis; and James A. Wolpert, cooperative extension specialist, Department of Viticulture and Enology, University of California–Davis

The fundamentals of nitrogen and potassium nutrition in grapevines are well known. Excess nitrogen leads to high vigor, increasing fruit yield and affecting juice composition (i.e., pH and concentrations of organic acids and esters), but may also create conditions favorable to disease such as bunch stem necrosis and Botrytis cinerea bunch rot (Keller et al., 2001). Potassium deficiency adversely affects ripeness, but excess berry potassium is detrimental to wine quality (Mpelasoka et al., 2003).

While adjusting nutrient input to attain the desired wine quality, viticulturists must also heed the call for sustainable management practices that minimize impacts on soil microorganisms and nutrient balances. The development and application of site-specific fertilization plans can increase sustainability by reducing nutrient runoff into waterways. By developing a better understanding of soil–vine interactions as well as the specific nutrient needs of particular rootstocks and cultivars, we hope to establish site-specific fertilization plans to save money and limit fertilizer input, ultimately promoting sustainability.

California vineyards are planted in diverse geographic settings and climates, on soil types ranging from acid to alkaline, fine textured to coarse, deep to shallow, level to sloping, and fertile to less fertile. Several-dozen rootstocks were developed in response to the inadvertent importation into Europe of the grapevine pest phylloxera, from its native eastern North America (Pongracz, 1983). The European grape Vitis vinifera is highly susceptible to phylloxera, but many American native species are not. As a solution, the practice of grafting European scions (the grafted fruit-bearing part of the plant) onto phylloxera-resistant rootstocks was developed (Pongracz, 1983). This practice is still in use today, and these rootstocks are suited to a variety of conditions reflecting the original environments of the parent plants (Granett et al., 2001). For example, high-vigor rootstocks are used with low-vigor scions on less fertile soils, while low-vigor rootstocks are used with high-vigor scions on fertile soils (Pongracz, 1983). Rootstocks also differ significantly in their resistance to drought (Carbonneau, 1985).

The range of available rootstocks represents an important resource for the viticulture industry with respect to the long-term sustainability of grapegrowing in California. However, much remains to be learned in order to fine tune the use of these genetic resources in the wide range of California growing conditions. Our current understanding of rootstock nutrient requirements is general yet incomplete, based in most cases on empirical findings.

Nutrient availability and uptake

Soil texture and structure have an important impact on nutrient availability to the plant. Soils rich in organic matter are generally high in available nutrients, including zinc and iron. Clay soils can fix potassium in soil, thereby decreasing the availability of this nutrient to the plant. Rapid leaching can drain nutrients from sandy soils.

Within the root zone, the availability of moisture and its movement in the soil can have significant effects on nutrient availability. Excess leaching may cause nitrogen loss to the water table, and waterlogging may cause denitrification (the conversion of nitrate to nitrogen gas, which occurs where oxygen is in short supply).

Rootstocks also have a pronounced influence on the mineral nutrition of the scion, which should be considered when developing fertilization programs (Koblet et al., 1996). Some rootstocks, such as Malègue 44–53 (44–53), have a higher affinity for potassium than magnesium and therefore may fail to take up sufficient magnesium from the soil. This is compounded by the fact that high levels of potassium in the soil solution can limit the solubilization of magnesium, reducing the availability of magnesium to the plant (Brancadoro et al., 1994). Other rootstocks, such as Paulsen 1103 (1103P), easily absorb magnesium (Sciienza et al., 1986). In high-potassium soils, selecting a “magnesium-absorbing” rootstock may be the easiest way to correct for a deficiency of this nutrient (Brancadoro et al., 1994).

Our understanding of rootstock–scion interactions is further complicated by the fact that grape cultivars respond differently to nutrients. For example, Chardonnay and Cabernet Sauvignon have high requirements for magnesium,
which can result in deficiencies in this mineral (Loue and Boulay, 1984).

Vines grown on different rootstocks may also differ in their tolerance to lime (calcium carbonate) and susceptibility to iron deficiency. High lime content induces chlorosis (a condition in which leaves produce insufficient chlorophyll due to iron deficiency) by slowing iron uptake and translocation (Bavaresco et al., 1992). In calcium-rich soils, total leaf chlorophyll and iron content were higher in Chardon- nay grafted onto lime-tolerant rootstocks such as Ruggeri 140 (140R) or Selection Oppenheim 4 (SO4) than on the less lime-tolerant rootstock Millardet et De Grasset 101–14 (101–14) (Bavaresco et al., 1992). Under high-salinity conditions, Syrah grafted on Ramsey and 1103P (both salt-tolerant rootstocks) had higher wine potassium, pH, and color than on its own roots (Walker et al., 2000, 2002).

Assessing rootstocks and soils

Ideally, vineyard management strategies should consider the site-specific properties of individual soils, the individual requirements of the rootstock and the scion, as well as the relationship between the two. By considering these factors individually and collectively, we will be able to better understand the soil–vine relationship and begin to develop site-specific, sustainable vineyard management plans.

In this study, we examined the nutrient status and growth characteristics of 14 common rootstocks on three distinct soil types. Two vineyards were located in the Sacramento River Delta near the town of Hood; the scion was Chardon- nay on Egbert clay (sandy loam variant) soils at one vineyard and Cabernet Sauvignon on Tinnin loamy sand soils at the other (Anamosa, 1998). A third vineyard was in Amador County’s Shenandoah Valley, and the scion was Zinfandel on a Sierra sandy loam soil.

At all three vineyards, we evaluated an identical set of 14 rootstocks: Teleki 5C (5C), Kober 5BB (5BB), Couderc 3309 (3309C), Millardet et De Grasset 101–14 (101–14), Richter 110 (110R), Paulsen 1103 (1103P), Millardet et De Grasset 420A (420A), Couderc 1616 (1616C), Rupestris St. George or Rupestris du Lot (St. George), Malègue 44–53 (44–53), Ramsey, Harmony, Freedom, and VR O39–16 (O39–16) (Table 1). Twenty-five replicate vines were planted for each rootstock/scion pair. All three sites were drip irrigated and managed according to routine pest and nutrient management practices. Weeds were controlled by a combination of contact and pre-emergent herbicides, and

**Table 1. Rootstock characteristics. Source: Christensen (2003) and Pongracz (1983).**

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Parentage</th>
<th>Vigor†</th>
<th>Drought resistance</th>
<th>Lime tolerance‡</th>
<th>Salt resistance</th>
<th>Wet feet§</th>
<th>Soil preference¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. George</td>
<td><em>V. rupestris</em></td>
<td>H</td>
<td>Var</td>
<td>14</td>
<td>M/H</td>
<td>L/M</td>
<td>deep, uniform, loam</td>
</tr>
<tr>
<td>1616C</td>
<td><em>V. solonis × V. riparia</em></td>
<td>L/M</td>
<td>L</td>
<td>11</td>
<td>L/M</td>
<td>H</td>
<td>deep/fertile</td>
</tr>
<tr>
<td>3309C</td>
<td><em>V. riparia × V. rupestris</em></td>
<td>L/M</td>
<td>L</td>
<td>10</td>
<td>na</td>
<td>H</td>
<td>loam/good fertility, high Mg</td>
</tr>
<tr>
<td>44-53</td>
<td><em>V. riparia × 144M</em></td>
<td>M</td>
<td>M/H</td>
<td>9</td>
<td>L/M</td>
<td>M/H</td>
<td>heavy, moist clay</td>
</tr>
<tr>
<td>101-14</td>
<td><em>V. riparia × V. rupestris</em></td>
<td>L/M</td>
<td>L/M</td>
<td>9</td>
<td>L/M</td>
<td>M/H</td>
<td>fine texture, deep/fertile</td>
</tr>
<tr>
<td>420A</td>
<td><em>V. berlandieri × V. riparia</em></td>
<td>L</td>
<td>L/M</td>
<td>20</td>
<td>L/M</td>
<td>L</td>
<td>fine texture, deep/fertile</td>
</tr>
<tr>
<td>5BB</td>
<td><em>V. berlandieri × V. riparia</em></td>
<td>M</td>
<td>L/M</td>
<td>20</td>
<td>L/M</td>
<td>Var</td>
<td>moist clay</td>
</tr>
<tr>
<td>5C</td>
<td><em>V. berlandieri × V. riparia</em></td>
<td>L/M</td>
<td>L</td>
<td>17</td>
<td>M/H</td>
<td>H</td>
<td>adapted to drought, saline soils</td>
</tr>
<tr>
<td>1103P</td>
<td><em>V. berlandieri × V. rupestris</em></td>
<td>H</td>
<td>H</td>
<td>17</td>
<td>M/H</td>
<td>M</td>
<td>hillside soils, acid soils, moderate fertility</td>
</tr>
<tr>
<td>110R</td>
<td><em>V. berlandieri × V. rupestris</em></td>
<td>M/H</td>
<td>H</td>
<td>17</td>
<td>M/H</td>
<td>Var</td>
<td>sandy to sandy loams</td>
</tr>
<tr>
<td>Freedom</td>
<td>1613 C × V. champinii</td>
<td>H</td>
<td>M/H</td>
<td>M</td>
<td>L/M</td>
<td>L</td>
<td>sandy to sandy loams</td>
</tr>
<tr>
<td>Harmony</td>
<td>1613 C × V. champinii</td>
<td>M/H</td>
<td>Var</td>
<td>M</td>
<td>L/M</td>
<td>L</td>
<td>sandy loams, loamy sands</td>
</tr>
<tr>
<td>Ramsey</td>
<td><em>V. champinii</em></td>
<td>VH</td>
<td>H</td>
<td>M</td>
<td>H/L</td>
<td>L/M</td>
<td>light sand, infertile soils</td>
</tr>
<tr>
<td>O39-16</td>
<td><em>V. vinifera × V. rotundifolia</em></td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>na</td>
<td>poor on coarse, sandy soils</td>
</tr>
</tbody>
</table>

† L = low; M = medium; H = high; VH = very high; Var = variable; na = not available.
‡ Tolerance to lime-induced chlorosis (percent by weight of finely divided calcium carbonate in soil that can be tolerated by the rootstock).
§ Wet feet = tolerance to excessive moisture caused by poor soil drainage.
¶ Actual performance characteristics of these rootstocks on specific soils and scions may vary.
resident vegetation was present between rows. Vineyards planted with multiple rootstocks were managed uniformly.

**Petiole nitrogen and potassium.** The sites were not deficient in nitrogen, and rootstock was the only treatment. At all sites, petiole (leaf stalk) and blade (leaf body) tissues were collected at bloom, veraison (color change at ripening), and harvest. Bloom samples were leaves opposite the basal-most grape cluster. Samples were collected over three sequential years. At each sampling date, 20 petioles and blades were collected per treatment replicate. The petioles and blades were separated, oven-dried, and sent to the University of California–Davis for processing and analysis. All samples were analyzed for nitrate-nitrogen, expressed as parts per million (ppm); total nitrogen, expressed as percent nitrogen; and percent potassium. Due to space considerations, only bloom petiole samples will be discussed in detail here.

**Soil sampling.** Soil sampling was performed at each site using a backhoe to dig a sampling pit to a maximum depth of 70 inches. Soil morphology was described as outlined in the U.S. Soil Survey Manual (Soil Survey Division Staff, 1993), and samples were collected from all horizons (distinct soil layers).

Geographic location was measured by a Garmin 45XL geographic positioning system. Soil samples were air-dried, ground, sieved to pass through a 2-mm grid, and submitted to the ANR (University of California Division of Agriculture and Natural Resources) Analytical Laboratory for analysis. Gravel content was calculated from the weight of material retained by the sieve. Soil pH was measured in a saturated paste, and electrical conductivity was measured in the saturated paste extract (Sparks, 1994). Exchangeable cations (calcium, magnesium, potassium, and sodium) were extracted using ammonium acetate, pH 7.0. Sand, silt, and clay were measured using the hydrometer suspension method (Klute, 1986). Official soil series descriptions were collected from the web site of the USDA National Soil Series Description Facility in Lincoln, NE.

**Delta Chardonnay vineyard**

**Soil characteristics.** The soils at the Delta Chardonnay site belonged to the Egbert clay loam series, which has subsoil textures of clay loam and silty clay loam. This was the heaviest-textured soil of the three studied, ranging from 13 to 50% clay (Fig. 1). The cations studied were potassium, sodium, calcium, and magnesium. This soil had a fairly high cation exchange capacity (CEC), ranging from 33 to 48 cmol(+)/kg (centimoles of charge per kilogram of soil), and the highest exchangeable cation content of the three soils studied (Fig. 2A, 2B, next page).

Potassium availability was measured by the potassium-to-CEC ratio, which was below the predicted value of 2.5 found in the literature for this soil texture (Champagnol, 1984; Etourneaud and Loue, 1986) (Fig. 3A, next page). The concentration of soluble salts in the soil solution was measured by electrical conductivity, which exceeded 2.5 in the two deepest horizons (Fig. 2A, next page). Electrical conductivity values above 2.5 may limit vine vigor (Nicholas, 2004). The exchangeable sodium percentage, defined as the sodium-to-CEC ratio, approached but did not exceed 6, the level above which sodium content can negatively affect vine vigor (Nicholas, 2004) (Fig. 3C, next page). High soil magnesium can induce potassium deficiency, which negatively affects vine growth and crop load. High magnesium also reduces soil aggregate stability, reducing water infiltration (Dontsova and Norton, 2001).

**Rootstock performance.** In this vineyard, four rootstocks gave above-average fruit yields and pruning weights (the weight of vine canes removed at pruning, a measure of plant vigor): 1103P, 101-14, 1616C, and Freedom (Fig. 4A, page 35). Rootstocks with below-average pruning weights and fruit yield in this soil included 420A, 44–53, and O39–16 (Fig. 4A, page 35). Rootstock 420A is sensitive to potassium deficiency (Pongracz, 1983) and so may have been affected by the lower-than-expected potassium availability for a heavy-textured soil (Fig. 3A, next page) (Etourneaud and Loue, 1986).

**Plant mineral content.** Petiole nitrate-nitrogen was on average lower at bloom and veraison, but higher at harvest (386 ppm and 382 ppm versus 947 ppm, respectively). In general, the highest bloom petiole nitrate values were seen in rootstock 1103P and the lowest in 1616C, 44–53, and

![Fig. 1. Soil textural triangle for three vineyards, showing percentages of sand, silt, and clay for each soil horizon. Numbers correspond to horizons, increasing with depth.](image)
Harmony (Fig. 4A). Linear regression analysis revealed a significant correlation between yield and petiole nitrate-nitrogen at bloom ($r^2 = 0.438$).

Petiole potassium was higher at bloom and veraison, while much lower at harvest (2.81% and 2.73% versus 1.59%, respectively). The highest bloom petiole potassium values included rootstocks 44–53 and 1616C (Fig. 4A). Notably, rootstock 44–53 had the highest petiole potassium levels at bloom in both the Chardonnay and Cabernet vineyards, as well as the third-highest levels in the Zinfandel vineyard (Fig. 4).

**Delta Cabernet Sauvignon vineyard**

**Soil characteristics.** The alluvial soils at the Delta Cabernet Sauvignon site were mapped as Tinnin loamy sand. The soil at the sampling site was characterized by a loamy surface horizon and light-textured subsoil horizons that increased in sand content with depth (Fig. 1). This soil had the highest pH range of those studied, from neutral at the surface to alkaline in the subsoil (Fig. 2A). It also had lower electrical conductivity and exchangeable cation levels than the Delta Chardonnay vineyard, with a relatively low CEC of 10 cmol[+]/kg except at the surface (Fig. 2A).

The potassium-to-CEC ratio was in the satisfactory range in the upper horizons, but there was a slight potassium deficiency in the lower root zone (Fig. 3A) (Etourneaud and Loue, 1986). Sodium content in this soil was low (Fig. 3B) (Nicholas, 2004). The calcium-to-magnesium ratio was below 1 in the subsoil, indicating a relative excess of magnesium (Fig. 3C) (Champagnol, 1984).

**Rootstock performance.** Pruning weights were above average in this vineyard for rootstocks Ramsey, 110R, and 1103P, while O39–16 gave the highest fruit yield (Fig. 4B). Rootstock 44–53 had the lowest pruning weight and among the lowest fruit yields.

**Plant mineral content.** Petiole nitrate-nitrogen declined significantly between bloom and veraison (from 567 to 307 ppm), but by harvest returned to a level similar to that at bloom (data not shown). Rootstocks with the highest petiole nitrate-nitrogen at bloom included Ramsey and O39–16 (Fig. 4B).

Petiole potassium levels declined sharply from bloom to veraison and harvest (2.33% versus 1.21%, and 0.38%, respectively). The highest levels at bloom were in rootstocks 44–53 and Freedom, while the lowest were in 420A and 110R (Fig. 4B).

**Amador Zinfandel vineyard**

**Soil characteristics.** The soil at the Amador Zinfandel site was mapped as Sierra coarse sandy loam, a light-textured soil with a large sand fraction and low clay content (Fig. 1). In addition, this soil had a high coarse-
fragment content, as the Sierra soil series developed from a fractured granitic substratum. This soil had a paralithic contact (direct contact with fractured bedrock) with soft, decomposing granite rock at a depth of 30 inches (Anamosa, 1998). Vine roots penetrated to 60 inches in rock cracks. Due to its light texture and high coarse-fragment content, this soil’s potential water-holding capacity was very low and would make it sensitive to drought if dry-farmed. It also had a slightly acidic pH with respect to the other two profiles studied (Fig. 2A) and a relatively low CEC, and therefore, a small nutrient reservoir (Fig. 2A, 2B). However, it also had high manganese content (not shown), likely due to the presence of this element in the parent material and the slightly acidic pH.

For light-textured soils, a satisfactory potassium-to-CEC ratio is in the range of 1.5 (Etourneaud and Loue, 1986). In this vineyard, the potassium-to-CEC ratio was highest in the topsoil, likely reflecting an excess of potassium due to fertilization (Fig. 3A). The potassium-to-CEC ratio was lower in the subsoil, indicating potassium deficiency in the lower horizons (Etourneaud and Loue, 1986). This soil also had a high calcium-to-magnesium ratio and the lowest exchangeable magnesium of the three sites studied (Fig. 2B, 3C).

Rootstock performance. Rootstocks with above-average pruning weights on this soil included 5BB, 1103P, 1616C, and Freedom (Fig. 4C). Rootstocks with high fruit yields included 5BB, 420A, 110R, and 1103P. Rootstocks 44–53, 101–14, and 420A gave the lowest pruning weights, while O39–16 gave the lowest average fruit yield (Fig. 4C).

Plant mineral content. Petiole nitrate-nitrogen levels declined sharply for all rootstocks from bloom to veraison and harvest (1,317 ppm versus 80 ppm and 102 ppm, respectively) (data not shown). Large differences in bloom nitrate-nitrogen values among rootstocks were seen, with the highest for O39–16 and 5BB and the lowest for 420A.

On average, petiole potassium levels were unchanged from bloom to veraison but declined significantly by harvest (2.06% and 2.00% versus 0.87%, respectively) (data not shown). Rootstocks with the highest petiole bloom potassium were Freedom, O39–16, and 44–53, and the lowest were 420A and 110R (Fig. 4C).

Three sites compared

Rootstocks had an impact on the foliar levels of nitrogen and potassium in petiole tissues at all three sampling dates throughout the growing season. Some rootstocks consistently showed high petiole potassium values in all three vineyards, notably 44–53, which has been previously noted for this characteristic (Champagnol, 1984). In contrast, rootstock 420A consistently showed low petiole potassium in all three vineyards. As reported by Wolpert et al. (2005), petiole potassium content at bloom was lower for rootstocks that had Vitis berlandieri genetic backgrounds than for those that did not (Fig. 4). In this study, rootstocks with V. berlandieri backgrounds were 420A, 5BB, 5C, 1103P, and 110R (Table 1).
berry juice chemistry and sensory characteristics must be taken into account when selecting rootstocks for particular scions.

Despite the site-specific differences in soils, some rootstocks showed similar trends in plant mineral content and vigor at all three sites. For example, rootstock 44–53 had below-average vigor, petiole nitrogen, and nitrate-nitrogen at bloom in all three vineyards.

Plant nutrient levels can be influenced by scion-specific differences in nutrient metabolism (Christensen, 1984), and scion genotype can also affect rootstock performance (Virgona et al., 2003). In the present study, the variability observed in rootstock performance also suggests a potential role for rootstock–scion interactions.

**Tailored vineyard fertilization**

Additional trials are needed in the diverse environments in which grapevines are grown within California, in order to better match rootstocks and scions to particular soil types and local edaphic conditions (such as soil water content, pH, aeration, and nutrient availability). As we learn more about the nutrient input requirements of specific rootstocks and scions, the measurement of plant nutrient levels, and the physical and chemical properties of soil, site-specific fertilization management programs can be tailored to individual vineyards. The ultimate goal of such programs is to decrease fertilization costs and environmental pollution, thus promoting sustainability. Future studies will include rootstock trials on soils with different physical and chemical properties in an effort to increase our understanding of the soil–vine relationship.

**Conclusions**

Sustainable vineyard fertilization can lead to cost savings while protecting the environment. However, appropriate fertilization conditions depend on the rootstocks, which differ in their uptake of macro- and micronutrients, as well as on the vineyard soils’ physical and chemical characteristics, which affect the soil nutrient reservoir.

We studied identical sets of 14 rootstocks on three different soils. Rootstocks had a significant impact on petiole levels of nitrogen and potassium throughout the growing season. Pruning weight and fruit yield also varied considerably by rootstock and site. However, rootstock performance was not consistent among sites, nor was the seasonal pattern of change in nitrogen and potassium consistent among sites. The observed differences emphasize the impact of soil texture and nutrient availability on plant growth. Further studies will help guide the development of site-specific sustainable fertilization regimens.

**Author notes**

The authors greatly appreciate the cooperation of Trinchero Family Estates and Montevina Vineyards, and University of California viticulture advisers Donna Hirschfelt (Amador) and Chuck Ingels (Sacramento); and funding support from the American Vineyard Foundation and the USDA Viticulture Consortium.

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**May–June 2010 Self-Study Quiz**

**Vineyard nutrient needs vary with rootstocks and soils (no. SS 04046)**

1. **Veraison refers to the**
   - a. condition in which leaves produce insufficient chlorophyll.
   - b. grafted fruit-bearing part of the plant.
   - c. color change at ripening.
   - d. full bloom.

2. **Scion refers to the**
   - a. thickened portion of a shoot or cane where the leaf petiole is attached.
   - b. green, leafy growth that develops from the compound bud.
   - c. grafted fruit-bearing part of the plant.
   - d. main, upright structure(s) of the grapevine.
3. Which of the following statements is true, according to the article?
  - a. The European grape *Vitis berlandieri* is highly susceptible to phylloxera, but many American native species are not.
  - b. The American grape *Vitis berlandieri* is highly susceptible to bunch stem necrosis, but many European native species are not.
  - c. The European grape *Vitis vinifera* is highly susceptible to bunch stem necrosis, but many American native species are not.
  - d. The European grape *Vitis vinifera* is highly susceptible to phylloxera, but many American native species are not.

4. Which of the following is true regarding the practice of grafting European scions onto phylloxera-resistant rootstocks?
  - a. High-vigor rootstocks are used with low-vigor scions on less fertile soils.
  - b. Low-vigor rootstocks are used with low-vigor scions on fertile soils.
  - c. High-vigor rootstocks are used with low-vigor scions on fertile soils.
  - d. Low-vigor rootstocks are used with low-vigor scions on less fertile soils.

5. Soils rich in organic matter generally
  - a. can fix potassium in the soil, thereby decreasing the availability of this nutrient to the plant.
  - b. can fix potassium in the soil, thereby increasing the availability of this nutrient to the plant.
  - c. are high in available nutrients.
  - d. are low in available nutrients.

6. Which is true of the Egbert clay loam series in this study?
  - a. It has subsoil textures of clay loam and sandy clay loam.
  - b. It has subsoil textures of clay and silty clay loam.
  - c. It was the heaviest-textured soil of the three studied, ranging from 23 to 40% clay.
  - d. It was the heaviest-textured soil of the three studied, ranging from 13 to 50% clay.

7. Which of the following statements is true?
  - a. Excess nitrogen is detrimental to wine quality.
  - b. Excess nitrogen may create conditions favorable to disease.
  - d. Excess potassium leads to high vigor.

8. Which of the following is NOT mentioned in the article?
  - a. High levels of potassium in the soil solution can limit the solubilization of magnesium, reducing the availability of magnesium to the plant.
  - b. Chardonnay and Cabernet Sauvignon have high requirements for potassium, which can result in deficiencies in this mineral.
  - c. Some rootstocks, such as Malègue 44–53, have a higher affinity for potassium than magnesium.
  - d. Rootstocks have a pronounced influence on the mineral nutrition of the scion, and grape cultivars respond differently to nutrients.

9. Vines grown on different rootstocks may differ in their tolerance to lime. Which of the following can result?
  - a. High lime content can lead to reduced vigor by slowing potassium and magnesium uptake.
  - b. Low lime content can tie up iron in the soil, thereby reducing its uptake.
  - c. High lime content induces chlorosis by slowing iron uptake and translocation.
  - d. Low lime content induces chlorosis by slowing magnesium uptake and translocation.

10. In all three vineyards in this study, some rootstocks consistently showed
  - a. high petiole potassium values.
  - b. high petiole nitrogen values.
  - c. below-average vigor.
  - d. below-average pruning weight.

11. The three soils in this study exhibited large differences in texture and in physical and chemical properties. Which of the following examples of this was given in the article?
  - a. The Cabernet Sauvignon vineyard’s Tinnin loamy sand was a heavy-textured soil with high sand content.
  - b. The Chardonnay vineyard’s Egbert clay loam was a heavy-textured soil with high exchangeable cation content.
  - c. The Zinfandel vineyard’s Sierra sandy loam was a light-textured soil with high exchangeable cation content.
  - d. The Merlot vineyard’s Zamora silt loam was a medium-textured soil with medium exchangeable cation content.

Quiz continues next page
12. The differences found in the three soils in this study contributed to differences in
☐ a. bloom nitrate-nitrogen values.
☐ b. petiole potassium levels.
☐ c. berry juice chemistry.
☐ d. plant vigor.

13. Which of the following was NOT mentioned as something that should be considered when evaluating vine performance?
☐ a. Berry juice chemistry.
☐ b. Sensory characteristics.
☐ c. Pruning weight.
☐ d. Winterhardiness.

14. In Table 1, what is the term used to describe a rootstock’s tolerance to excessive moisture caused by poor soil drainage?
☐ a. Wet feet.
☐ b. Veraison.
☐ c. Moisture resistance.
☐ d. Water uptake capacity.

15. Which of the following statements is true about this study?
☐ a. Neither rootstock performance nor the seasonal pattern of change in plant mineral content was consistent among sites.
☐ b. Rootstock performance was consistent among sites, but the seasonal pattern of change in plant mineral content among sites was not.
☐ c. Both rootstock performance and the seasonal pattern of change in plant mineral content was consistent among sites.
☐ d. Rootstock performance was not consistent among sites, but the seasonal pattern of change in plant mineral content was consistent among sites.

SELF-STUDY QUIZ REGISTRATION FORM

Name: ________________________________

Address: ________________________________ City: ________________________________

State/province: ______________________ Zip: ____________________________ 

CCA certification no.: __________________________

☐ $30 check payable to the American Society of Agronomy enclosed. 

☐ Please charge my credit card (see below)

Credit card no.: __________________________ Name on card: __________________________

Type of card: ☐ Mastercard ☐ Visa ☐ Discover ☐ Am. Express Expiration date: __________________________

Signature as it appears on the Code of Ethics: __________________________

I certify that I alone completed this CEU quiz and recognize that an ethics violation may revoke my CCA status.

This quiz issued May 2010 expires May 2013

SELF-STUDY QUIZ EVALUATION FORM

Rating Scale: 1 = Poor  5 = Excellent

Information presented will be useful in my daily crop-advising activities: 1 2 3 4 5

Information was organized and logical: 1 2 3 4 5

Graphics/tables (if applicable) were appropriate and enhanced my learning: 1 2 3 4 5

I was stimulated to think how to use and apply the information presented: 1 2 3 4 5

This article addressed the stated competency area and performance objective(s): 1 2 3 4 5

Briefly explain any “1” ratings: ____________________________

Topics you would like to see addressed in future self-study materials: ____________________________
New headquarters building creates efficiencies, opportunities

The American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, along with the certification programs, recently moved into a new headquarters building located at 5585 Guilford Road in Madison, WI. The former headquarters office was built in the early 1960s and served the Societies well, but there were inefficiencies as well as structural constraints that prompted this move. In addition, the flat commercial real estate market made for a favorable purchase price.

A highlight of the new 18,400 ft² building is its modern, energy-efficient office space, including lighting and environmental controls. Built in 2000, the two-story building also features a large multi-purpose, education training center for use with meetings, training, and outreach programs.

Education training center

The education training center will allow the Societies and the certification programs to serve and interact with members, certified professionals, and the wider community of people with interests in agriculture, science, K-12 education, and conservation. Capabilities of the new education training center include: video conferencing, webcasting capabilities, wireless connections, projector and projection screen, and other training aids.

An ongoing use of this center will be to host our successful online seminar program for certified professionals to earn CEUs. View an upcoming calendar of online seminars at: www.agronomy.org/certifications/seminars. We have also recently initiated certification for advisers in India. The center will allow us to provide distance education and provide knowledge transfer to this region.

Members of the Societies, practicing professionals, community members, civic organizations, private corporations, and local university faculty and students can utilize the center upon request.

Office space

The three Societies are joint owners of the new building, and there was a successful move of staff, offices, and equipment in early April. The new building provides office and modular space to comfortably house current staff. The office space has been configured for maximum efficiency, grouping together departments that have regular interaction. An unfinished space above the warehouse will allow for additional offices or other uses in the future.

In addition, there are two smaller conference rooms that can accommodate department meetings, board meetings, and educational training. The building has a reception area, a kitchen and eating space, storage space for publications, and room for our in-house printing activities.

While all phone numbers remain the same, please note the new mailing address as 5585 Guilford Road, Madison, WI 53711-5801.

Certification update

Spring is usually the time of year when we update the certification numbers. CCAs, CPAg’s, and CPSS/Cs ending their two-year CEU cycle have completed their records to satisfy requirements, and renewals have been finalized.

CCA

There are 12,687 CCAs this year compared with 13,189 CCAs in 2009. We saw a 99% renewal rate among all CCAs and a 95% renewal rate among those ending their two-year CEU cycle (5,550). In addition to the CEUs, renewing requires an annual fee.

CCA exams were given to 881 applicants in February 2010. That’s a 5% increase over the number of exams given in February 2009. If we have 185 or more examinees in August, we will be at or greater than last year’s numbers (820 in February and 1,066 total). We have been consistently between 1,000 and 1,200 examinees for the past five years.

CPAg

There are 632 CPAg’s this year, which is about the same amount as a year ago (622). There are five associate professionals who are on their way to full certification.

CPSS and CPSC

There are 947 CPSS’s and 173 CPSCs this year, up from last year’s numbers of 889 and 161, respectively.

Soils exam numbers are down 27% compared with this time last year (82 in 2010 compared with 113 in 2009). There were 200 total soils exams last year, which was the highest amount on record, so we are not quite half way to being at the same level as 2009.

Numbers don’t always tell the full story. They indicate trends but don’t really tell us why someone became certified or decided to drop their certification. In prior surveys of those who did not renew their certification, the top reason was that they were no longer in the profession. We will be conducting a similar survey in the coming months to add more qualitative data to the numbers.
Soil mapping in the Napa Valley as related to vineyard establishment and management

By Paul W. Skinner, Terra Spase, Inc., St. Helena, CA

The relationship between vineyard soil or site characteristics and fruit and wine quality has recently been a topic at international, national, and regional conferences on viticulture. At the local level, soil data has become increasingly important for vineyard management and vineyard development practices in the premium wine grape growing area of Napa Valley, as well as many other coastal and central San Joaquin Valley viticultural areas in California.

A renewed interest in this subject has led to the production of two manuscripts that describe the soil and weather conditions that influence grape growing in the Napa Valley AVA of California (Skinner, 2003a; Skinner, 2003b). As the demand for consistent yields, increased fruit and wine quality, and more uniform ripening continue to spread through the wine grape industry, accurate soil data is becoming more and more important for adjusting vineyard practices to meet these goals.

Terra Spase has been actively describing, analyzing, and mapping vineyard soils in these areas since 1992 (Freeze, 1997). As the information has become more valuable and new technologies have become available, the approach as shifted from hand-augering samples, to collecting samples from backhoe pits, to using new electronic equipment such as electromagnetic sensors, capacitance probes, and multisensor penetrometers. These tools, coupled with GIS and GPS software, are currently being used to locate, describe, analyze, and map important soil properties that characterize the spatial variability that is present in newly developed fields or in existing vineyard blocks.

This information is being used to design new vineyards, irrigation systems, and blocks; select vine spacing, scions, and rootstocks; and determine soil preparation practices and amendment and fertilizer applications. In existing vineyards, the data is being used to adjust irrigation and fertility practices, as well as define canopy management areas and direct harvest sampling and scheduling.

Methods

Soil chemical and physical data were collected from a potential vineyard site in the Napa Valley AVA during the spring of 2005 using a suite of sensors and software referred to as the Soil Information System (SIS). The site is in a valley floor location in the northeastern corner of the Napa Valley AVA and consists of approximately 100 acres of...
open ground that was developed into a vineyard during the winter and spring of 2006.

Both the Geonics EM 38, an electromagnetic conductivity sensor (EM), and the Veris electrical conductivity (EC) or resistivity sensor are pulled behind a four-wheel all-terrain vehicle that is also outfitted with GPS equipment. The SIS penetrometer is capable of working in open and sloping (<30%) ground as well as in existing vineyards with a minimum row spacing of 5.7 ft. The probe is mounted on either a six-wheeled gator or on a four-wheel drive tractor.

The EM and GPS sensors produce soil variability maps based on the effects of elevation, slope, aspect, and soil moisture, texture, and salinity levels. The EM-generated soil variability maps are used to direct the sampling with the SIS penetrometer (Fig. 1). The SIS penetrometer consists of resistance as well as resistivity and capacitance sensors, a color sensor, and a video for detecting visual characteristics of the soil profile. The physical data is collected every 2.5 cm as the probe moves vertically through the soil profile. The data includes resistance (PSI), tip and sleeve resistivity, moisture status, depth, and root-limiting depth. From the soil texture data, plant available water-holding capacity, field capacity, wilting point, and saturation levels are calculated for each probe site.

Based on the EM and EC variability maps and the data from the SIS penetrometer, sites are selected within the sample area for collecting soil chemical data. A soil-coring device is then used to collect samples across the site. The soil cores are then taken to the laboratory and visually inspected for horizon boundaries, color, mottles, structure, permeability, and root numbers. Samples from surface and sub-surface horizons are then aggregated and sent to a certified soil-testing laboratory for chemical analysis including soil pH, cation exchange capacity, organic matter, EC, K, P, Ca, Mg, Na, B, Zn, and Cu.

Soil maps are produced from the point data collected by the SIS penetrometer and soil core data using interpolation methods including kriging and inverse distance.

Data and results

Soil physical data (texture and moisture content) collected with the SIS penetrometer from one of the approximately 100 probe sites are displayed in Fig. 2. Texture is shown varying from approximately 35% sand, 40% silt, and 25% clay in the surface horizons to approximately 20% sand, 50% silt, and 30% clay in the subsurface horizons. The relationship between texture and water-holding capacity is shown in Fig. 3, where field capacity is indicated by the green line, wilting point or –15 bar soil matrix potential by the brown line, and plant available water by the yellow line. The crosshatched area is the amount of water present in the profile at the time the measurement was taken.

A vertical display of the penetrometer data for the same site shows an increase in soil resistance to approximately 450 PSI between 40 cm and 60 cm in depth (data not shown). A reading of 350 PSI is considered to be root limiting in some soils.

Soil texture for the B1 horizon varies from a clay loam in the southern section to loam and sandy loam and loam in the northern section (data not shown). The moisture...
content as measured by the soil capacitance probe on this day ranged from a high of 76 cm in the central section to a low of 17 cm in the northern section (data not shown). Root zone plant available water (Fig. 4) varied from 10 to 20 cm over the site while the water held in the profile below the wilting point ranged from 12 to 29 cm (data not shown).

Soil samples for chemical analysis were collected from soil cores from 22 different locations across the site. The cores were taken to a laboratory, inspected, and then separated at different depths and sent to the laboratory for chemical analysis. The soil chemical data was interpolated using geostatistical algorithms to produce maps showing the spatial variation across the site as shown for the surface cation exchange capacity in Fig. 5 and the subsurface phosphorus levels in Fig. 6.

The combined effects of selected soil physical and chemical parameters on potential vine growth were calculated using a proprietary model developed by Terra Spase and are displayed in Fig. 7. This map shows the combined effects of depth and parameter-weighted values across the site and is used in preplant design of vineyard blocks, irrigation systems, varietal and rootstock selections, and spacing and trellis configurations.

Discussion

Vine variability has been recently described as an important determinant of overall juice and wine quality from vineyards (Bramley, 2005). Soil variability is a major factor influencing vine growth and is therefore a key component in understanding and managing vine variability within most vineyard production units or blocks. Removing or managing vine variability with accurate soil information can lead to more uniform production and fruit ripening, easier and less costly canopy management practices, and successful irrigation and water management programs. Therefore, it is becoming increasingly important for viticulturists and managers to collect, evaluate, understand, and utilize soil information in their vineyard management programs.

Vineyard irrigation practices, especially the adoption of regulated deficit irrigation (RDI) strategies, have become increasingly important for the management of vine canopy growth and a resulting increase in desirable fruit quality parameters (i.e., color, phenolics). These strategies limit the amount of water available to the root system while monitoring vine moisture status using midday leaf water potential measurements commonly without accurately characterizing the plant available soil water status. This can be particularly dangerous when there are significant swings in environmental conditions that exert stress on the vine canopy. Significant crop loss occurred in some vineyards in California during the 2004 harvest, which may have been averted if the soil moisture status going into a three-day heat wave in early September had been adequately characterized.

Soil texture, moisture, plant available water, and field capacity maps can be used to select areas to monitor vine water status and as a basis for placing sensors to monitor soil moisture conditions. Irrigation practices can then be managed with this information to accurately guide RDI strategies that do not result in excessive vine stress or significant crop loss (Lebron et al., 2003).
Soil cation exchange capacity is a function of soil texture, pH, and organic matter content and when used in conjunction with specific nutrient data, the maps can be used to adjust preplant applications of soil amendments such as lime, gypsum, and potassium to precise locations across the vineyard.

Adequate soil phosphorus levels are important for maintaining uniform growth and fruit production in vineyards planted to low-P soils. Soil P levels less than 10 ppm can significantly reduce vine cluster numbers and cluster size (Skinner et al., 1989). Soils with high Ca/Mg ratios or low pH and Mg levels can also benefit from having increased P levels (Skinner et al., 1990). Adjusting soil P to adequate levels in either preplant situations (broadcast and rip) or in existing vineyards (inject through drip) can have significant positive effects on vine production. Soil potassium levels are also important to maintaining healthy canopies that are capable of ripening normal crop loads. Soil potassium levels less than 100 ppm are too low to support normal production levels for most varietal and rootstock combinations in current use.

Soil vigor potential maps (Fig. 7) are useful in designing vineyard blocks (Fig. 8) and irrigation systems, choosing vine spacing and trellis configurations, and for selecting scion and rootstock combinations (Fig. 8) that match the vineyard and winery’s production and quality goals. Areas with high vigor potential are more normally suited to the production of white wine cultivars using wider spacing, low or moderately vigorous rootstocks, and larger trellis systems. Vineyard areas with low soil vigor potential are usually more suited to red wine varietals, closer spacing, and are planted with moderate to vigorous rootstocks.

**Conclusion**

Soil data that was collected, analyzed, and displayed with new sensors and software mapping techniques are successfully being used to map soil variability across vineyard sites. This data is useful for planning new vineyard developments as well as for adjusting current vineyard irrigation and fertilization management practices to improve uniformity, production, and fruit ripening in California vineyards.

**References**


Carbon fixation technology

Biagro Western has secured international rights to market a new product that the company claims will allow farmers to increase crop carbon fixation and thereby increase nitrate uptake and nitrogen use efficiency. The product is called Take-Off.

The company says that the product speeds plants to maturity, allowing them to more efficiently assimilate nitrogen by coordinating its uptake with the photosynthesis processes. It cites field tests, which indicate that Take-Off reduced nitrogen inputs by 25 to 35%.

Biagro Western says Take-Off enhances plant yield without the use of growth hormones by simply enhancing the levels of growth materials already in the plant. The product can be applied as a spray to a plant’s leaves, using traditional sprayer equipment, or to the plant’s root system. It is said to enhance tree fruit, vines, vegetables, and cereals, including wheat and corn.

“We watched the results of field tests and pursued the rights to license and distribute the product because we saw the benefits,” says Pete Alvitre, chief operating officer of Biagro Western. “We know that this will help growers produce a better crop while saving on input costs. This technology represents a major breakthrough in improving crop productivity.”

Biagro Western says that the product was developed for use on cereals, forage, fruit, vegetables, and energy crops. Field tests continue in the United States on wheat, corn, sugarcane, rice, melons, peppers, and potatoes, under the supervision of Nigel Grech, director of research and development for Biagro Western.

“We continue to research new uses and best practices for Take-Off,” Grech says. “Through exacting science and field research, we will make a highly effective product even more beneficial. The product is already commercialized in the UK, where it is used on more than 500,000 acres of crops.”

For more information, see www.biagro.com.

Container reliability for liquid fertilizers

New venting products that prevent leakage in liquid fertilizer containers for organic, foliar, gardening, and horticultural fertilizers and supplements have been developed by W.L. Gore & Associates. The packaging vents are said to protect against product leaks by equalizing pressure, which reduces container distortion caused by altitude, temperature, or climate changes.

Liquid fertilizer formulations contain active ingredients that can release gases that cause containers to collapse or bloat when combined with altitude and temperature changes during transportation and storage. Bloated containers are at risk for leaks that can result in loss of product and potential sales revenue. In addition, damaged containers can cause harm to a product’s brand image.

According to W.L. Gore & Associates, these packaging vents protect the container and its contents because the gas-permeable, microporous-expanded polytetrafluoroethylene membrane used in the vents’ construction repels liquid fertilizer formulations while allowing air to pass through freely. These unique vents eliminate the need for increasing headspace in the container or increasing container wall thickness.

“Packaging engineers can reduce a container’s weight, which in turn reduces shipping and recycling costs, ultimately affecting the bottom line,” says Terry Czerwinski, global product manager for Gore. “By integrating our vents into liquid fertilizer containers, customers have been able to control excess material costs while improving the integrity of their containers and fertilizer products.”

For more information, see www.gore.com/fertilizers.

Herbicide-tolerant lentil varieties

According to BASF, the weed control and yield increase benefits of its CLEARFIELD Production System are now available to lentil growers in the United States. Pulse USA, based in Bismarck, ND, will be the sole supplier of CLEARFIELD-designated lentil varieties.

The company says that the designated lentil varieties are the only herbicide-tolerant lentils available in the United States. Varieties are bred to reflect regional growing conditions and requirements and are available only as certified, genetically pure
seed, which BASF says offers better yield potential than bin-run seed. They have bred-in tolerance (non-GMO) to Beyond herbicide, which offers broad-spectrum, long-lasting weed control, excellent crop safety, and an easier harvest, according to the company.

“Bringing CLEARFIELD to the U.S. lentils market will provide growers with a post-germination weed control solution unlike any they have had before,” says Nocha Van Thielen, product manager for the BASF CLEARFIELD Production System for lentils. “This will help keep weeds at bay and yields on the rise.”

Weeds such as mustards, pennycress, and volunteer wheat have been a source of frustration for conventional lentil growers in the past. Beyond herbicide has been shown to provide excellent control of tough weeds, reducing competition to increase lentil yields. The company says that research trials showed that CLEARFIELD lentils treated with Beyond herbicide averaged 190 lb/acre higher yields than their conventional counterparts.

“Growers who gave up on lentils because of frustrations with weed control options now have a good reason to give the crop another try,” says Byron Lannoye, Pulse USA General Manager. “While there is no such thing as a bulletproof program, overall weed control is vastly improved, and using the system reduces trips across the field.”

Pulse will market the CDC Impala CL and CDC Maxim CL seed varieties. Growers will be required to sign the CLEARFIELD stewardship agreement, which helps them understand how to engage in best practices for using the BASF CLEARFIELD Production System. Stewardship practices include purchasing certified seed each season, strictly adhering to label directions, crop rotations, and use of non-ALS inhibitor herbicides for burndown in fallow rotations.

For more information on lentils and other crops, see http://agproducts.basf.us.

Sprayer control systems

Two solutions for ISOBUS sprayer control have been introduced by TeeJet Technologies. One solution is for owners of factory-installed virtual terminals. The other is for operators who require a complete system including a virtual terminal.

In 2001, farm machinery manufacturers agreed to implement a common standard for communication interfaces on tractors, implements, and farm management systems. The standard is called ISO 11783 and is commonly referred to as ISOBUS.

The common standard enables products from different manufacturers to communicate and eliminates the need for separate terminals, displays, and controls. Once ISOBUS is fully implemented, tractors will have a single virtual terminal in the cab.

The new sprayer control systems can use a John Deere, CASE IH, or AGCO virtual terminal. The kit includes the IC18 ISOBUS Sprayer Electronic Control Unit (ECU), Boom-Pilot automatic boom section control module, a switch box, and all cable and connection to operate on Deere, CASE IH, or AGCO virtual terminals. The IC18 Sprayer ECU has an intuitive interface with advanced features such as multiple-rate selection, section status, and task control for prescription applications.

A new common standard developed by TeeJet Technologies enables sprayer control systems from different manufacturers to communicate and eliminates the need for separate terminals, displays, and controls. Once the new standard, called ISOBUS, is fully implemented, tractors will have a single virtual terminal in the cab.

TeeJet Technologies also offers a sprayer control solution that includes the components noted above plus the new Matrix 570VT interface, which features a bright 5.7-inch touch screen suitable for both daylight and nighttime viewing and can be used with other ISOBUS-compatible ECUs in addition to the IC18.

“We’re fully committed to the ISOBUS standard and want to help as many growers as possible experience the benefits of it,” says Jim Shone, business unit manager at TeeJet Technologies. “Most growers don’t yet own a virtual terminal and will find our Matrix 570VT ISOBUS Sprayer System an affordable way to take full advantage of the ISOBUS platform. For the operators that do have a virtual terminal, our ISOBUS components are an economical way to leverage their current investment.”

The company claims it was among the first to sell ISOBUS compatible products in North America. ISOBUS job computers and controls have been in the field the last two growing seasons, and product line expansion is underway.

TeeJet Technologies manufactures a line of products including lightbar guidance systems, sprayer control systems, ISOBUS compatible job computers/controllers, assisted steering systems and other precision farming products, agricultural spray nozzles for various herbicide/fungicide applications, boom components, valves/manifolds, strainers, spray guns, and speed sensors.

For more information, see www.teejet.com.
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Agronomy and entomology go together like bees and flowers, so consider attending the Entomological Society of America’s Annual Meeting in sunny San Diego this fall. Last year’s meeting attendance was more than 2,600 and had 1,265 oral presentations and 610 posters, with more than 50% covering agronomy-related research such as extension, ecology, pest management, disease vectors, transgenic crops, bioenergy, forestry, and regulation. It is also a great opportunity to network with colleagues in related fields and to have some fun doing so.

For further information, see http://www.entsoc.org/am/cm/index.htm

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