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"Managing vineyard soil organic matter with cover crops"

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The authors review the role of cover crops in vineyard soil management, with an emphasis on things we can do to build organic matter in our soils.

· Soil fertility, buffering capacity, and biological activity all diminish when soils are cultivated and organic matter (OM) is not replenished. Cover crops are a way to help reverse these trends. By adding carbon and nitrogen (legumes) to the soils, cover crops are also an inexpensive method of fertilization. As cover crops grow, they create *macropores* (by displacing soil with their taproots), as well as soil *aggregates* (through the effect of their small roots). **Macropores and aggregates improve infiltration, water storage, and gas exchange.**

· **Types of cover crops.** There are 3 types of cover crops: grasses, legumes, and forbes. 1) **Grasses** have fibrous roots that are very effective in aggregating soil, and their C/N ratio is high. Because of their large root mass, OM increases most rapidly under grass crops. 2) **Legumes**, in association with *Rhizobium* bacteria, can fix enough nitrogen to meet annual grapevine needs. Because their C/N is lower, they decompose rapidly and contribute less OM. They are also less efficient in improving soil structure. 3) **Forbes** include broad-leaved and herbaceous plants other than grasses and legumes. Examples are mustards, composites, and buckwheat. Their contributions to the vineyard vary depending on the species, but they are known to prevent N leaching, create insectaries, suppress nematodes, reduce erosion, and aid in a controlled deficit irrigation regime. Grapegrowers often mix cover crops to gain multiple benefits simultaneously.

· **Soil physical improvement and protection.** Cover crops protect the soil from erosion by shielding the surface from the strong energy of falling raindrops (broadleaf forbes are particularly effective). As fibrous roots explore the soil, root exudates cause soil particles to aggregate, preventing crusting and runoff, and improving water infiltration. After a storm, cover crop transpiration also helps in preventing water-logging. Finally, crop residues left as mulch help keep the soil moist and cool in hot summers, which in turn stimulates biological activity. As a side effect, the authors warn us that cooler soils can also cause some delay in budbreak and plant growth.

· **Soil organic matter.** Organic matter (OM) is "living or dead plant and animal tissue in the soil". Typically, there are 3 organic matter fractions in the soil: 1) biomass, 2) plant and animal residues, and 3) humus, the stable fraction of OM that remains after the organisms have decomposed. OM in the soil serves the following purposes:
1) exudates and waxes from microorganisms in the OM bind particles together and improve soil structure,
2) OM creates larger voids between aggregates, which increase soil porosity,
3) OM helps lower soil bulk density and soil strength, facilitating rooting,
4) decomposing microorganisms in OM provide nutrients, like N (main one, which mineralizes to nitrate), S and P.

5) OM can act as a chelating agent, mobilizing micronutrients otherwise not available.
6) because of its large molecular size, humus increases cation-exchange and water-holding capacities.
7) Finally, OM additions have been able to reduce the incidence of several pathogens.

· **Soil biological activity.** Soil roots exude compounds (amino acids, sugars, organic acids, polysaccharides) "appealing" to many microorganisms. For this reason, **soil with vegetation supports higher microbial populations than fallow soil**. When a cover crop is plowed into the soil, and soil moisture is favorable, there will be a flush of soil microbe activity until the crop residues are utilized, after which microbe populations decline. (This microbe explosion can sometimes cause less nitrogen to be available for higher plants, as we will see later).

· **Cover crop decomposition.** When organic residues are added to the soil, microbes incorporate much of the N. At this stage, N is fairly stable and unavailable to plants. With time, protozoa, nematodes and earthworms consume the microbes, using the N for energy, and excreting much of the N back into the soil in the ammonium form. Ammonium is then rapidly converted into nitrates, which can be utilized by plants. **The rate of OM decomposition is temperature and moisture dependent, as well as particle-size dependent**, coarser materials on the surface decomposing slower than smaller particles in intimate contact with the soil.

· **C/N ratios.** Carbon (C) is a basic fuel for soil microbes, which use it both as energy source and to build cell walls. Nitrogen (N) and other elements are needed to build compounds essential for life. For this reason, to build OM, both C and N need to be present in adequate proportions, and normally, **a C/N ratio around 20:1 is desirable** (most good compost have values ranging from 10:1 and 20:1). Legumes generally have a C/N ratio less than 20:1, whereas grasses generally have a C/N ratio higher than 20:1, making them slower to decompose. When we add materials to the soil exceeding a C/N of 24:1, the microbes need to find additional N from other sources, like free N in the soil, making that nitrogen unavailable to the plant. This temporarily N deficiency is called "nitrogen draw", something to avoid.

· **Building soil organic matter.** OM accumulation is affected by the following factors: climate, soil texture, tillage, cover crop selection, and compost additions. 1) OM accumulation is highest in **cool, humid regions**. So, as the authors explain to us, our sunny, dry climate in California makes OM accumulation more challenging. 2) **Fine- and medium-textured** soils accumulate OM faster than coarse-textured soils, 3) Accumulation is more difficult if soils are tilled. **Conservation tillage** (allowing residues of the previous crop, thus economizing on equipment passages) removes less OM and decreases erosion. Leaving materials on the surface as mulch also maximizes OM accumulation. 4) **Grasses and sod-forming cover crops** are the most effective in building OM, because their residue is high in C. Mixing grasses and legumes in cover crops ensures a good rate of decomposition, not too slow, not too fast. Finally, 5) **compost** contains long-lived OM similar to humus that helps build soil OM, particularly in soils with good biological activity. Compost can also stimulate cover crop growth through the N, P, and K it brings to the soil.

· In the authors' experience, it takes 5 years of a soil-building program (compost and cover crops) before OM begins to make noticeable differences. But other benefits of cover crops (erosion protection, N increase, controlling vigorous vines, weed suppression) can be enjoyed sooner.

In summary, the following are some of the tools that cover crops offer to grapegrowers: 1) protect soil from erosion and crusting, 2) regulate vine growth, 3) improve soil fertility, 4) improve soil structure and water-holding capacity, 5) enhance biological diversity in the rootzone, 6) provide habitat for beneficial predators, and 7) provide firm footing for cultural operations.

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