Soil biology; cover crops; and how important is soil for good wine?

Melanie Weckert

Soil microbiologist/plant pathologist
National Wine and Grape Industry Centre
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Best soil conditions for wine grapes?

- Good wine can be produced from a wide range of soils (range of styles).

- Many wines depend on primary fruit flavour development within grapes.

- Could this be related to soil characteristics such as structure, Water Holding Capacity, minerals, biology?
Soil minerals create ‘soil signatures’ in berries

Hunter Valley vineyard - soil position was more important than vintage for:

- Yield, bunches per vine, berries per bunch, pH, TA, colour
- Juice calcium, manganese, magnesium, phosphorus, aluminium.
- Ratio of calcium to magnesium constant for soil types –
  - High ratio – lighter more perfumed styles.
  - Low ratio – richer tannic full bodied.

(Andrew Rawson, 2002, thesis) (Shiraz)
Soil minerals create ‘soil signatures’

- Specific trace elements found in wines are good markers of particular production areas.

(Greenough et al., 1997; Martin et al., 1999)
Different soils produce different berry flavours

- An Ontario Riesling study demonstrated that ‘mineral’ aroma was higher for clay soils than sandy soil (Reynolds 2007).

- Distinctive taste, aroma of wines made by one winemaker in separate batches from different terroirs in Niagara, Canada.

- Distinctive flavour profiles for Chardonnay from different soils, north and south side of Highway 81, Niagara (evidence of micro-level terroir).

  (Haynes 2000)
Soil water and berry flavours

• Niagara study (2005-07) High water status – “more intense aroma scores for baking spice, honey”.

• Low water – “more intense…citrus, peach, tropical fruit, sour taste”. (Willwerth & Reynolds 2008, Riesling).
Soil nitrogen and berry flavours

• High soil N led to lower TDN (petrol) and higher actinidol (camphor) and ß-damascenone (fruity) in Riesling (Germany) (Linsenmeier and Löhnerz 2007)

• Grape-derived compounds were of greater importance to the aroma attributes of Riesling wine than fermentation-derived compounds (Heather Smythe, Thesis, Uni Adelaide, 2007)

• Shaded berries decreased monoterpenes (linalool, geraniol, nerol (flowery) and norisoprenoid TDN (aged aromas, kero) (Marais 1992)
Good soil for healthy vines

The best wines come from **mature, healthy, balanced** vines which are supported by a soil which is:

- Easily penetrated by plant roots.
- Holds adequate water for plant requirements.
- Has adequate supplies of all nutrients.
- Is well drained and aerated.
- Supports a varied population of beneficial microorganisms.

Helen Waite, NWGIC
Soil structure

- Soil structure is the arrangement of the organic and inorganic soil fraction into discreet and relatively stable aggregates (peds).

- Interconnecting spaces between the peds = macropores (movement of oxygen, water, roots).

- Spaces within the peds = micropores (hold water).
Why aggregate stability is important

- Unstable aggregates = poor structure
- Aggregates disintegrate during rainstorms.
- Dispersed soil particles fill surface pores and a hard physical crust can develop when the soil dries.
Aggregate stability is important

- **Soil aggregate** stability is important for low *bulk density* and high plant available water.

- Aggregates $\rightarrow$ better *infiltration*.

- An increase of 1mm of moisture storage in soil over 100 ha = 1 ML ($$)
Bacteria are important for soil structure

Clay minerals (negatively charged) and positive bridging ions (e.g. Ca\(^{2+}\)) form a nano-aggregate. Bacterial polysaccharide (EPS) negatively charged.

1. Clay minerals and positive ions interact.
2. Bacteria encapsulate the nano-aggregate.
3. More clay particles join the nano-aggregate (bacterium is now encapsulated – OM stabilised).
4. Two nano-aggregates combine.
5. More clay particles join the nano-aggregate, covered in EPS.

*Perdrial et al., 2010. Scale bar = 1µm*
Fungi are important for aggregation

Cryo SEM – fungus on grapevine root hair

Scale bar = 50µm,

Photo M. Weckert

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Cover crops

One way of increasing soil microbial activity

- ensure all soil contains living plant roots – root exudates

- Permanent living ground cover is the best for microbes (pastures have very high activity and biodiversity).
Winter perennial rye grass vs straw mulch
(Vineyard near Echuca, Victoria)

- Rye grass caused greater macroporosity and greater depth of soft soil (penetration resistance <1 MPa) than wheat straw.

- The root system of ryegrass stabilised the macroporosity created during initial tillage and hilling process.

- Wheat straw had more pores of smaller size (including mesopores, 30–0.2 mm diameter) so greater water content at field capacity and pre-irrigation.

“Management to increase the depth of soft soil improves soil conditions and grapevine performance in an irrigated vineyard”
Permanent swards

- Deep rooted winter growing perennial grass swards that die off in spring so do not compete with grapevines for nutrients and water are successful in all climates:
  - Ground cover catches dew even when it doesn’t rain.
  - Cooler under the vine.
Permanent swards Tumbarumba trial

Shallow A horizon of silty clay loam over a deeper (up to 90 cm) B horizon of light clay.
Permanent swards Tumbarumba trial

No herbicide

Herbicide

Chardonnay
Results

• Labile soil carbon (available as food for microbes) was increased by 73% in three years.

• Soil structure was improved

• better infiltration

• soils wetter at 30 cm and 90 cm depth

• Lower soil water evaporation loss.

• Lower bulk density

Results

• Herbicided soil had lower soil organic carbon.

• Decreased microbes contributing to soil structure → soil crust and lower infiltration.

• Later pot trials showed that glyphosate may damage vine roots
Soil labile carbon*

(* HWC = food for microbes) under-vine at Wagga Wagga
(r = 0.91, \(P < 0.001\))

(Whitelaw-Weckert et al., Applied Soil Ecology 2007)
Cellulolytic bacteria

Soil labile carbon

**Tumbarumba** $(r = 0.82, P < 0.001)$

Many cellulolytic bacteria and actinomycetes are ‘suppressive’ towards pathogens (Whitelaw-Weckert *et al.*, *Applied Soil Ecology* 2007)
Suppressive soil bacteria

• Soil microbes can attack or suppress grapevine pathogens

• disease ‘suppressive’ – controlling plant pathogens
Soil actinomycete MW555
Suppressive bacteria prevent root disease

*Cylindrocarpon*, cause of young vine decline in Griffith, soil treated with glyphosate

Healthy grapevine root inoculated with bacteria MW555 and *Cylindrocarpon*

*Cylindrocarpon* – cause of black foot

Photos Melanie Weckert and Loothfar Rahman.
Cylindrocarpon in grapevine root

M. Weckert, CryoSEM
Suppressive soil bacteria increased with sward

*Fungus (Botryosphaeria)* inoculated in centre of plate but cannot grow near MW555 bacteria

Bacteria MW555, first isolated from vineyard soil
*Cylindrocarpon* (black-foot and Young Vine Decline)
Eutypa lata
Colletotrichum (cause of ripe rot)
Ripe rot
Suppressive vineyard soils –
Soil bacteria inhibiting *Botryosphaeria obtusa*.

![Graph showing suppressive effects of soil bacteria on Botryosphaeria obtusa](image)

---Under-vine---  ----inter-row----
low               low           low        high organic matter
Grape marc compost (many feeder roots)
(Marina Alonso, Wagga)
Under bare soil (no feeder roots)
(Marina Alonso, Wagga)
Close up of feeder roots under grape marc compost
(Marina Alonso, Wagga)

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Healthy Chardonnay roots
Diseased Chardonnay root (young vine decline)
Field trial Griffith June 2010

Root surface area per core

Control

Green waste compost

(P < 0.001)
Field trial Griffith - June 2010

Root length (cm)

Root diameter (mm)

(P < 0.05)
Beneficial nematodes increased with sward

- Beneficial nematodes increased under permanent swards

- Plant parasitic nematodes (e.g. root knot nematode) decreased.

Bacterial feeder nematodes
Predatory nematodes
Beneficial nematodes

Bacterial feeders increased with sward

Plant parasitic nematodes decreased
Swards do not necessarily decrease soil moisture

Swards

• increased infiltration.

• shaded soil - so less evaporation.

• Increased organic matter so improved water holding capacity.

• Clean cultivation = 30% less soil moisture than Rye grass (1 year growth)

(Song 2004)
Swards can increase soil Ca, P, Mg

Example

• After 3 years of rye grass, soil available K and Ca decreased (taken up by the rye grass); but after 6 years increased.

• Soil available P and Mg increased after 6 years rye grass.

Song 2004: _Vitis labruscana cv. Sheridan_ (table grapes),
Swards can increase soil available P

Tumbarumba available P in vine row soil (40-50 cm depth)

Soil available P

Bare soil

Partial sward

Complete sward

Mineralisation, solubilisation

Tesic et al., 2002
AMF in healthy grapevine root tip.

Photo M. Weckert
Wagga Wagga
AMF arbuscules in healthy grapevine root

Photo M. Weckert
AMF vesicles in healthy grapevine root.

AMF vesicles in grapevine root Tumbarumba
(Photo M Weckert)