Assessing effects of copper fungicide use on the biological health of vineyard soils

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Copper-based fungicides applied to protect against downy mildew

Copper accumulates in surface soils:
- Often over 100 mg/kg total Cu
- Brazil up to 3216 mg/kg total Cu
  (Typical background: <20 mg/kg)

Cu can cause adverse effects to soil organisms, long-term fertility of soil
Science needs to inform policy on the sustainability of farming practices

- Use of Cu fungicides may effect future use of land for agriculture (a precious public asset)
  - need to assess the risks – to inform risk management policy

- Can not make generic assessments:
  - bioavailability of Cu varies widely in diff soils (i.e. with pH)
    (EC50 nitrification <100 to >1000 mg/kg total Cu) (Oorts et al, 2006)
  - important in Australia as around 60 different viticultural regions

- Experiments with ‘artificially’ contaminated soils are not desirable:
  - bioavailability of Cu in spiked soils higher than field
  - difficult to replicate incremental increases in Cu over many years
    (in field soil organisms have had time to gradually adapt)
Field studies are the gold standard:
But there are challenges

• Activity of soil organisms influenced by site specific conditions (i.e. temperature, rainfall, farm practices)

• Field soils have received other pesticide inputs

• Are effects due to persistent Cu or other factors?

• A compromise: microcosm approach
  - bring the field to the lab
  - allow soils to equilibrate under common conditions for a period of time
  - greater confidence in assessing effects of persistent Cu
Aims of this study

Used a microcosm approach to:

- Determine the effects of Cu accumulation on microbial activity in vineyard soils from 3 different regions of Australia
- Evaluate the relative risks posed to key nutrient cycles in soil (N, P, C, S cycles)
- Investigate relationships between Cu, physical-chemical soil properties and microbial activity
Three regions different soil types:
- A: neutral, high CEC
- B: alkaline, moderate CEC
- C: acidic, low CEC

Soil sampling:
- 10 vineyards in each region
- Surface soil (5 cm)
- Composite sample (10 sub-samples)
  - Undervine
  - Mid-row
  - Reference
- Sieved, homogenised

Soil analysis:
- Total and CaCl$_2$ available metals
- Physical-chemical soil properties
Soil microcosms

- 81 samples
- 3 tubes for each soil
- Randomly assigned

- 20°C, 60% WHC
- Destructive samples: 27, 54 and 93 days
Microbial activity measured using soil enzyme activity assays

- soil
- substrate
- water

Mix and incubate

Centrifuge

Four different assays/enzymes:

• Urease - N cycle
• Phosphomonoesterase – P cycle
• Phenol oxidase – C cycle
• Arlysulfatase – S cycle

- UV-VIS Spec: measure colour of supernatant
- enzyme activity reported as amount of substrate utilised (or converted) per gram dry soil per hour
Concentrations of Cu were higher in vineyard soils than reference soils.
Enzyme activities were lower in vineyard soils than the reference soils

Similar trend for urease and arylsulfatase
But not phenol oxidase
Poor relationships between increasing Cu and decreasing enzyme activity

$R^2 = 0.06, P = 0.03$

No significant relationships for other enzyme activities

No improvement when use CaCl$_2$ Cu (bioavailable)
Relationships improved when total Cu relative to organic C

$R^2 = 0.46$
Relationships improved when total Cu relative to organic C

Similar trend for urease: $R^2 = 0.15$

Arylsulfatase activity ($\mu$g p-nitrophenol/g dry soil/h)

$R^2 = 0.16$
Soil enzyme activity closely related to TOC

Phosphomonoesterase: $R^2 = 0.43$

Urease: $R^2 = 0.38$

Arylsulfatase activity
($\mu$g p-nitrophenol/g dry soil/h)

$R^2 = 0.59$
Enzyme activity controlled more so by soil properties than Cu

- Multiple step-wise regression analysis

- **Phosphomonoesterase:**
  - pH and TOC explain 84% of variation
  - pH, TOC, **total Cu/Org C**, P, CaCl₂ Mn, (R² = 0.88)

- **Arylsulfatase:**
  - pH and TOC explain 63% of variation

- **Urease**
  - TOC and total N explain 41% of variation

- **Phenol oxidase**
  - total Ni, total N, Ca, K, total Pb (R² = 0.56)
Conclusions

• In this study, Cu higher in vineyard soils than reference, enzyme activities lower in vineyard (suggesting Cu impact)

• But, at Cu concentrations in studied soils, enzyme activity controlled mostly by physical-chemical soil properties (i.e. TOC, pH)

• Increasing Cu causing some effects to phosphomonoesterase (P cycle) (maybe very minor effect to arylsulfatase, urease?)

• Current and future work:
  - has Cu adversely effected the ability for soil microbes to cope with additional stressors (e.g. a heat wave) (resilience)
  - assessment of alternative fungicides: are they safer? (relative risks)
Cu is a persistent soil contaminant, continued use of Cu-fungicides will at some point critically impact long-term sustainability of land for agriculture (potentially costly to remediate).

When to take serious action?
- unnecessary management action – cost burden on fragile agricultural industries
- action too late may have big cost to public/community, given:
  - rapidly expanding population, shrinking base of fertile land
  - need to produce more with less
  - Cu impacting on P cycle – significance of shrinking P resources
  - opportunity for bio-fertilisers – but will Cu toxicity restrict their use?
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