Impact of Vineyard Practices on Grape and Wine Composition

James A. Kennedy

UC Davis
April 20, 2018
Davis, CA
Assumption: Managing wine composition in the vineyard is effective

- General thoughts to think about
- Berry structure
- Berry development
  - Compositionally, time is the primary driver
- Response of plants to environment
  - Upshot: complex
- Managing composition in the vineyard
  - Temperature/light/exposure
    Thoughts wrt phenolics
Wine composition and perception

- Wine is complex
  - Over 1000 compounds identified
    - Sensory thresholds vary
    - Variable concentration
    - Interactions affect perception
  - Multiple sources of variation
    - Vineyard
    - Yeast and bacteria
    - Wood extraction
    - Compounds produced during storage
- Perception of wine is complex
Challenges: Perception is Complex

Delwiche, Food Quality and Preference, 2004

Research has shown that human perception is complex and experience is generally influenced by multiple inputs.
Nitrogen Inputs: Wine Composition

Direct vs. Indirect Management of Composition
After: Bell and Henschke, 2005

Big Driver: Temperature

Short vs. Longterm Management of Composition

van Leeuwen C et al. PNAS 2013;110:E3051-E3052
The Grape Berry
The Grape Berry

Skin
- Color
- Tannins
- Flavor

Pulp
- Water
- Acids
- Sugar
- Flavor

Seed
- Tannins

Coombe, AJEV, 1987
Grape Berry Development

Year 1

- Inflorescence

Year 2

- Budburst
- Bloom
- Set
- Véraison
- Harvest

Month

Jan   Mar   May   Jul   Sep   Nov   Jan
Stages of Berry Development

Date
24-Jun  08-Jul  22-Jul  05-Aug  19-Aug  02-Sep  16-Sep  30-Sep

Berry weight, gm
0.0  0.2  0.4  0.6  0.8  1.0  1.2  1.4  1.6

Woodhall Vineyard
Pinot noir, Pommard
Block C

Berry weight

Stage I
Stage II
Stage III

Berry Set
Veraison
Harvest

2002
2001
Alternatively . . . .

Woodhall Vineyard
Pinot noir, Pommard
Block C

- 2002
- 2001

Berry weight, gm

Stage I
Stage II
Stage III
Stage IV
Stage V

Berry Set
Veraison
Harvest
Stage I of Development

- Period between bloom and set
- Duration provides feedback on crop uniformity
- Weather is important at this time
  - Warm and dry
  - Excessive heat damaging

Glynn and Boulton, 2001
Stage II of Development

• Approximately 2 months in duration
• Rapid cell division
  – Berry is formed
  – Seed is formed
• Compounds of significance
  – Organic acids (tartaric, malic, hydroxycinnamic)
  – Tannins
  – Flavor compounds (green characters)
• Reasonably resistant to heat damage
  – If acclimated
Stage III of Development

- Little growth in berry
- Final stages of seed development
- Berry weight at the end of this stage is approximately one-half of its final weight
- Susceptible to heat damage at veraison
Stage IV of Development

• Fruit ripening
  • Compounds increase
    – Anthocyanins
    – Sugars
    – Flavors (fruity and floral aromas and precursors)
  • Compounds decrease
    – Tannins
    – Organic acids
    – Flavors (green flavors)
• Reasonably resistant to heat damage
  – if acclimated
Stage V: Senescence

- Berry shrivel
- Cell breakdown
  - More easily extracted
- Concentration
- Flavor development
Berry Development - Summary

Australian Viticulture from text: “Ripening berries – a critical issue” by Dr. Bryan Coombe and Tony Clancy (Editor, Australian Viticulture), March/April 2001. Illustration by Jordan Koutroumanidis and provided by Don Neel Practical Winery and Vineyard
Solute Accumulation

Time

Accumulation

Sugars
Anthocyanins
Fruity flavors
Floral flavors

Reduction

Organic acids
Tannins
“Green” flavors

Tannins
Malic acid
“green” flavors
Flavor Evolution

Riesling
Floral–perfumed–apple-pear–citrus-lime–passionfruit–tropical fruit

Sauvignon Blanc
Asparagus-capsicum-herbaceous-grassy-gooseberry-tropical fruit

Semillon
Herbaceous-straw-gooseberry-apple-quince-lemon-lime-passionfruit-tropical fruit

Chardonnay
Cucumber-grapefruit-gooseberry–apple-lime–melon-peach-rockmelon-fig-tropical fruit

Pinot Noir
Cherry-strawberry-violet-raspberry-plum-stewed plum

Grenache
Floral-boiled lolly-spicy-raspberry-pepper-plum-stewed plum-prunes-liquorice

Merlot
Herbaceous-leafy-perfumed-fruity-violet-cherry-raspberry-plum-fruitcake-blackcurrant

Cabernet Sauvignon
Herbaceous-capsicum-tomato bush-leafy-mint-dusty-black olive-blackcurrant

Shiraz
Herbaceous-spicy-raspberry-plum-pepper-blackberry-mulberry-liquorice-black olive-jam

Response of Plants to Environment
Inputs Responsible for Wine Quality

Jackson and Lombard, AJEV, 1993
Types of Stress

- **Abiotic**
  - Solar radiation
  - Temperature
    - Heat, freezing, chilling
  - Drought
  - Salinity
  - Ozone
  - Heavy metals
  - Herbicides

- **Biotic**
  - Insects
  - Viruses
  - Fungi
  - Bacteria
  - Wounds
Response to Environmental Stress

High light causes production of excess excitation energy in the photosynthetic reaction centers, resulting in direct accumulation of a variety of reactive oxygen species.

High temperature stress denatures proteins and causes lipid peroxidation.

Water deficit, or drought, interferes with metabolism. ROS produced under drought conditions trigger signaling pathways that generate defense responses.

Soil salinity is usually caused by excess salts of chloride and sulfate. Salinity results in ion cytotoxicity and osmotic stress, and decreases uptake of nutrients. Resulting metabolic imbalances lead to oxidative stress.

Air pollution with oxidizing species (including ozone and sulfuric acid) causes direct oxidative damage to tissues. Local and systemic signaling responses also occur.

Mechanical damage—both biotic (e.g., from insect feeding) and abiotic (e.g., from wind damage)—triggers expression of defense-related genes.

Cold stress interferes with metabolic processes (particularly enzyme activity) and alters membrane properties. Frosting can severely damage tissues when ice forms. Extracellular ice formation also causes intracellular water deficit.

Response to Environmental Stress

Response to Environmental Stress

Verma et al., BMC Plant Biol., 16: 86, 2009
Response to Environment is Complex

Response to GRBaV

cv. Zinfandel, Oakville/Sonoma, 2015

Blanco-Ulate et al., J. Exp. Bot. 68: 1225-1238, 2017
Environmental cues affecting berry ripening parameters

Influence of Temperature

Big Driver: Fruit Exposure

- Exposure improves flavor profile
  - Reduced veggie and more fruity/floral
    - Reducing veggie: exposure driven
- Exposure improves phenolics
- Exposure reduces disease pressure
- How much exposure is sufficient?
  - Depends on growing region
    - cooler – more exposure
Microclimate and Chemistry

Phenolic Development and Management

- High phenolics
  - High sun exposure
  - Lower levels N
  - Low soil moisture
  - Moderate canopy size
  - Moderate crop load
  - Low soil fertility
  - Small berry size

Moderate stress tends to increase phenolic quantity and quality.

Interest generally on color and tannins

Jackson and Lombard, 1993
Phenolics and Environment

- Anthocyanins
  - Temperature is important
  - Concentration increases up to 30 °C

- Tannins
  - Seed
    - Monomers decline with maturity
    - Less sensitive than skin tannin to change
  - Skin
    - Sensitive to exposure
    - Light is important
      - Quality is open question (UV-B)
    - Evidence for upregulation

Figure 4.1 Tentative diagram of the generalized effect of temperature treatments on the concentration of some compounds in grape berries (from Coombe 1987).
Exposure Management

• Optimize exposure for your region
  – North Coast different than San Joaquin Valley

• If temperatures exceed 90 °F during growing season, sun protection in order.
  – N-S row orientation:
    • Avoid excessive shoot positioning/leaf removal on W-side of canopy
  – E-W oriented rows
    • Avoid excessive shoot positioning/leaf removal on S-side of canopy

• Adequate cover: 1-2 leaf layers
Shade Cloth Application

Mt Veeder – Napa Valley

cv. Cabernet Sauvignon, 5 reps, 2016

Campbell et al. In preparation
Monomeric Anthocyanins

cv. Cabernet Sauvignon, 5 reps, 2016

Campbell et al. In preparation
Pigmented Tannin

cv. Cabernet Sauvignon, 5 reps, 2016

Campbell et al. In preparation
Tannin Molecular Mass

Molecular Mass at 50% Elution (g/mol)

Growing Degree Days

40% Shade

80% Shade

cv. Cabernet Sauvignon, 5 reps, 2016

Campbell et al. In preparation
Tannin Activity

cv. Cabernet Sauvignon, 5 reps, 2016

* = <0.05
** = <0.01
*** = <0.001
**** = <0.0001

Campbell et al. In preparation