



A Master Brewers Association Workshop

FINDING THE EDGES:

The Intersection of Art and Science for Hop Picking Windows

PANELISTS

TOM NIELSEN, SIERRA NEVADA BREWING

ALEXANDRA NOWELL, CLS FARMS

REID LUNDGREN, CLS FARMS

STEPHANIE CONN, HOPTECHNIC

Finding the Edge



- Sierra Nevada/CLS feedback loop on hop picking windows – Finding the Edge
- Fixed vs. Dynamic picking dates
- Traditional methods
 - Dry matter
 - Date windows
 - 2023 Centennial



Harvest Time Windows Vary by *Variety*

| | WA-Cascade | WA-El Dorado® | WA-Amarillo® |
|--------|--------------|---------------|--------------|
| Early | September 2 | September 15 | September 3 |
| Middle | September 10 | September 20 | September 12 |
| Late | September 18 | September 28 | September 18 |

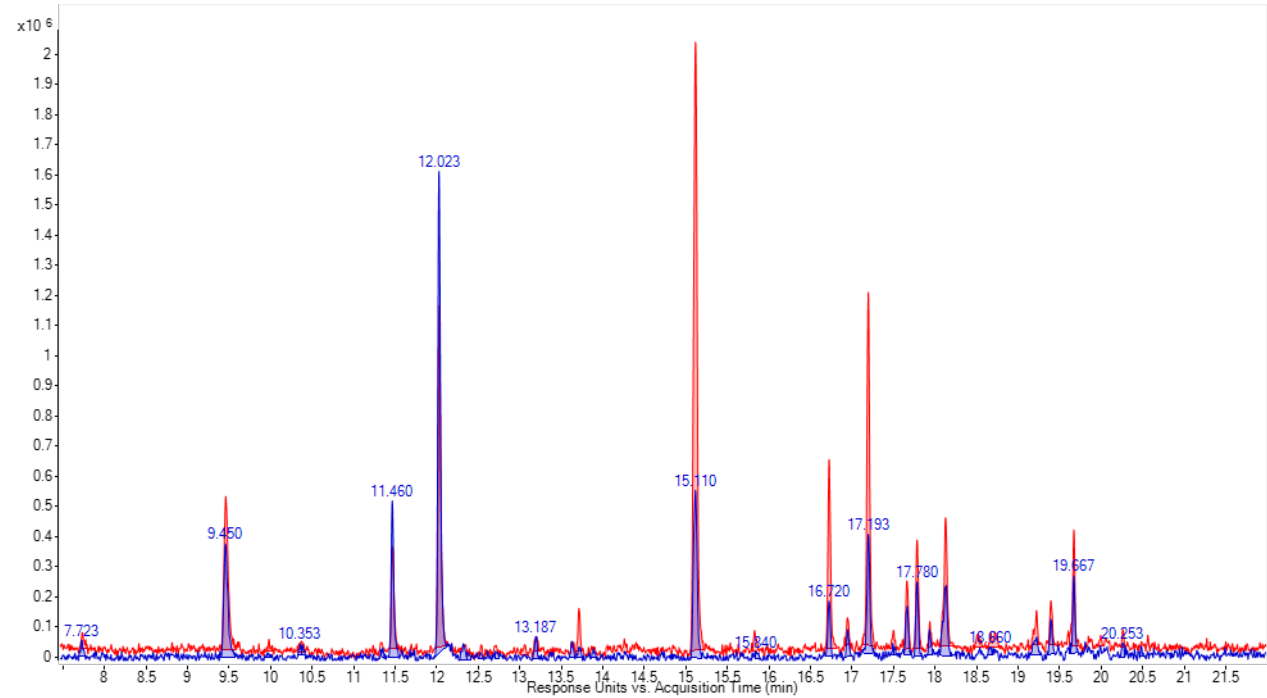
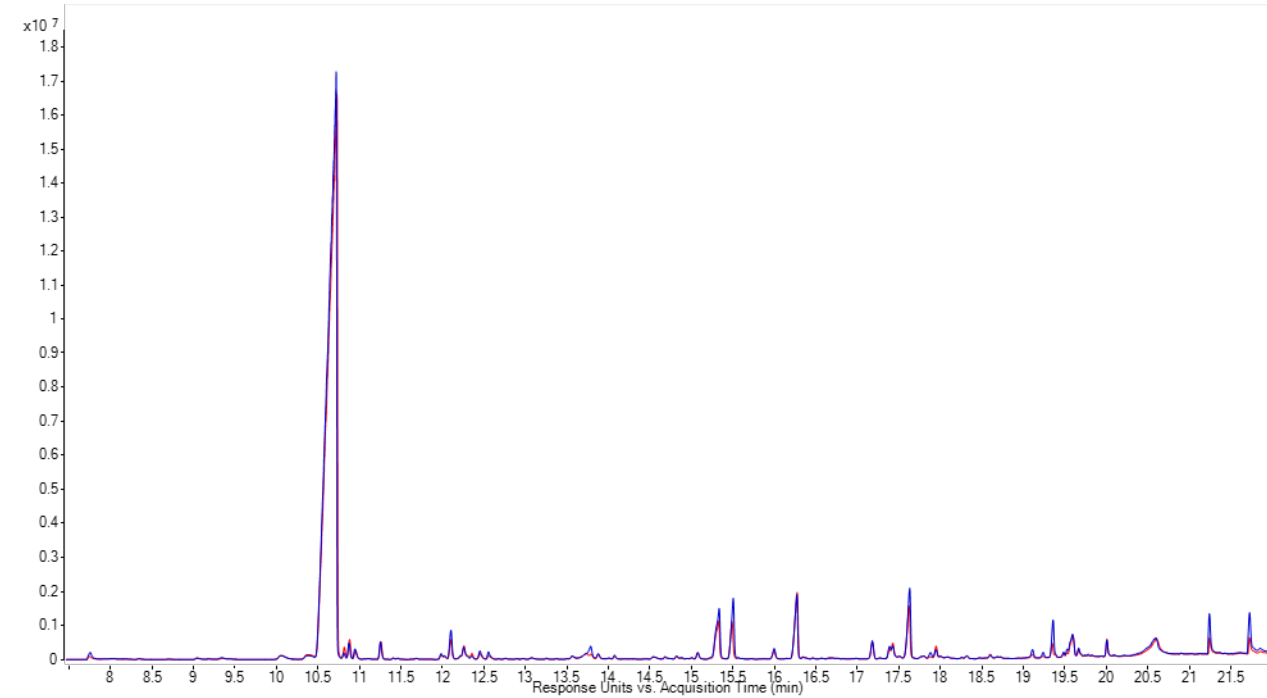


CLS Farms In-Field Sensory

- Consists of multiple people: Eric, Reid Lundgren, Alexandra Nowell
- Decision Matrix
 - Training Dates
 - Location, soil types
 - Plant material, virus vs. virus-free
 - Field maturity, age, babies
 - Physical indicators
- Velocity of maturity, dominant aromas
- Open Mind → off aromas vs. targeted
- Quick assessment for decisions
- Incorporating HopTechnic Harvest Readiness program for 2023



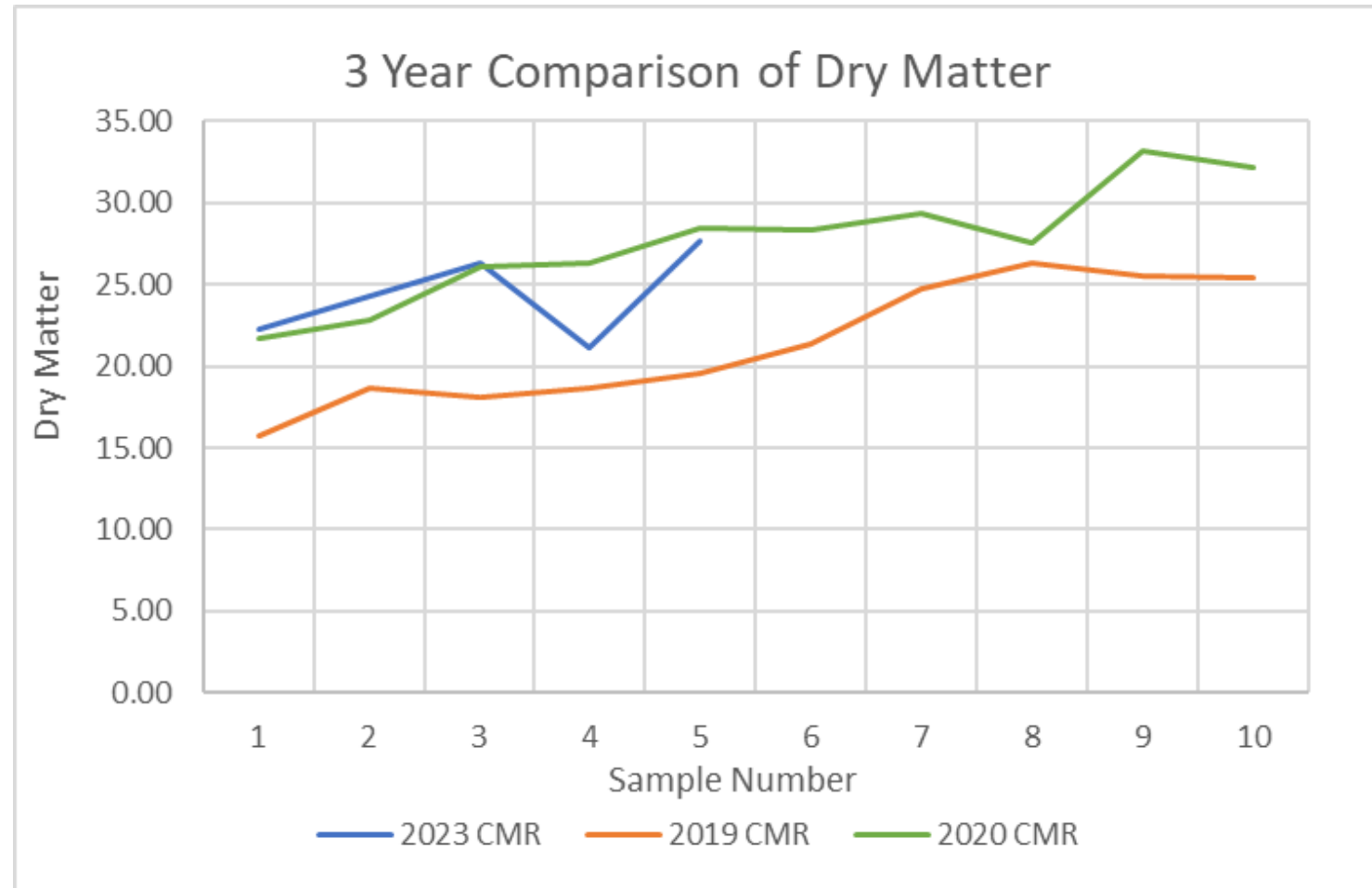
HopTechnic® Harvest Timing Program



| | Terpene Confidence Score | Free Thiol Confidence Score |
|---------------------------|--------------------------|-----------------------------|
| Farm A compared to Farm B | 0.96 | 0.73 |

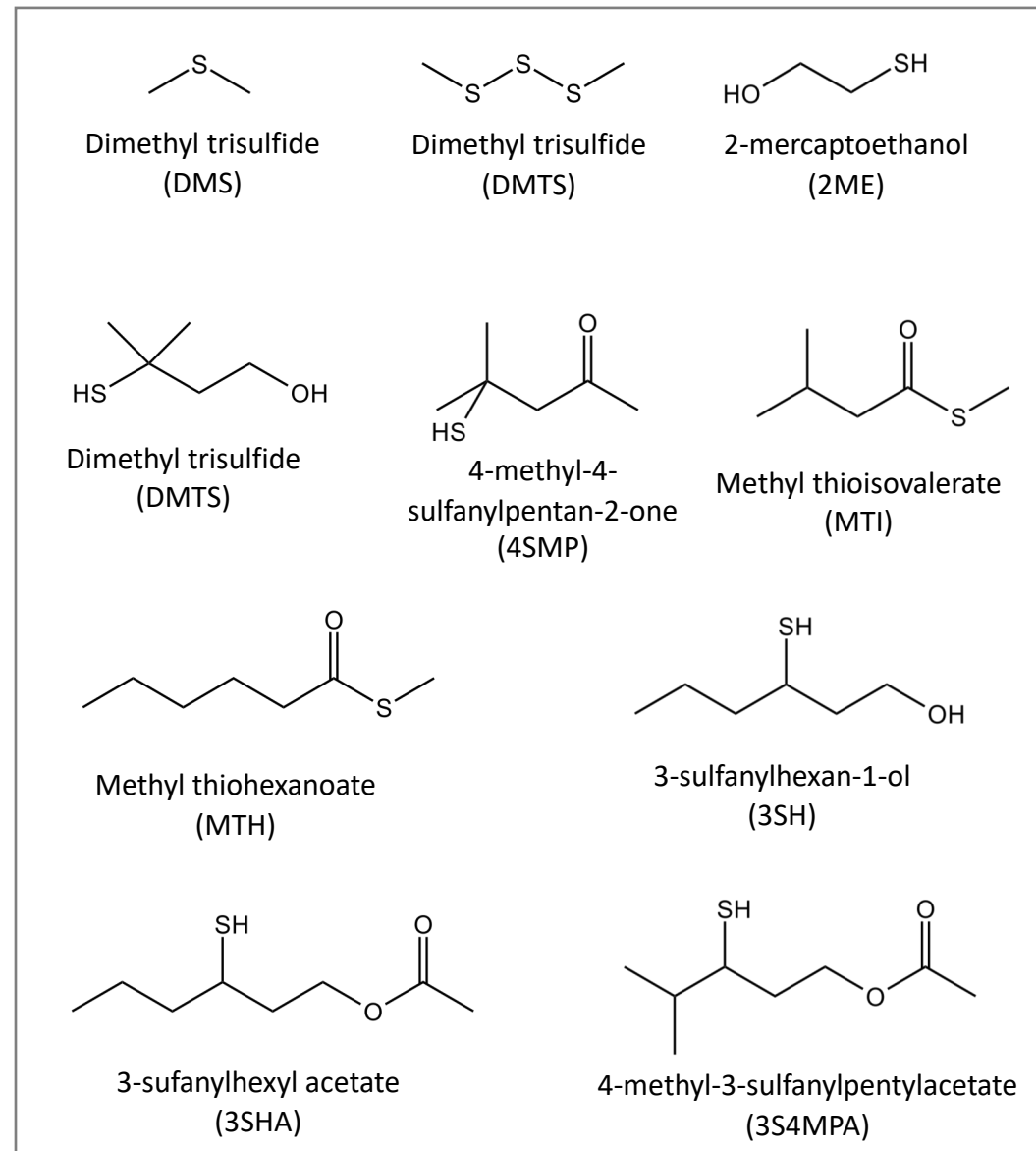
Targeting Aroma Profiles

- Pros & cons of targeting aroma profiles
- Dry matter content
- Terpenes and polyfunctional thiols
- Harvest window duration
 - Variety dependent



Free Thiols in Hops

- Thiol compounds tracked by Hoptechnic®:
 - 2ME/DMS** – 2-mercaptoethanol/dimethyl sulfide: grilled, gas/ vegetal, cooked corn
 - 4SMP(4MMP)/MTI** – 4-sulfanyl-4-methylpentan-2-one/methyl thioisovalerate: catty, black currant/ cheesy, fermented fruit
 - DMTS** – dimethyl trisulfide: savory, garlic, sulfurous
 - 3M3SB (3M3MB)**– 3-methyl-3-sulfanyl-butan-1-ol-: savory, soup
 - MTH** – methyl thiohexanoate: guava, passionfruit, grapefruit
 - 3SH (3MH)** – 3-sulfanylhexasn-1-ol: passionfruit, guava, tropical, grapefruit
 - 3SHA (3MHA)** – 3-sulfanylhexasn acetate: passionfruit, black currant, tropical



A wooden cutting board with several slices of blood orange and a white citrus squeezer. The background is a dark blue surface with some dried grasses in the bottom right corner.

Polyfunctional Thiol Chemistry



Effect of “Late Harvest” of Hops (*Humulus lupulus* L.) on the Contents of Volatile Thiols in Furano Beauty, Furano Magical, and Cascade Varieties

Mitsuhiro Uemoto,* Kiyoshi Takoi, Atsushi Tanigawa, Koji Takazumi, Kensuke Ogushi, Koichiro Koie, and Narushi Suda

 Cite This: *J. Agric. Food Chem.* 2022, 70, 607–614

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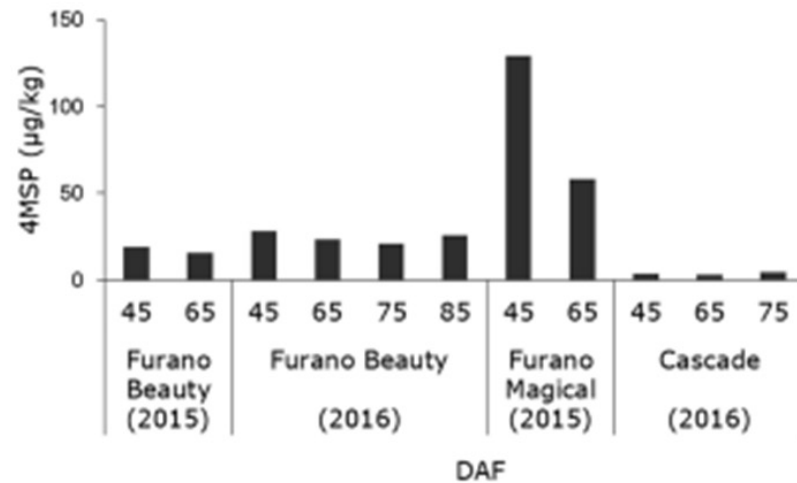


Figure 2. Concentrations of 4MSP in hop cones. DAF, days after flowering and 4MSP, 4-methyl-4-sulfanyl-pentane-2-one.

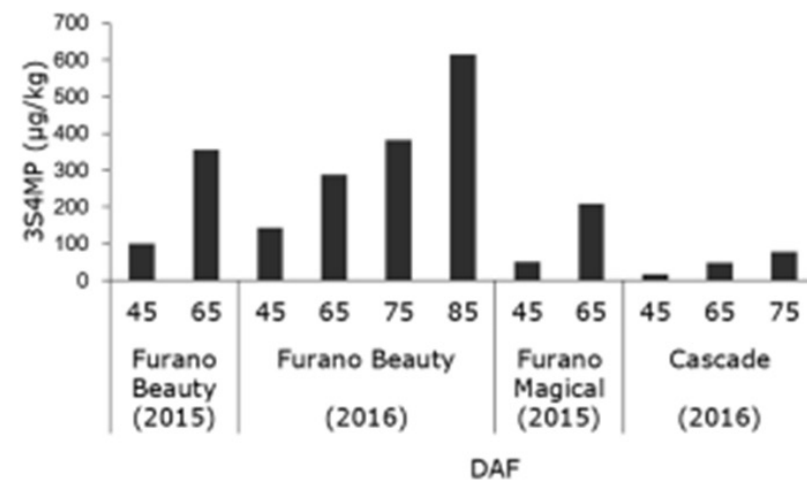


Figure 3. Concentrations of 3S4MP in hop cones. DAF, days after flowering and 3S4MP, 3-sulfanyl-4-methyl-pentane-1-ol.



2023 El Dorado Thiol Profile

| Crop year | Variety | Harvest Point | 4MMP (ng/g) | 3S4MP (ng/g) | 3MH (ng/g) |
|-----------|-----------|---------------|-------------|--------------|------------|
| 2023 | El Dorado | Early | 0.8 | 2.9 | 2.5 |
| 2023 | El Dorado | Middle | 1.5 | 10.6 | 3.0 |
| 2023 | El Dorado | Late | 1.8 | 12.9 | 0.7 |



2023 Amarillo Thiol Profile

| Crop year | Variety | Harvest Point | 4MMP (ng/g) | 3S4MP (ng/g) | 3MH (ng/g) |
|-----------|----------|---------------|-------------|--------------|------------|
| 2023 | Amarillo | Early/Middle | 3.9 | 45.3 | 5.6 |
| 2023 | Amarillo | Middle | 4.3 | 34.3 | 3.3 |
| 2023 | Amarillo | Middle/Late | 4.0 | 56.9 | 4.3 |



Curious Case of 2020 Eureka! (tm)

| CY | Variety | 4MMP(ng/g) | 3SH(ng/g) | 3S4MP(ng/g) |
|------|---------------|------------|-----------|-------------|
| 2020 | Eureka! EARLY | 15.2 | 2.9 | 24.5 |
| 2020 | Eureka! MID | 15.3 | 2.7 | 29.7 |
| 2020 | Eureka! LATE | 15.8 | 2.7 | 28.8 |



Terpene Chemistry



2023 El Dorado – Terpene Profile

| Crop year | Variety | Harvest Point | GCMS Corrected Responses | | |
|-----------|-----------|---------------|--------------------------|--------------------|---------------------|
| | | | Linalool | Geraniol | Citral |
| 2023 | El Dorado | Early | 2.87 | 0.10 | 0.08 |
| 2023 | El Dorado | Middle | 2.40 | 0.14 | 0.11 |
| 2023 | El Dorado | Late | 4.08 | 0.19 | 0.23 |
| | | | | | |
| | | | | | |
| Crop year | Variety | Harvest Point | GCMS Corrected Responses | | |
| | | | Geranyl Acetate | Geranyl Propionate | Geranyl Isobutyrate |
| 2023 | El Dorado | Early | 17.24 | 8.14 | 19.25 |
| 2023 | El Dorado | Middle | 13.36 | 5.53 | 12.76 |
| 2023 | El Dorado | Late | 32.31 | 13.00 | 29.07 |



2023 Amarillo – Terpene Profile

| Crop year | Variety | Harvest Point | GCMS Corrected Responses | | |
|-----------|----------|---------------|--------------------------|--------------------|---------------------|
| | | | Linalool | Geraniol | Citral |
| 2023 | Amarillo | Early/Middle | 3.15 | 0.04 | 0.08 |
| 2023 | Amarillo | Middle | 3.10 | 0.03 | 0.07 |
| 2023 | Amarillo | Middle/Late | 3.87 | 0.08 | 0.09 |
| | | | | | |
| | | | | | |
| Crop year | Variety | Harvest Point | GCMS Corrected Responses | | |
| | | | Geranyl Acetate | Geranyl Propionate | Geranyl Isobutyrate |
| 2023 | Amarillo | Early/Middle | 9.03 | 1.21 | 1.84 |
| 2023 | Amarillo | Middle | 8.27 | 1.40 | 2.21 |
| 2023 | Amarillo | Middle/Late | 16.15 | 2.17 | 3.49 |



Biotransformation of Hop-Derived Monoterpene Alcohols by Lager Yeast and Their Contribution to the Flavor of Hopped Beer

KIYOSHI TAKOI,^{*,†,‡} KOICHIRO KOIE,[§] YUTAKA ITOGA,[§] YUTA KATAYAMA,[‡]
MASAYUKI SHIMASE,[†] YASUYUKI NAKAYAMA,[†] AND JUNJI WATARI[†]

[†]Value Creation Department, and [‡]Frontier Laboratories of Value Creation, Sapporo Breweries Ltd., 10 Okatohme, Yaizu, Shizuoka 425-0013, Japan, and [§]Bioresources Research & Development Department, Sapporo Breweries Ltd., 3-5-25 Kamifurano-cho Motomachi, Sorachi-gun, Hokkaido 071-0551, Japan

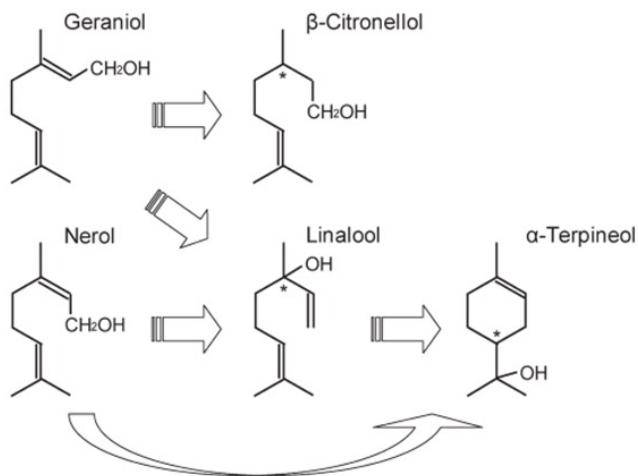
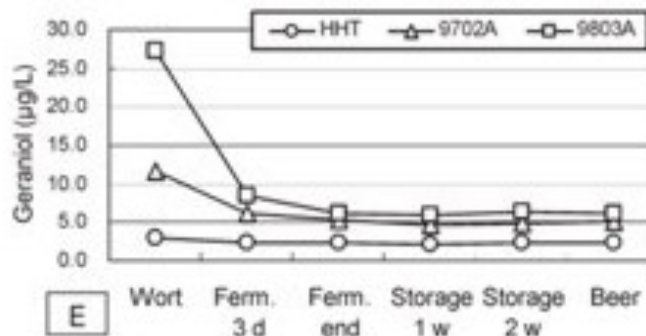
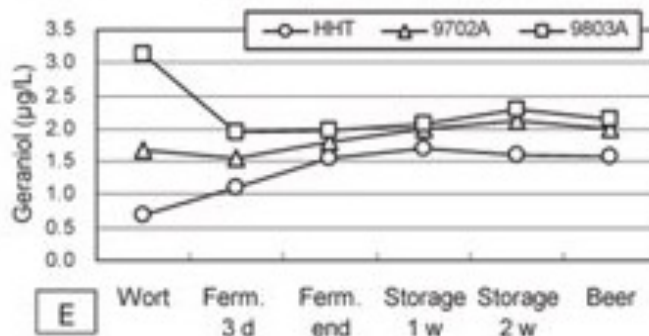
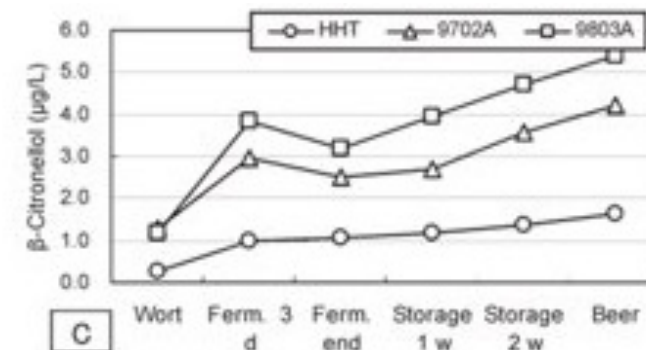
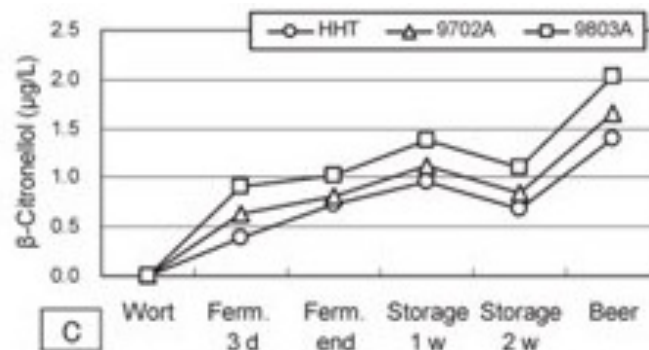


Figure 2. Metabolism cascade of monoterpene alcohols by lager and ale yeast (proposed by King et al. (13, 14)). An asterisk indicates a chiral center.



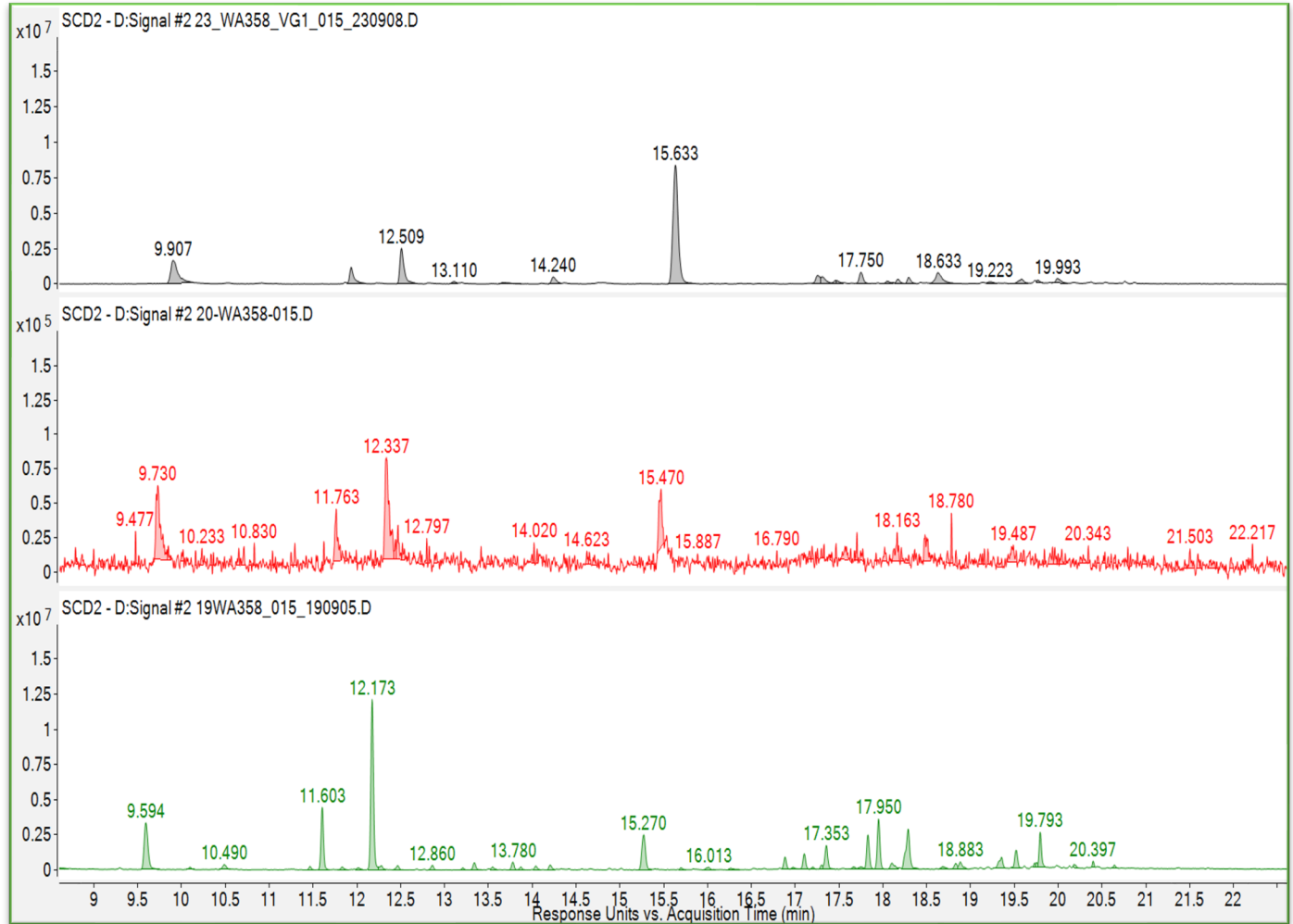
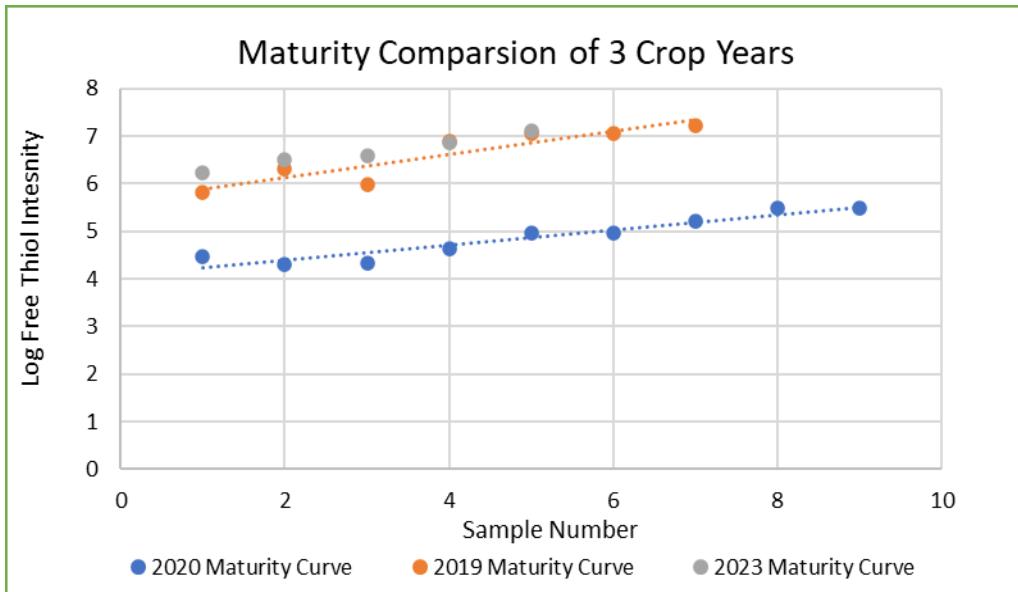
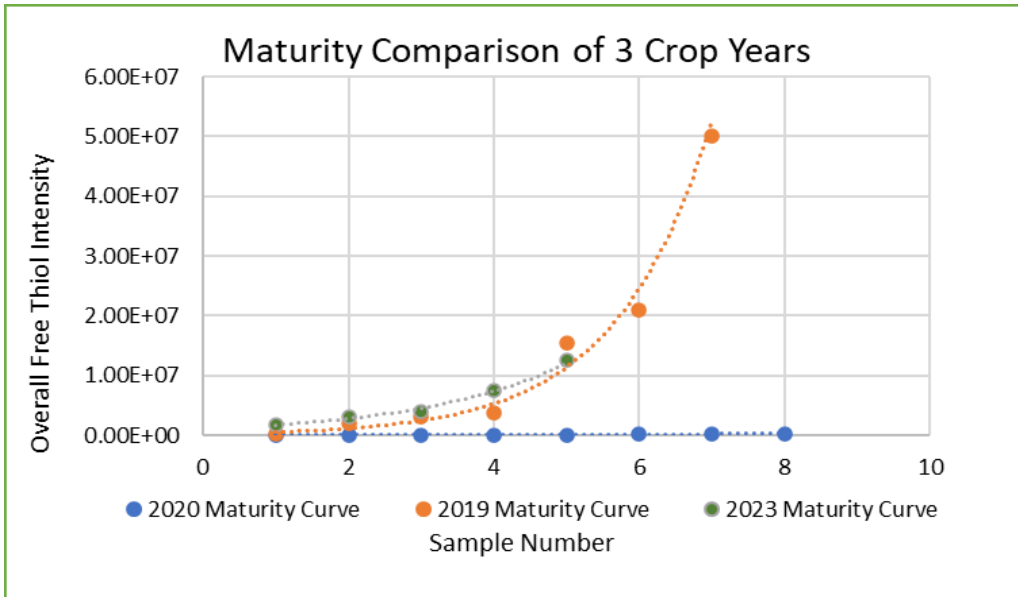
Sensory

Sample
Ox 



JOIN CODE: Q7WXH

Dynamic Harvest Windows



Early Harvest – El Dorado®

Picking Window - September

Post Citra® – later is better than early.

GREEN = **Early Maturity**

Aroma notes: citrusy, brighter

YELLOW = **Middle Maturity**

Aroma notes: melon/watermelon, pear

ORANGE = **Peak Maturity**

Aroma notes: stone fruit, tropical, hard candy, deeper aromas



September

| Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday |
|--------|--------|---------|-----------|----------|--------|----------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 1 | 2 | 3 | 4 | 5 |

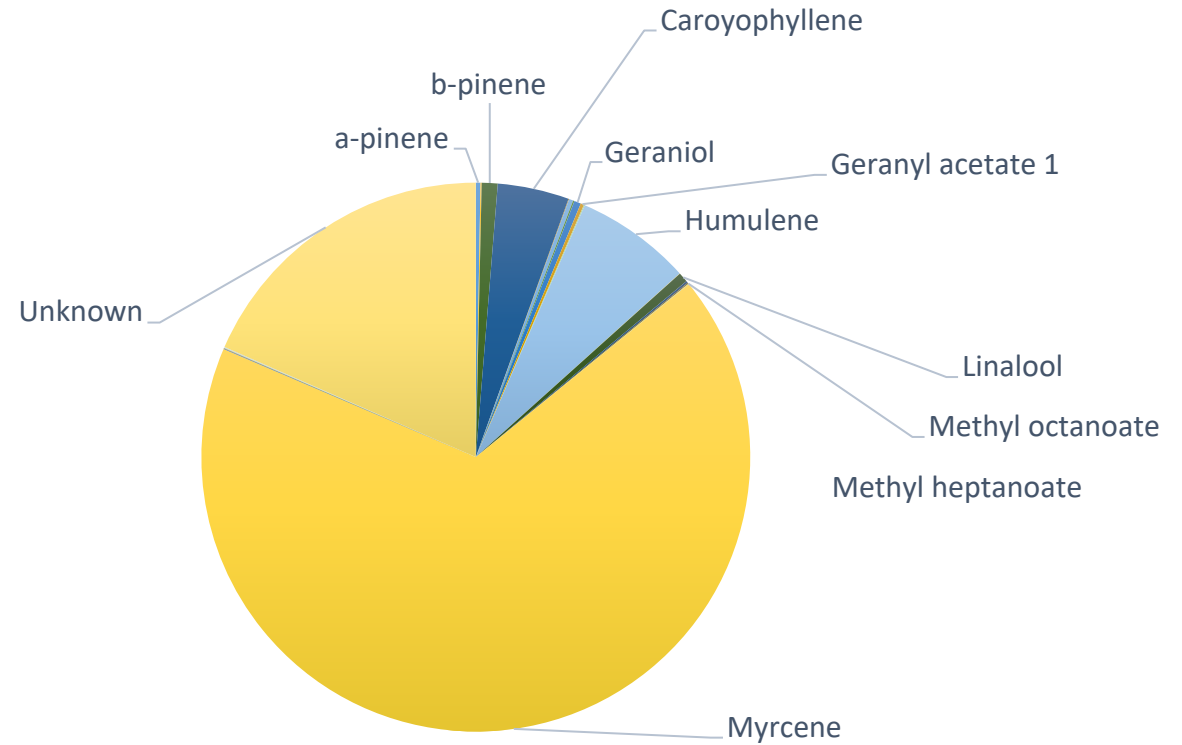
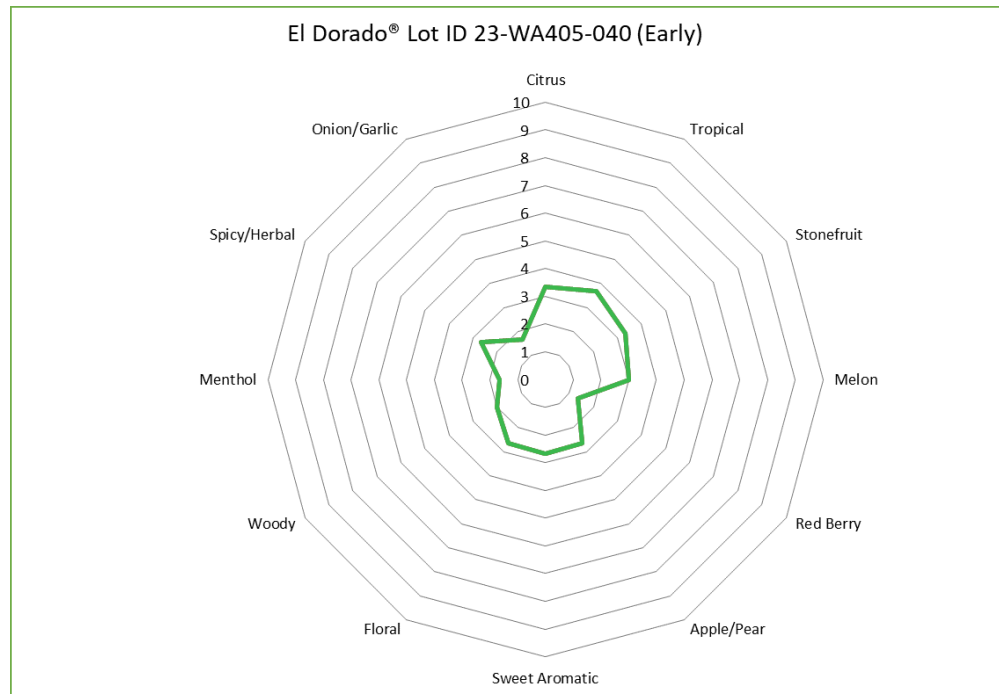
- Early harvested CTZ (heavy ruby red fruit, grapefruit, zest, tangerine)
 - Pushing the boundaries of a defined picking window
 - Flexibility
- Agronomic impact
 - Possible yield impact



Early Harvest – El Dorado®

GREEN = Early Maturity
Aroma notes: citrusy, brighter

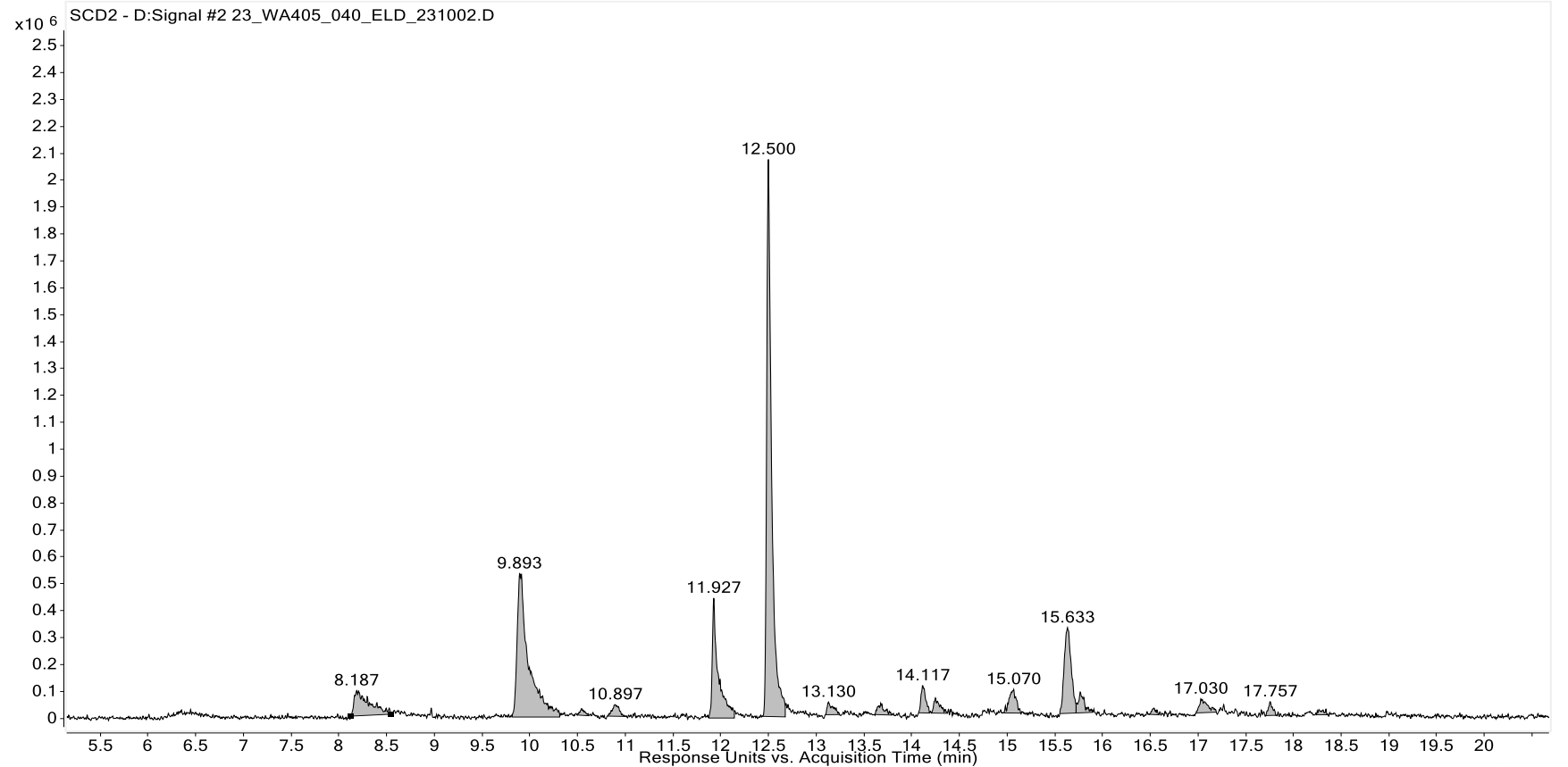
- Candied lemon, orange, slightly greener



Early Harvest – El Dorado®

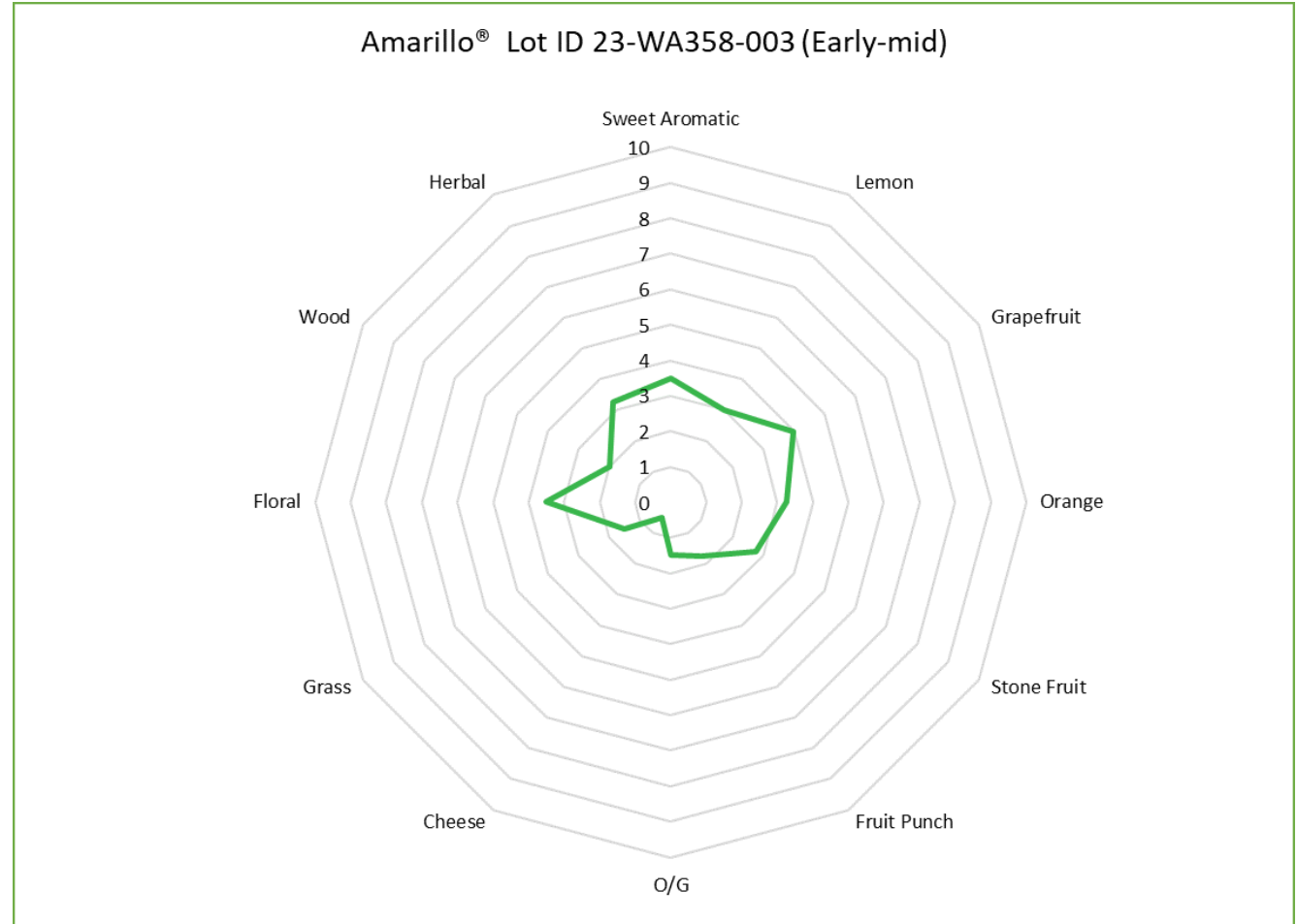
GREEN = **Early Maturity**
Aroma notes: citrusy, brighter

| Aroma Compound | % of Thiols |
|--|-------------|
| 2-mercaptoethanol/ dimethyl sulfide (1) | 0.00% |
| 4-mercapto-4-methylpentan-2-one/ Methyl isothiovalerate (2) | 23.16% |
| Dimethyl trisulfide (3) | 0.44% |
| 3-mercapto-3-methylbutan-1-ol (4) | 10.03% |
| Methyl thiohexanoate (5) | 38.81% |
| 3-mercapto-4-methyl pentanol (6) | 0.00% |
| 3-mercapto-hexan-1-ol (7) | 1.06% |
| 3-mercapto-4-methyl-pentylacetate/ 3-mercaptohexyl acetate (8) | 0.00% |
| 8-mercapto-octan-1-ol (9) | 1.61% |
| Unidentified | 24.90% |

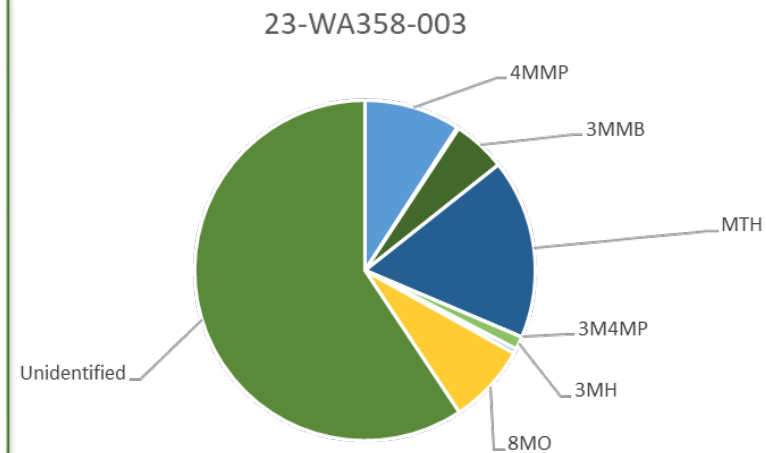
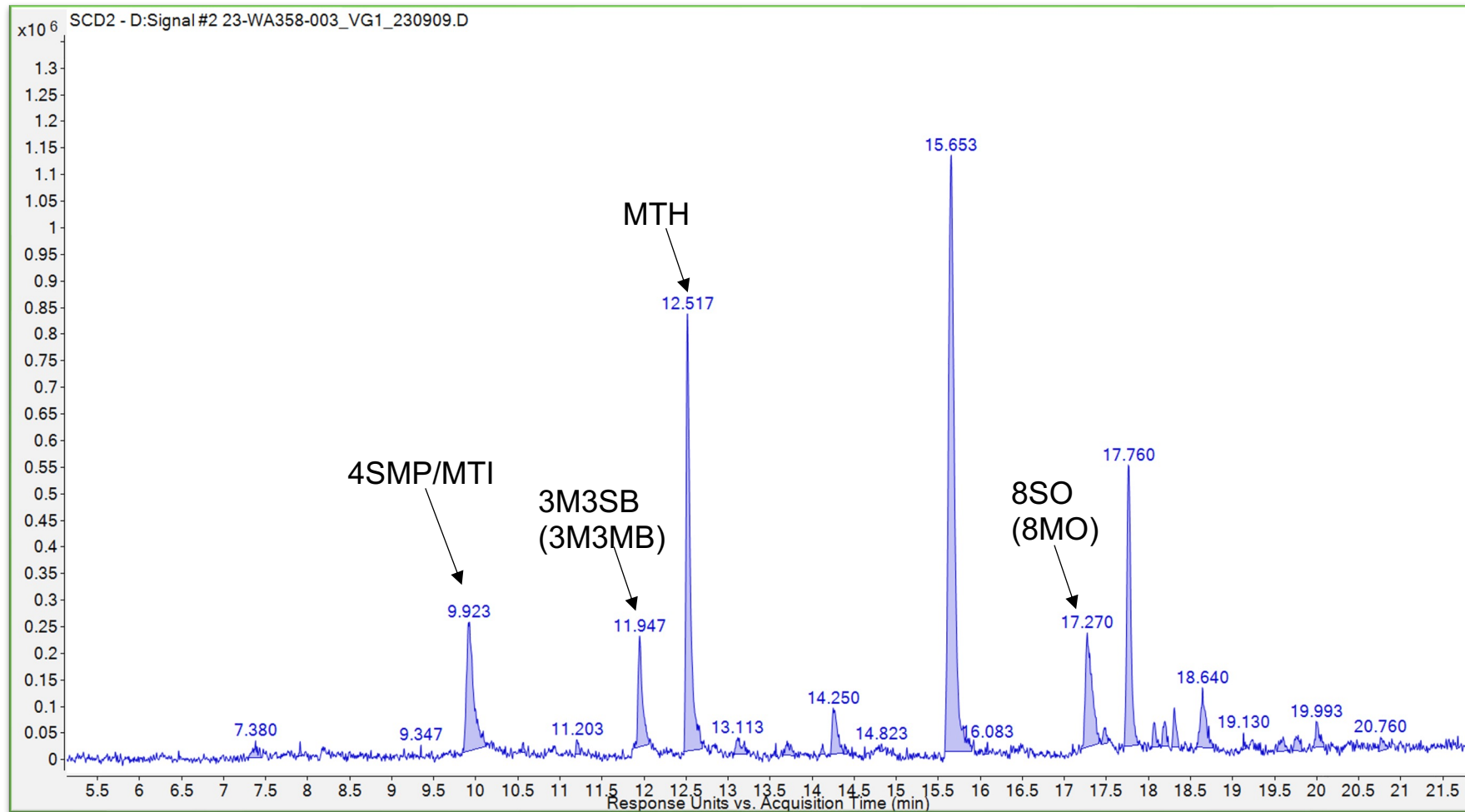


Early Harvest Profile – Amarillo®

- Early harvest:
 - VG1: Lemon, sweet candy, floral
- Most often harvested as an “Early-mid”
 - Grapefruit, lemon, floral, herbal, slightly sweet, little to no o/g



Early Harvest Profile – Amarillo®



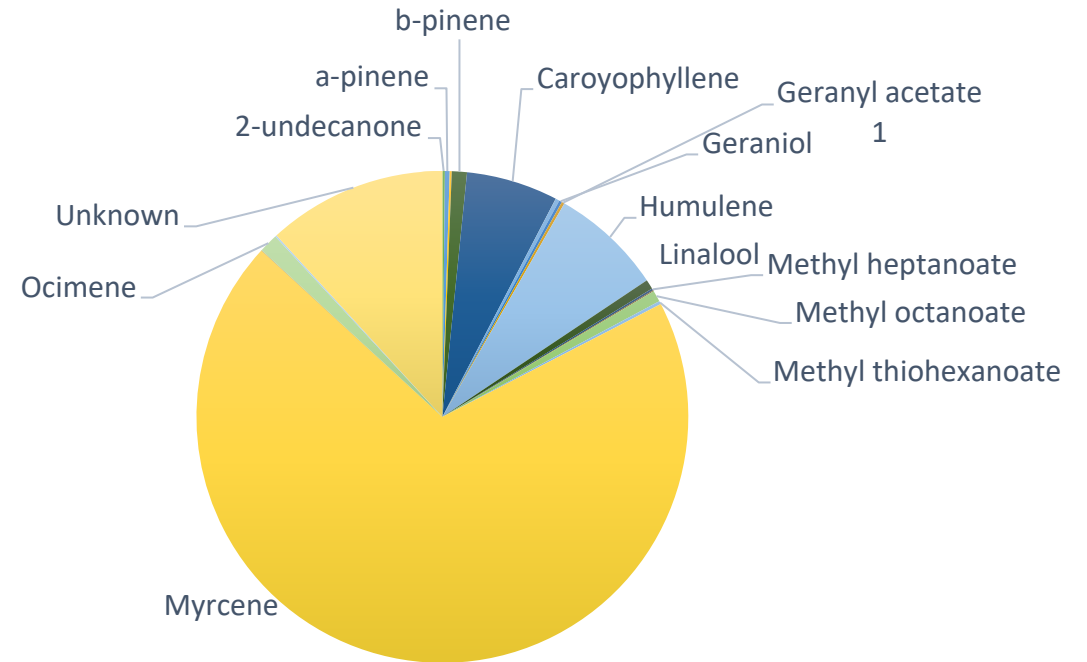
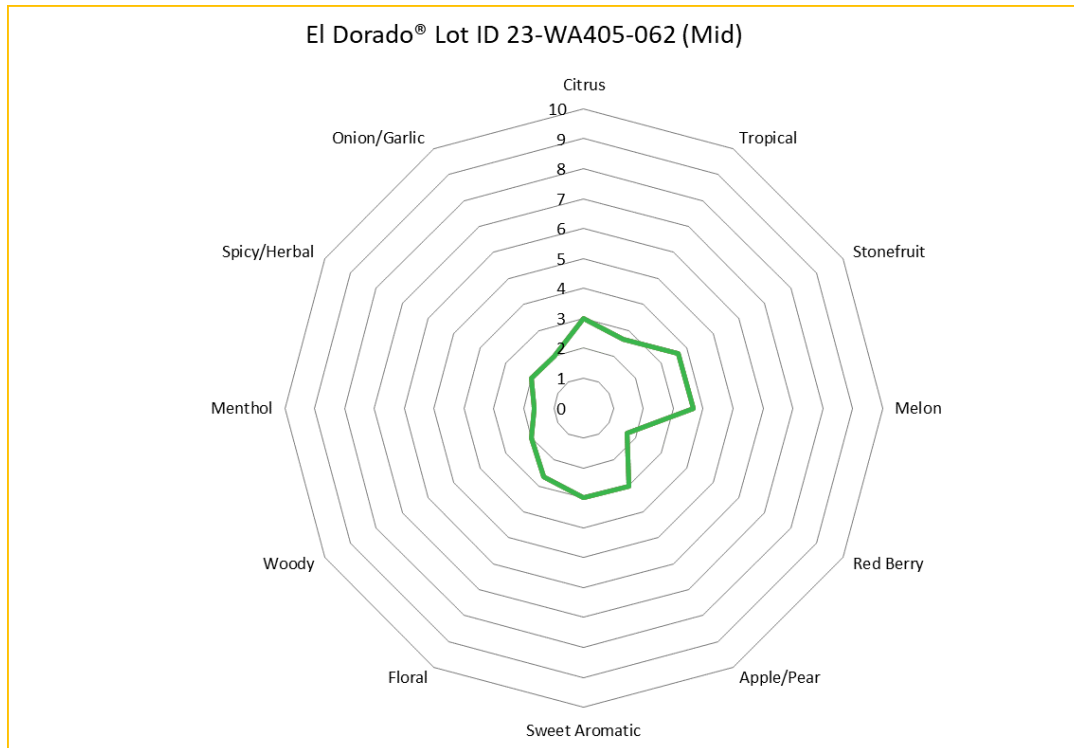
| Thiol Percentage | Compound |
|------------------|--------------|
| 0.00% | 2ME/DMS |
| 9.11% | 4MMP/MTI |
| 0.16% | DTS |
| 5.05% | 3MMB |
| 17.08% | MTH |
| 0.00% | 3M4MP |
| 1.23% | 3MH |
| 0.46% | 3MHA/3M4MPA |
| 7.59% | 8MO |
| 59.32% | Unidentified |

Mid Harvest – El Dorado®

YELLOW = Middle Maturity

Aroma notes: melon/watermelon, pear

- Watermelon jolly rancher, green fruit

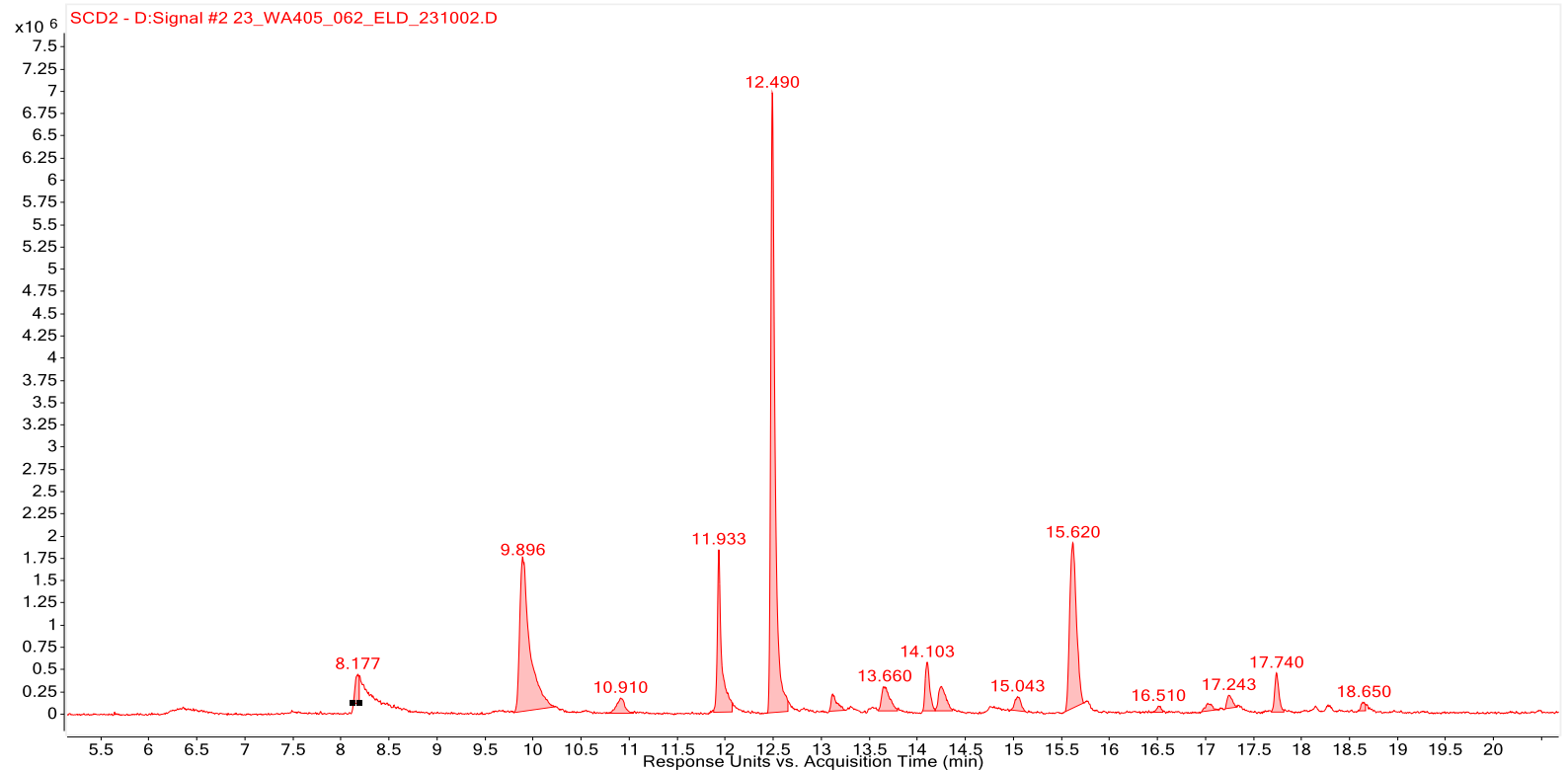


Mid Harvest – El Dorado®

YELLOW = Middle Maturity

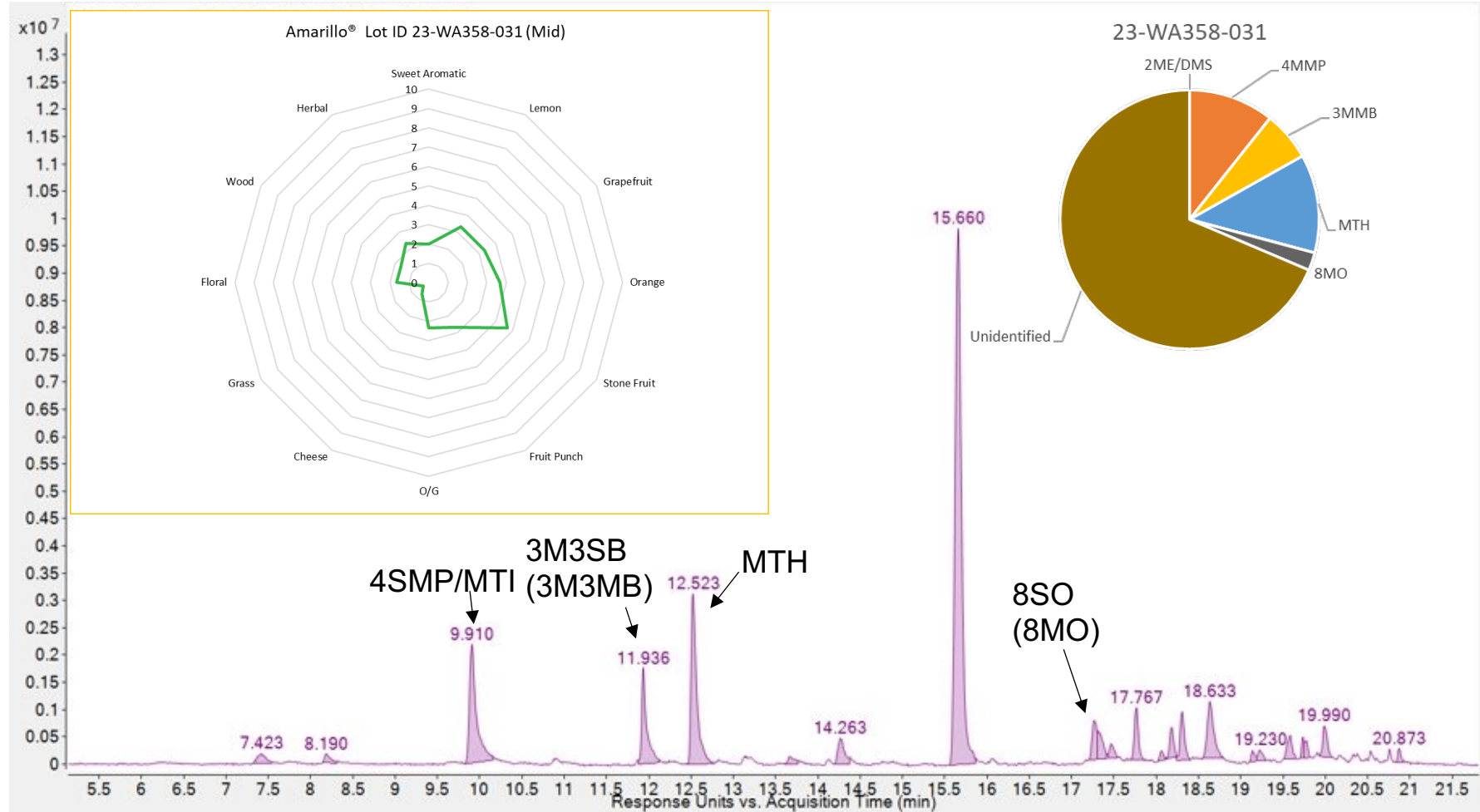
Aroma notes: melon/watermelon, pear

| Aroma Compound | % of Thiols |
|---|-------------|
| 2-mercaptoethanol/ dimethyl sulfide (1) | 0.00% |
| 4-mercapto-4-methylpentan-2-one/ Methyl isothiovalerate (2) | 18.45% |
| Dimethyl trisulfide (3) | 0.00% |
| 3-mercapto-3-methylbutan-1-ol (4) | 8.06% |
| Methyl thiohexanoate (5) | 26.91% |
| 3-mercapto-4-methyl pentanol (6) | 0.00% |
| 3-mercapto-hexan-1-ol (7) | 1.32% |
| 3-mercapto-4-methyl-pentylacetate/ 3-mercaptohexyl acetate (8) | 0.00% |
| 8-mercapto-octan-1-ol (9) | 0.92% |
| Unidentified | 44.35% |



Mid Harvest Profile – Amarillo®

- Mid harvest
 - VG1: Citrus, stone fruit and fruit punch, herbal/floral, more pronounced o/g



| Thiol Percentage | Compound |
|------------------|--------------|
| 0.00% | 2ME/DMS |
| 10.68% | 4MMP/MTI |
| 0.00% | DTS |
| 6.17% | 3MMB |
| 12.31% | MTH |
| 0.00% | 3M4MP |
| 0.00% | 3MH |
| 0.00% | 3MHA/3M4MPA |
| 2.23% | 8MO |
| 68.61% | Unidentified |

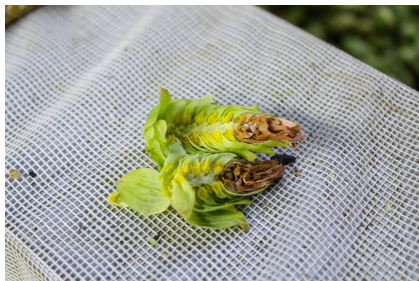
Late Harvest – El Dorado®

ORANGE = Peak Maturity

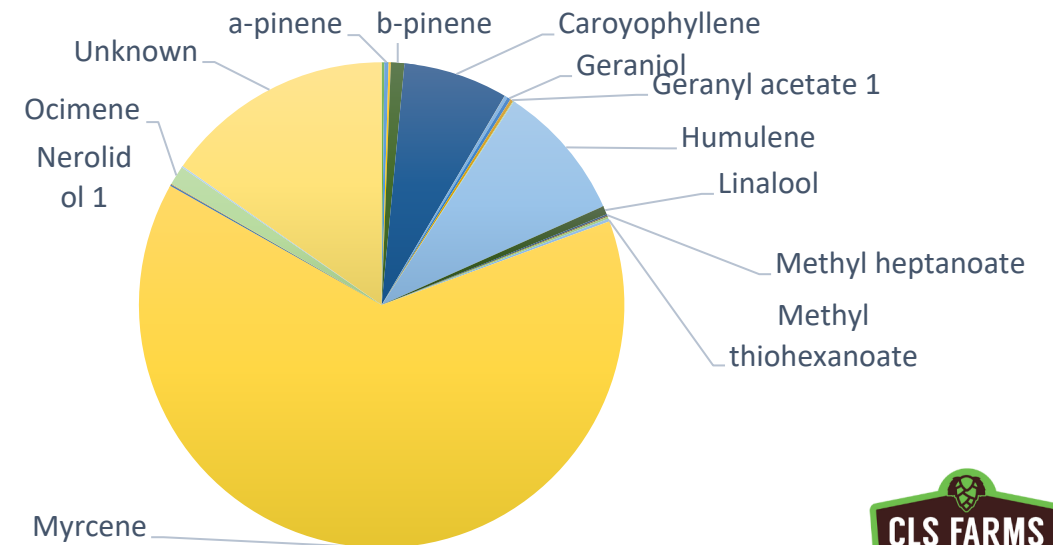
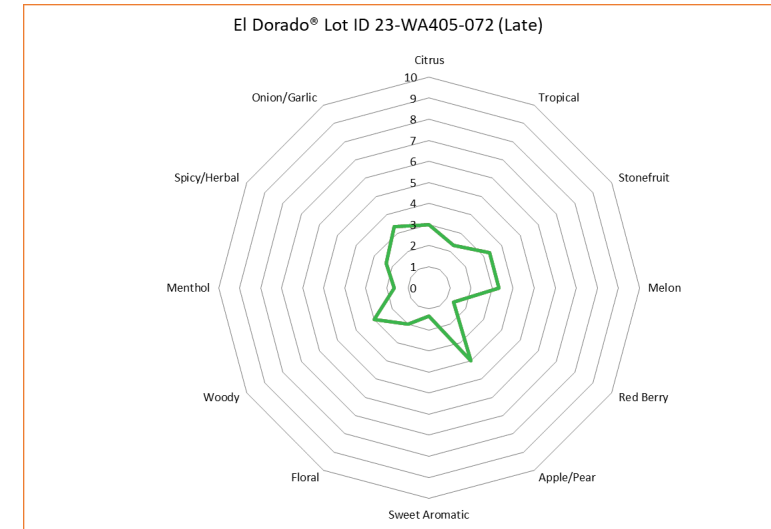
Aroma notes: stone fruit, tropical, hard candy, deeper aromas

- Pineapple, apricot, cherry, watermelon, Peachie Rings, fruity pebbles, sweet fruit, mango

Physical Indicators:



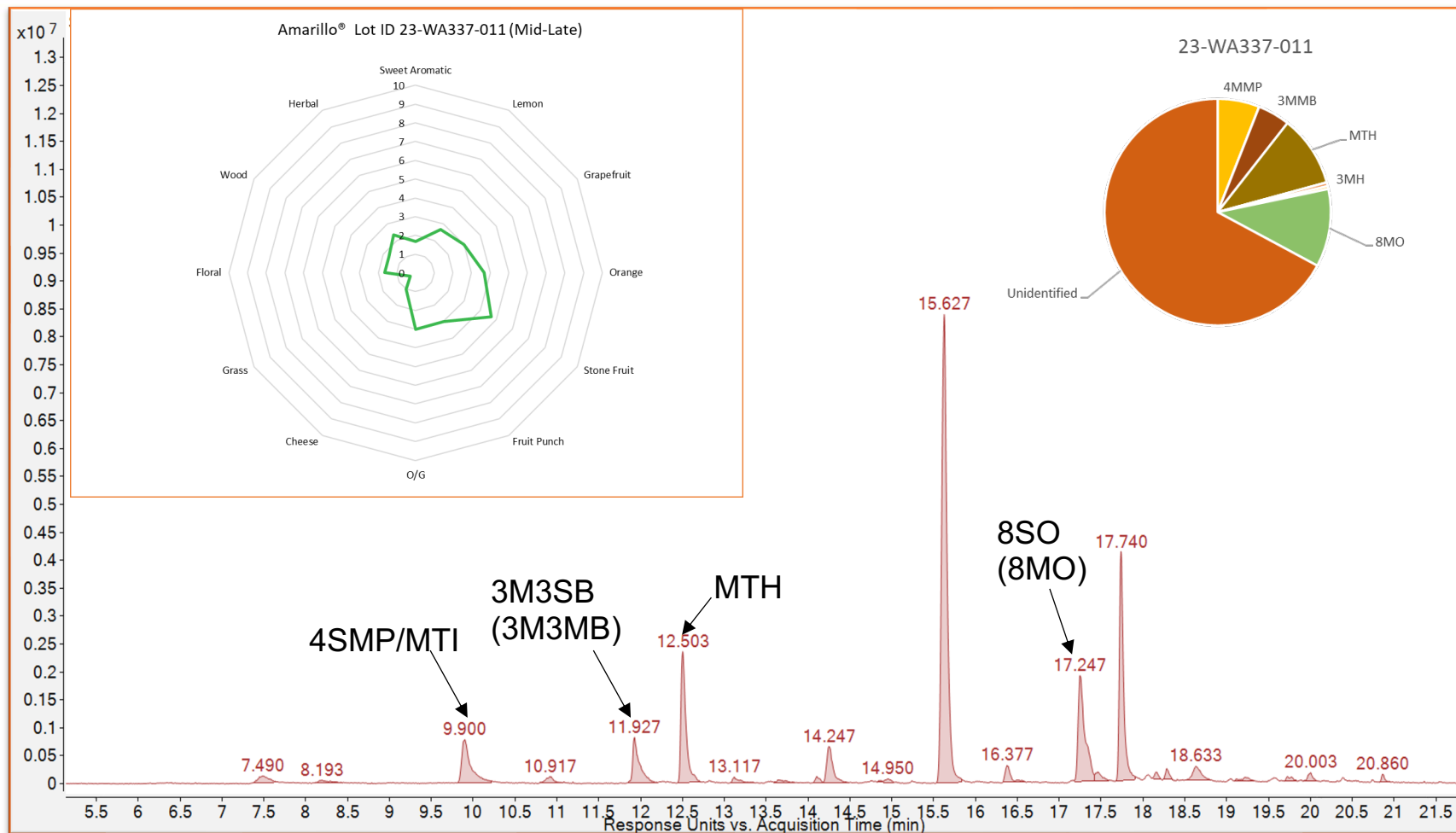
| Aroma Compound | % of Thiols |
|--|-------------|
| 2-mercaptoethanol/ dimethyl sulfide (1) | 0.00% |
| 4-mercapto-4-methylpentan-2-one/ Methyl isothiovalerate (2) | 24.44% |
| Dimethyl trisulfide (3) | 0.00% |
| 3-mercapto-3-methylbutan-1-ol (4) | 10.67% |
| Methyl thiohexanoate (5) | 35.65% |
| 3-mercapto-4-methyl pentanol (6) | 0.00% |
| 3-mercapto-hexan-1-ol (7) | 1.13% |
| 3-mercapto-4-methyl-pentylacetate/ 3-mercaptohexyl acetate (8) | 0.00% |
| 8-mercapto-octan-1-ol (9) | 0.00% |
| Unidentified | 28.11% |



Late and Mid-Late Harvest Profile – Amarillo®

- Late harvest
 - VG1: Citrus (muddled), stone fruit, fruit punch, herbal, heavier onion/garlic, aged cheddar

| Thiol Percentage | Compound |
|------------------|--------------|
| 0.00% | 2ME/DMS |
| 5.98% | 4MMP/MTI |
| 0.00% | DTS |
| 4.62% | 3MMB |
| 10.17% | MTH |
| 0.00% | 3M4MP |
| 0.53% | 3MH |
| 0.41% | 3MHA/3M4MPA |
| 11.12% | 8MO |
| 67.16% | Unidentified |



Summary

Highlights

- In-field sensory gives flexibility and speed
- CLS is moving towards a blend of the two
- Harvest windows are dynamic & shift based on natural events
- Analytics can help navigate aroma variances between crops years, especially when paired with traditional sensory



El Dorado®

Early: Citrus lemon, orange, greener

Mid: Watermelon, jolly rancher, pear, green fruit

Late: Sweet fruit, pineapple, mango, cherry, candy, fruity pebbles



Amarillo®

Early: Lemon, sweet candy, floral

Mid: Citrus, stone fruit and fruit punch, herbal/floral, more pronounced o/g

Late: Citrus (muddled), stone fruit, fruit punch, herbal, heavier onion/garlic, aged cheddar





HOP CREEP



Fermentable Sugar contribution post DH Reduction

Amarillo (15g/L, 3.87 lb. / bbl.)

| Harvest Time | RE pick-up (P) |
|--------------|-----------------|
| Early 2018 | 0.415 +/- 0.007 |
| Mid 2019 | 0.395 +/- 0.007 |
| Late 2020 | 0.44 +/- 0 |

El Dorado (15g/L, 3.87 lb. / bbl.)

| Harvest Time | RE pick-up (P) |
|--------------|-----------------|
| Early 2022 | 0.405 +/- 0.007 |
| Mid 2022 | 0.40 +/- 0.02 |
| Late 2022 | 0.395 +/- 0.007 |

Extract from Hops: Fermentable Sugars are directly extracted from hops by any beer or liquid. Significant empirical evidence suggests 0.1 Plato is contributed to the liquid per 1 lb./bbl addition of whole cone or T90 hops. Extractable fermentable sugar fluctuates very little between crop year, harvest window or variety.

~1 lb. / bbl. DH = ~0.1 Plato Fermentables



Fermentable Sugar contribution post DH Reduction

Amarillo (15g/L, 3.87 lb. / bbl.)

| Harvest Time | RE pick-up (P) |
|--------------|----------------|
| 2023 – E/M | 0.38 +/- 0.00 |
| 2023 - M | 0.39 +/- 0.00 |
| 2023 – M/L | 0.39 +/- 0.02 |

El Dorado (15g/L, 3.87 lb. / bbl.)

| Harvest Time | RE pick-up (P) |
|--------------|----------------|
| 2023 - E | 0.39 +/- 0.00 |
| 2023 - M | 0.38 +/- 0.01 |
| 2023 - L | 0.37 +/- 0.00 |

~1 lb. / bbl. DH = ~0.1 Plato Fermentables



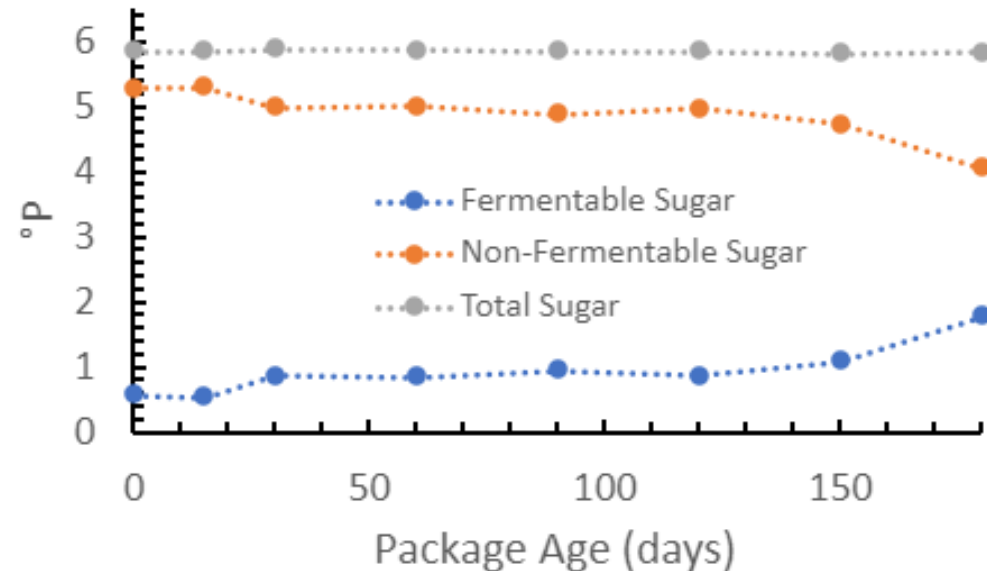
Maltose & Maltotriose Reduction Post DH – Evidence of Enzymes Activity

Amarillo (15g/L, 3.87 lb. / bbl.)

| Harvest Time | Maltose (P) | Maltotriose (P) |
|--------------|-------------|-----------------|
| Early 2018 | 0.10 | 0.04 |
| Mid 2019 | 0.12 | 0.05 |
| Late 2020 | 0.10 | 0.04 |

El Dorado (15g/L, 3.87 lb. / bbl.)

| Harvest Time | Maltose (P) | Maltotriose (P) |
|--------------|-------------|-----------------|
| Early 2022 | 0.19 | 0.06 |
| Mid 2022 | 0.18 | 0.06 |
| Late 2022 | 0.21 | 0.06 |



Maltose & Maltotriose Reduction Post DH – Evidence of Enzymes Activity

Amarillo (15g/L, 3.87 lb. / bbl.)

| Harvest Time | Maltose (P) | Maltotriose (P) |
|--------------|-------------|-----------------|
| 2023 – E/M | 0.13 | 0.04 |
| 2023 - M | 0.19 | 0.06 |
| 2023 – M/L | 0.16 | 0.06 |

El Dorado (15g/L, 3.87 lb. / bbl.)

| Harvest Time | Maltose (P) | Maltotriose (P) |
|--------------|-------------|-----------------|
| 2023 - E | 0.26 | 0.09 |
| 2023 - M | 0.38 | 0.13 |
| 2023 - L | 0.34 | 0.11 |



Thank you!



***SCAN TO RECEIVE A COPY OF THE
PRESENTATION***