IMPACT OF HARVEST MATURITY ON THE CHEMICAL, BIOCHEMICAL, AND SENSORY CHARACTERISTICS OF 2021 CITRA® HOPS

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Abstract: Hop growers recognize that on-bine maturity can have a significant impact on the chemistry, biochemistry, and sensory properties of hops. As the plant matures, the hop cone changes in a dynamic process that is not fully understood. Although prior studies have explored how harvest date impacts Cascade[1] and Willamette[2] hops, no published information exists with respect to Citra®, which recently became the hop variety with the most planted acreage in the US. In this study, samples of Citra® hops were harvested weekly at seven different time points from August 18, 2021, until September 28, 2021, from three fields located in Yakima Valley, WA. Results show that total oil content, alpha acids, and hop storage index all increased with on-bine maturity. Enzymatic activity decreased substantially as maturity increased. Sensory data indicate that Citra® hops harvested between 9/8 and 9/15—the typical picking window—displayed the highest incidence of the defining characteristics sought by brewers: namely high "citrus," "tropical" and "resinous" aromas, with some "onion" and "garlic" and minimal "grassy" aromas. Hops that were harvested before 9/8 had higher "grassy," "celery," and "green pepper" characteristics, while hops that were harvested after 9/15 had higher "onion," "garlic," and "sweaty" attributes. These results add to the growing body of work suggesting that on-bine maturity plays a pivotal role in the chemical, biochemical, and sensorial properties of hops.

Materials & Methods:

Hop collection methods:
Samples of Citra® hops were harvested weekly at seven different time points from August 18, 2021, until September 28, 2021, from three fields located in Yakima Valley, WA. The hops were kilned, vacuum-sealed, and shipped cold by Yakima Chief Ranches to OSU where they were placed in subzero cold storage until analysis.

Chemistry methods
Moisture content, hop acids (HPLC and UV), hop storage index, and total essential oil content, were measured using ASBC Methods of Analysis. Volatile analysis was performed via GC-FID.

Biochemistry methods
Dextrin-reducing enzymatic activity was measured using a lab-scale dry hopping method[3], whereby hops are added to finished beer with a high residual dextrin concentration in the presence of sodium azide and incubated for 48 hours at 30C. Samples were filtered through a 0.45 µm nylon filter and analyzed on Agilent 1200 series HPLC with a refractive index detector using a Rezex RSO Oligosaccharide Ag+ column.

Sensory methods
Descriptive analysis of ground Citra® hops was performed by a trained 20-member panel using the Check-All-That-Apply method with 16 pre-selected attributes.

Statistical software and analyses
CATA analysis for sensory evaluations was performed using XLSTAT® software (version 2018.5.52280, Addinsoft, New York). Data visualization and Pearson's Correlation Coefficient analysis were performed using R (Version: 3.6.1 GUI 1.70, The R Foundation) ggplot2. Microsoft Excel (Version 16.0.5332.1000 32-bit, 2016, Redmond, WA) was also used for data visualization.

Results: *Chemistry*

Prior studies[1,2] showed that total oils, alpha acids, and HSI increase and plateau as harvest date and % dry matter increase. The results of this study were consistent with prior studies: total oil, alpha acids, and HSI all increased and plateaued as harvest date and % dry matter increased.

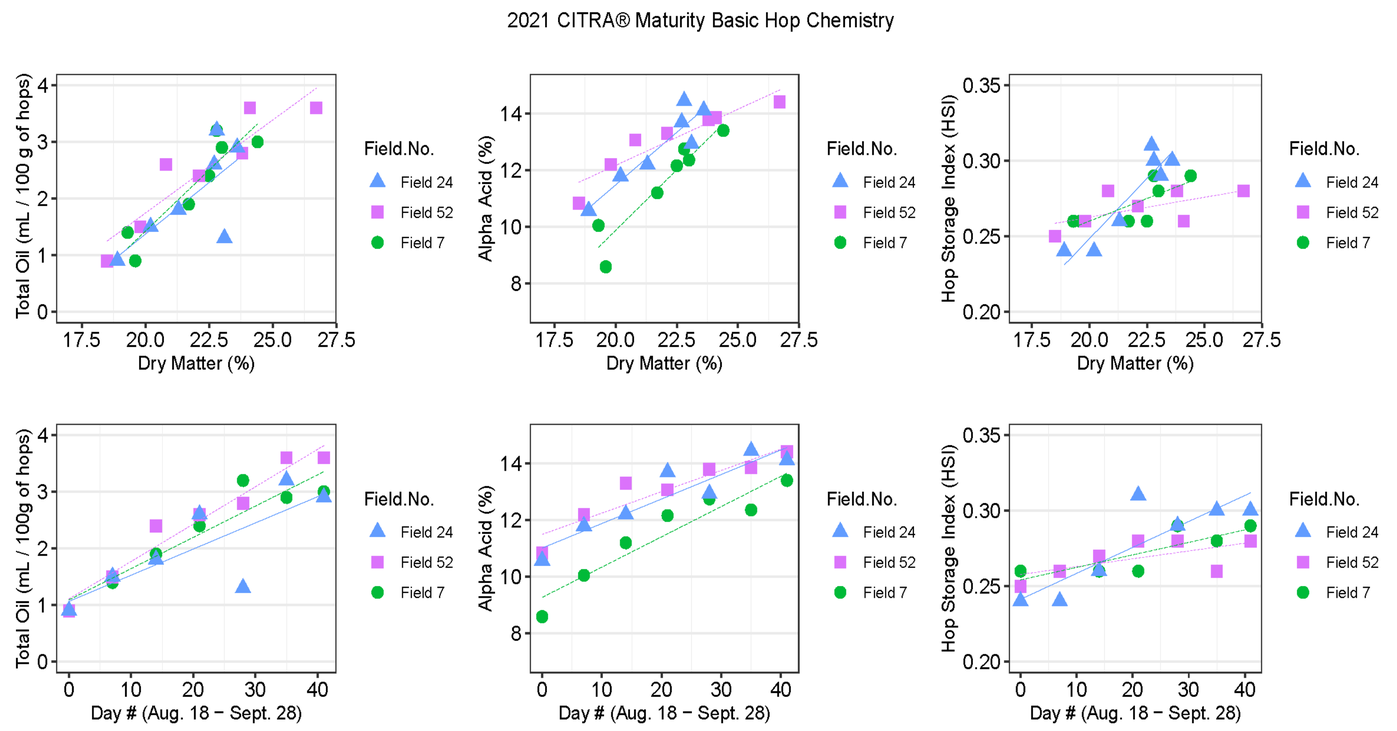

Figure 1: Graphical representation showing interactions between dry matter and total oils, alpha acids, and HSI and the interaction between harvest date and total oils, alpha acids, and HSI.

Results: *Sensory*

The official harvest window for Citra® hops is between September 6 and September 15, according to Yakima Chief Hops. In this study, Citra® hops harvested on September 8 and September 15 displayed the highest incidence of desirable "citrus," "tropical," and "resinous" aromas. Hops that were harvested before September 8 had higher "grassy," "celery," and "green pepper" characteristics. Hops that were harvested after September 15 had higher "onion," "garlic," and "sweaty" attributes. Notably, as "grassy" character decreased, "onion" and "garlic" character increased. The sensory characteristics were similar across all three fields.

			Attribute							
		Sample	Grassy	Celery	Green pepper	Floral	Resinous	Citrus	Onion	Garlic
Early	18-Aug	Field 7	12	9	5	6	8	7	4	3
		Field 24	15	10	9	5	4	9	6	5
		Field 52	12	9	7	3	7	8	4	0
	25-Aug	Field 7	12	7	4	6	10	12	3	3
		Field 24	8	6	7	5	8	10	4	4
		Field 52	13	7	8	8	9	13	2	3
	1-Sep	Field 7	5	3	4	1	16	12	7	3
		Field 24	10	6	6	3	9	16	2	8
		Field 52	9	2	5	4	12	13	5	5
Ideal Citra® Picking Window	8-Sep	Field 7	4	5	2	1	16	16	10	7
		Field 24	8	2	3	3	15	11	5	3
		Field 52	4	3	1	2	16	19	12	7
	15-Sep	Field 7	3	2	2	1	17	15	11	6
		Field 24	5	5	3	4	11	12	12	10
		Field 52	4	2	4	2	13	11	12	10
Late	22-Sep	Field 7	3	2	2	2	16	12	16	13
		Field 24	6	5	3	3	10	12	11	11
		Field 52	3	3	4	3	14	11	13	10
	28-Sep	Field 7	4	2	3	1	16	12	7	9
		Field 24	4	1	1	2	12	9	16	14
		Field 52	3	2	0	2	17	15	9	5

Figure 2: Heat map showing the frequency of attribute selection across 20 panelists. All attributes are significant to $p<0.05$ using Cochran's Q test.

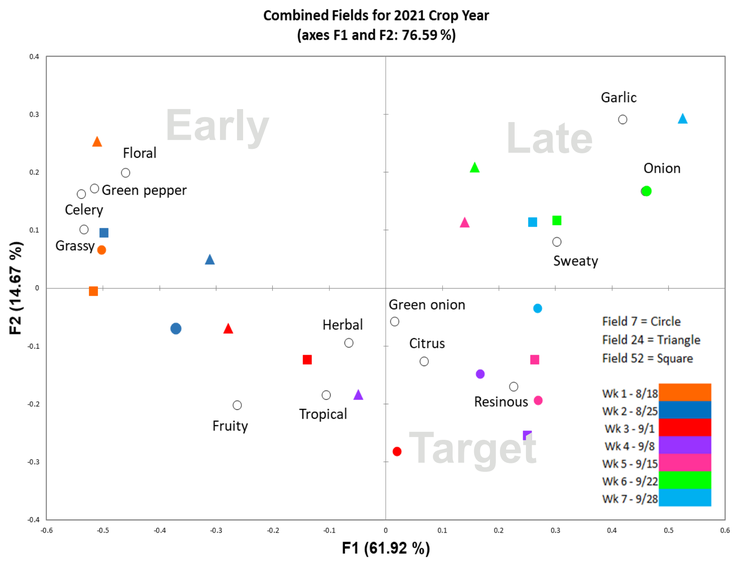

Figure 3: F1/F2 chart showing the relationship between harvest date, field, and attribute descriptors.

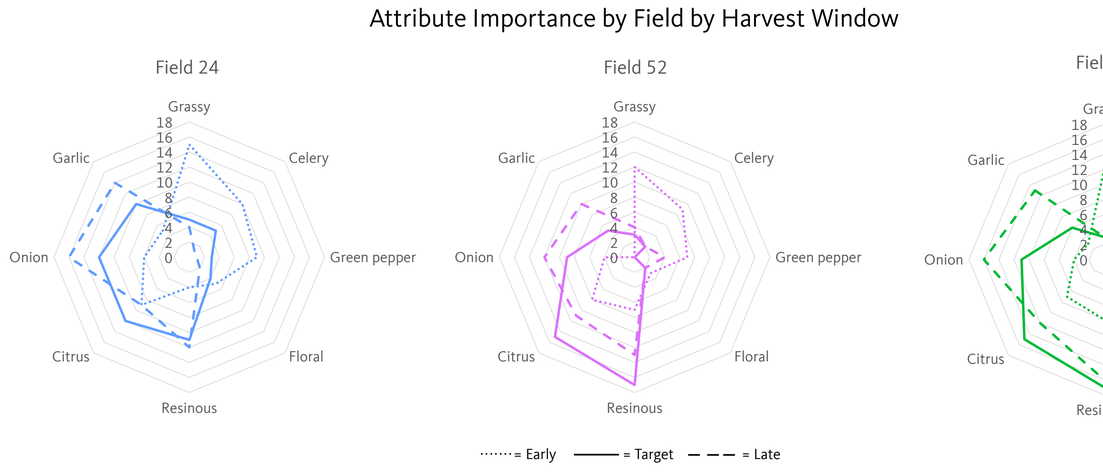

Figure 4: Spider diagrams showing attribute intensity by field and by harvest window (early, typical, or late). Citra hops are typically picked in a two-week window around September 8 and September 15. For the purposes of this diagram, "Early" is considered prior to September 8, and "Late" is considered after September 15.

Results: *Biochemistry*

"Hop creep" is the potential for dry-hopped beers to have higher-than-anticipated ABV and CO_2 levels, and lower-than-anticipated residual extract, due to the enzymatic release of fermentable sugars and subsequent fermentation by yeast remaining in suspension. The release of maltose and glucose from residual dextrin provides an indicator of "hop creep" potential when adding hops to beer post-fermentation.

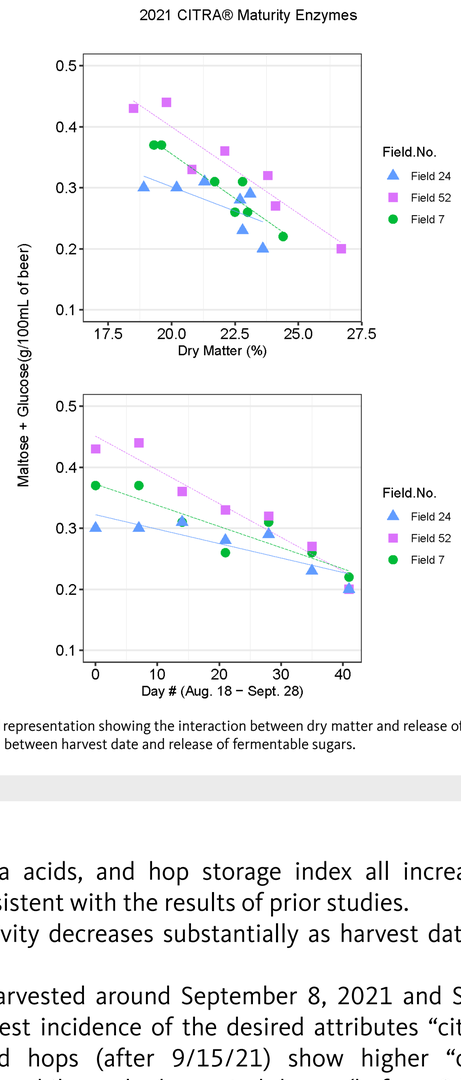

Figure 5: Graphical representation showing the interaction between dry matter and release of fermentable sugars and the interaction between harvest date and release of fermentable sugars.

Conclusions:

- Total oil, alpha acids, and hop storage index all increase as harvest date increases, consistent with the results of prior studies.
- Enzymatic activity decreases substantially as harvest date and % dry matter increase.
- Citra® hops harvested around September 8, 2021 and September 15, 2021 show the highest incidence of the desired attributes "citrus" and "resinous." Late harvested hops (after 9/15/21) show higher "onion" and "garlic" characteristics, while early harvested hops (before 9/8/21) show higher "grassy," "green pepper," and "celery" characteristics.

References:
1 Lafontaine, S.; Varnum, S.; Roland, A.; Delpech, S.; Dagan, L.; Vollmer, D.; Kishimoto, T.; Shellhammer, T. Impact of Harvest Maturity on the Aroma Characteristics and Chemistry of Cascade Hops Used for Dry-Hopping. *Food Chemistry* 2019, *278*, 228–239.
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3 Kirkpatrick, K. R.; Shellhammer, T. H. A Cultivar-Based Screening of Hops for Dextrin Degrading Enzymatic Potential. *Journal of the American Society of Brewing Chemists* 2019, *76* (4), 247–256.

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