

USDA-ARS Hop Breeding and Genetics Program

Presented by:
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Special Thanks!

- *USDA-ARS Hop Team Members (Past & Present)
- Oregon State University Collaborators
- Hop Research Council
- Oregon Hop Commission
- Private Industry Collaborators
- Hop Producers in Oregon and Washington

Overview

- History of hop Breeding
- Major hop breeding groups (public & private)
- Breeding hops
- Factors affecting production—Breeding targets
- Genetic Studies
- Summary—USDA-ARS Genetics and Breeding

Hop Breeding History: 750 – 1700's

- Early use of hops from collecting wild hops
- Wild hops brought into gardens
- Growers would only replant the best growing to replant
- Called "Clonal Selection"
- After centuries of clonal selection ----> "Noble Hop"
- Saazer, Halletauer, Tettnanger, Alsace, Hersbrucker...

Hop Breeding History: 1700 - 1900

- Some growers had wild male hops nearby or in field
- Selected plants that were superior in field
- Some of these arose by natural hybridization
- Fuggle—Picker dropped seed near barn while eating lunch?? Named after Mr. Fuggle
- Cluster—thought to be a natural cross between old European variety and wild NA hop
- "Goldings" – a selection named after Mr. Golding

Hop Breeding History: Early 1900's England

- Prof. Salmon @ Wye College—First hop breeder
- Obtained a wild N. American female hop--"BB1"
- Grew it out in GB among male hops
- Collected seed ("Open Pollinated")
- One seedling = 'Brewers Gold'
- First verified "cross" or "hybridization" ~ 1919
- 'Bullion' was obtained from the same cross
- Brewers Gold & Bullion = half sisters
- 'Northern Brewer' is a Granddaughter of BG
- All "super-alpha" hops derived from BG

Hop Breeding History: Early 1900's Germany

- Prof. Zattler in Huell, Germany
- Focused upon selecting for downy mildew resistance
- Much of the downy mildew resistant crosses from 1930's to 1960's used germplasm from his program

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Hop Breeding History: USA 1930's

- USA had later start in hop breeding
- Hop research prior to Prohibition focused on pathology and agronomics
- After Prohibition in 1930 USDA began hop research and breeding in Corvallis, OR
- Continuous since 1930
- Much of early work was evaluating foreign developed hop for production in USA
- Early 1950's began breeding in earnest

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Hop Breeding History: USA 1950-1965

- USDA (Stan Brooks) program made significant strides in developing "germplasm"
- One cross in 1955 turned out as 'Cascade'
- Not released to public till 1972
- Several other crosses laid the groundwork for 'Nugget'

Hop Breeding History: USA 1965 - 1996

- A Renaissance took place during this time
- Al Haunold (USDA-ARS) took over breeding operations in Corvallis, OR
- Inherited a large resource of potential varieties and germplasm
- Side USDA operation in Idaho (R. Romanko) bred and released 'Galena' and several others.
- Haunold released 'Nugget' – First "Super-Alpha" and hugely popular 'Willamette' – First successful triploid hop

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Hop Breeding History: USA 1965 - 1996

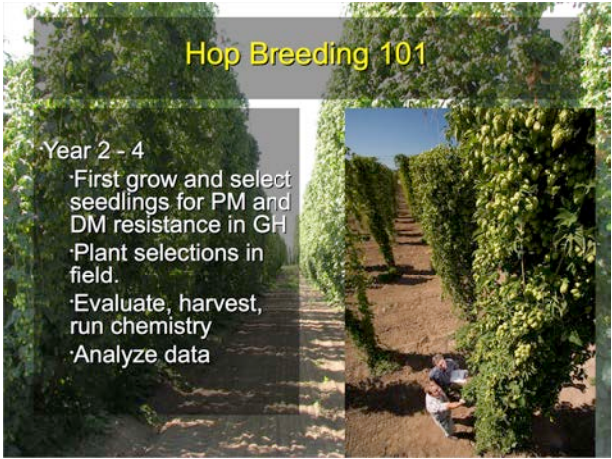
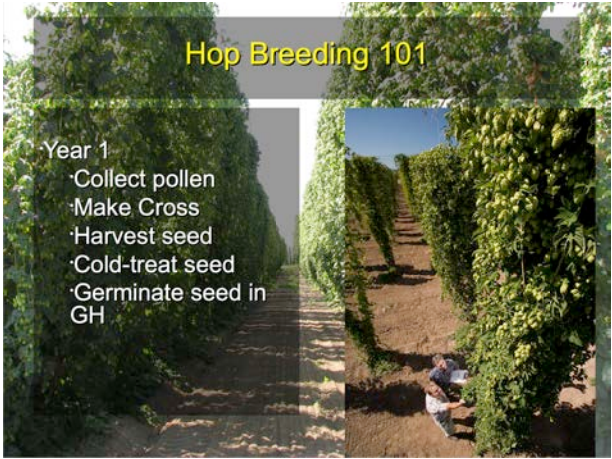
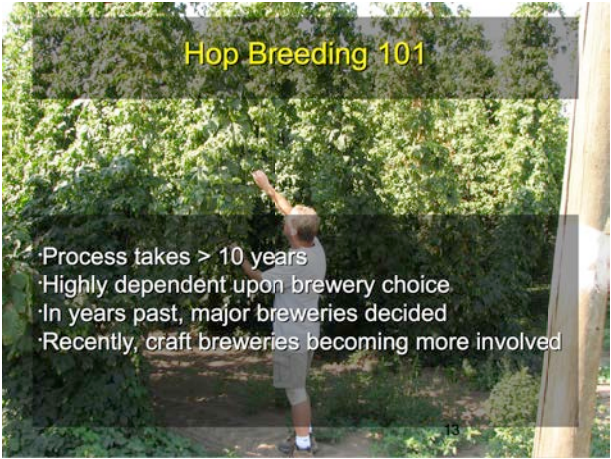
- First private plant breeding companies start in early 1980's
- Private companies all owned by major hop merchants
- Soon started developing their own competing varieties
- Columbus, Tomahawk & Zeus produced early 1990's

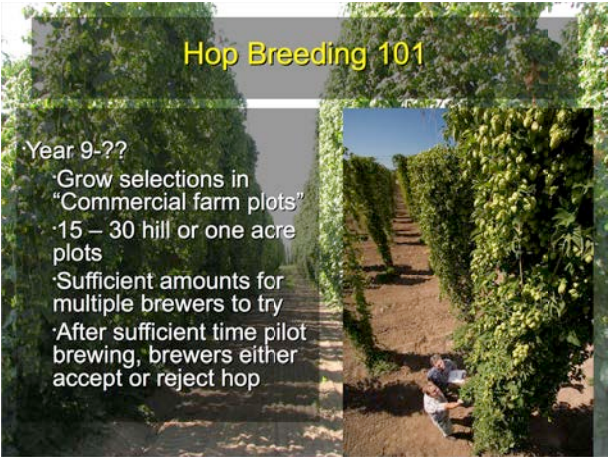
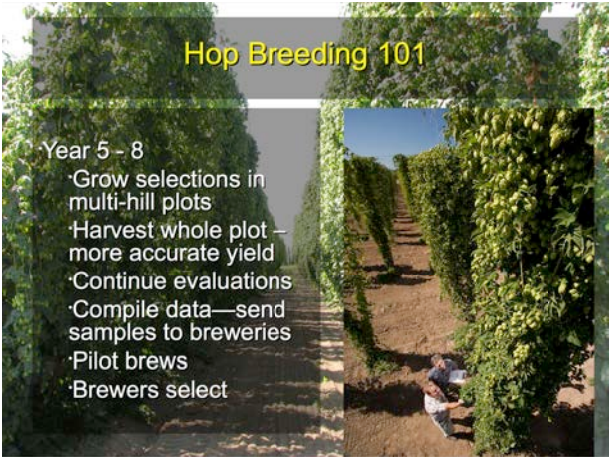
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Hop Breeding History: USA 1996 - Present

- Time of variety proliferation!
- Each of three major private plant breeding programs releasing large numbers of varieties
- Washington State University (Steve Kenny—Breeder)—'Chinook', 'Vanguard' & 'Glacier'
- USDA-ARS releases 'Santiam', 'Horizon', 'Sterling', 'Newport', 'Teamaker' & 'Mt. Rainier'

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Powdery Mildew

- Can kill off plant quickly
- Dramatically reduces yield
- Affects quality of cones
- Controlled via use of resistant hop varieties and fungicides



Hop Aphid

- Weakens plant
- Aphids leave "honeydew" excretion
- Can spread some viruses
- Honeydew on hop cones acts as reservoir for molds
- If uncontrolled, crop can be judged as unacceptable for brewing
- No known resistant varieties—some more tolerant than others

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Two Spotted Spider Mites

- Big problem during hot summer months
- If uncontrolled can quickly kill off a plant
- Uncontrolled water loss—shrivels up and dies
- No known resistant varieties
- Controlled via miticides

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Newest Disease-Hop Stunt Viroid

- Stunted growth
- Limited cone production
- Leaves inter-vein speckling
- Spread via contact and seed
- Clean equipment between fields



Genetic Studies

- 10 Chromosomes with X and Y
- Differential gamete success; males ~ 15 to 30%
- Causes unexpected segregations of Y-linked traits
- Important areas of research: bittering acids, disease resistance, dwarfing genes
- Still in our "infancy stages" compared to maize, wheat or barley

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Summary of What's Been Done

- Inheritance studies
- Genetic diversity studies
- Molecular Marker Identification
- Genetic Mapping
- Hop Genome Sequence Initiative

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Inheritance Studies

- Study: likelihood offspring will resemble parent(s)—"Additive Effects"
- Heterosis—likelihood that a combination of two parents gives superior offspring
- Use Phenotypic or Genotypic selection? Also suggests use of hybrid program
- Are some traits "correlated"?
- May provide info on number of controlling genes

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Inheritance Studies

TRAIT	Heritability	YLD	CoH	CoL	ALPHA	BETA	XAN
	h^2_{pooled}	r_g					
YIELD	0.71 ± 0.001						
CoH	0.87 ± 0.03	0.636*					
CoL	0.89 ± 0.02	0.685*	0.881**				
ALPHA	0.76 ± 0.06	0.282	0.385	0.592			
BETA	0.57 ± 0.19	0.729*	0.775**	0.874**	0.714*		
XAN	0.60 ± 1.14	0.921**	0.509	0.759*	0.864**	0.588	

*, ** Significant at $P \leq 0.05$ and $P \leq 0.01$ level, respectively.

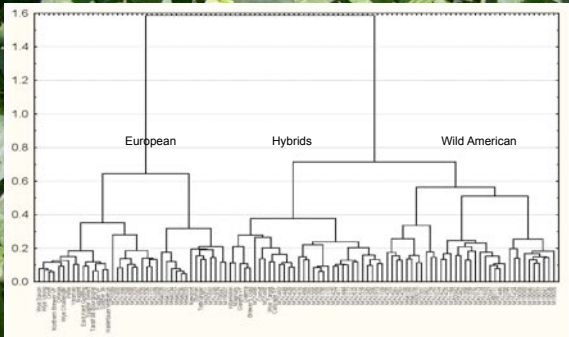
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Genetic Diversity

- Several studies performed on diversity
- Most focused upon female cultivars
- More important: male and female diversity
- Henning et al. (2004)
- Townsend and Henning (2005)
- DArT Cooperative Group, 2008

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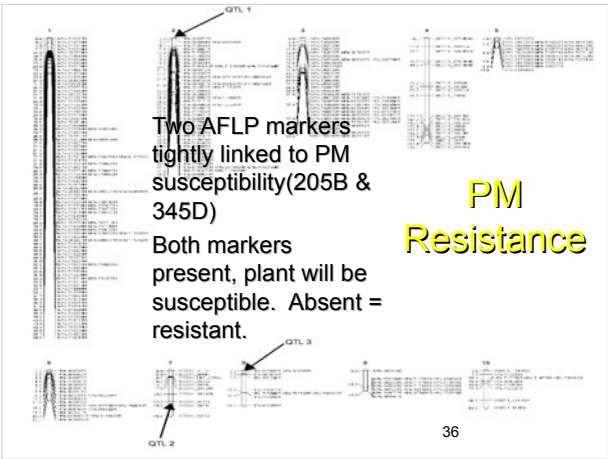
Genetic Diversity Groups



Molecular Marker Identification

- Male and female markers – Seigner et al, 2000
- Chemistry Compounds – Koie et al., 2005
- Alpha-acid content – Cerenak et al. 2006
- Recently completed work – Powdery Mildew Resistance (Henning, Townsend, Matthews et al 2011)

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Molecular Marker Identification & Genetic Mapping

- Working with private industry to identify markers for DM resistance as well as alpha and beta acid production
- Working on identifying markers to select for 'dwarf hop'
- Developing "next generation sequencing" tools to make quantum jump in marker ID and genome mapping

Hop Genome Sequencing Initiative

- Working with private industry (Dr. Paul Matthews) and international scientists from Czech Republic, Slovenia, Great Britain and New Zealand.
- In process of obtaining grant funds to complete
- Cost of genome sequencing using Next Gen sequencers dropped
- Time for sequencing dropped

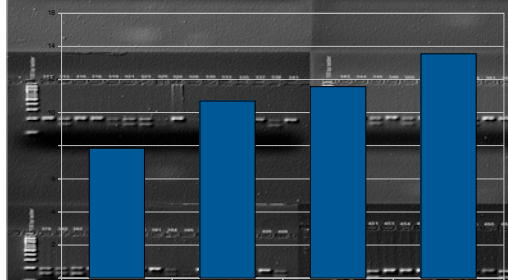
Gene Identification and GMO's

- Beta-Chitinase for general resistance to fungal pathogens
- Chalcone synthases—secondary metabolites
- 21 new genes involved in resistance to PM (Henning and Dombrowski, 2011)
- Stilbene synthase inserted into hop (GMO)—Germany
- Future of hop genetics and breeding???

Other Uses for Molecular Tools

- Recent work by Henning et al. (2009)
- Use of AFLP to predict offspring performance
- Genetically diverse parents produce superior yielding offspring
- Significant correlation between genetic diversity and yield
- Takes "Guesswork" out of parent selection

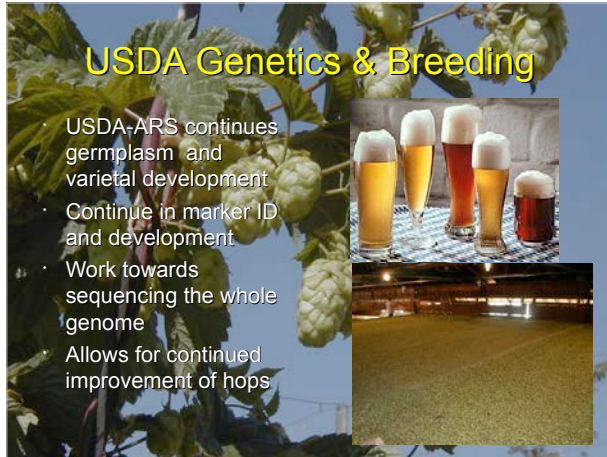
Using Genetic Distance to Select Parents



Changes in the Hop World?

- Labor costs
- Labor availability
- Fuel and pesticide costs—skyrocket!
- Pesticide regulations
- Hop supply and demand??
- Craft Breweries—Market share UP!





USDA Genetics & Breeding

- USDA-ARS continues germplasm and varietal development
- Continue in marker ID and development
- Work towards sequencing the whole genome
- Allows for continued improvement of hops