ANNUAL REPORT TO THE U.S. HOP RESEARCH COUNCIL

1981 Hop Research

Alfred Haunold, Genetics, USDA-ARS
Sam T. Likens, Chemistry, USDA-ARS
Richard Hampton, Pathology, USDA-ARS
Gail B. Nickerson, Chemistry, OSU

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HOP BREEDING AND GENETICS

Alfred Haunold

Significant research progress this past year can be summarized as follows:

1. Release of four triploid hop pollinators (approved).
2. Release of male hop germplasm line 63015M (in review).
3. Yield/quality data obtained from commercial plots of USDA 21193.
4. Establishment of additional commercial plots of USDA 21193 in Washington, Oregon, Idaho, and California.
5. Establishment of commercial off-station plots of USDA 21254, Record (Acc. No. 21078), and Perle (Acc. No. 21227).
6. Evaluation of potential aroma lines 21245, 21180, 21181, and 21202.
7. Establishment of a new seedling nursery to combine high alpha, yield, storage, and early maturity.
8. Demonstrating viability of hop pollen stored for two years in liquid nitrogen.

GERMPLASM RELEASE

In general, release of hop germplasm is done cooperatively under the Pacific Northwest Tri-State Agreement (Washington, Oregon and Idaho), similar to a variety release. In case only one state is interested, a line may be released for that state only.

Two germplasm releases are presently pending:

1. Triploid hop pollinators: Four early flowering triploid pollinators(Table 1) have been tested for several years, primarily in Oregon. The four were sent to C. E. Zimmermann, Prosser, on April 16, 1979, but no performance data were obtained.

Table 1. Early Flowering Triploid Hop Pollinators

Genotype [1/]	Pollen shedding time	Pollen quantity	Downy mildew reaction
21189M	Early	Very good	Resistant
21190M	Very early	Good	Resistant
21191M	Very early	Good	Resistant
21192M	Very early	Very good	Resistant

[1/] Pedigree: [XS x (Fu x EG - ECS)] x OP^2. XS = unknown seedling; Fu = Fuggle; EG = Early Green; ECS = Early Cluster seedling; OP = open pollinated.

The four genotypes have been found to be suitable for stimulating higher cone yields with negligible seed production in early flowering female cultivars such as Fuggle, Styrian and Tettnanger.

2. USDA 63015M: This male genotype, genetically 3/4 Brewer's Gold, 1/8 East Kent Golding, 1/16 Bavarian, and 1/16 OP (unknown), has been used successfully in the USDA Hop Breeding Program since 1967. The genotype is the father of the high alpha acid selection USDA 21193, of W406-57 (Accession No. 21223), a potential aroma hop, and of the Washington selection W412-18 (Accession No. 21224), a potential high alpha hop. Both 21193 and 21224 are now in commercial off-station trials.

Over a six-year period beginning in 1976, 63015M averaged 51.0% alpha, 24.2% beta, 21% cohumulene, and an alpha ratio of 67 (Table 2). The genotype has good storage stability of its soft resins which has been successfully passed on to its progeny. The oil composition (humulene/caryophyllene ratio = 2.46) and low cohumulene content (21%) may be indications of European quality traits.

Table 2. Quality Data of USDA 63015M (lupulin gland basis).

Year	% alpha	% beta	Ratio [1/]	HSI_6 [2/]	% alpha remaining [2/]	CoH
1976	59.1	23.0	72	-	-	-
1977	49.6	26.8	64	0.27	95	17
1978	48.9	20.4	70	-	-	-
1979	51.8	23.4	68	-	-	21
1980	52.8	27.3	65	0.56	61	24
1981	42.7	24.5	63	-	-	23
Average	51.0	24.2	67	0.41	78	21.3

[1/] $\alpha/\alpha+\beta$

[2/] HSI_6 = Hop Storage Index, six months at room temperature.

USDA 63015M has one of the longest safe periods of male genotypes in our collection (average 8.2 hours) and a very low 3-hour crush rating (average 0.35), pointing to its superior storage characteristics.

DEVELOPMENT OF NEW HIGH ALPHA HOP CULTIVARS

1. USDA 21193: The first mature commercial crop of this high alpha selection was obtained from one Washington and two Oregon test locations in 1981 (Table 3). A brief summary of the commercial production data of 1981 is presented in Table 3. An updated information sheet of 21193 is found on pages 7 - 8.

Table 3. Yield and Quality Data of the First Mature Commercial Crop of USDA 21193 Grown in Oregon and Washington, 1981

Location	Grower	Yield lbs/acre	Alpha acids (dry wt. basis)
Independence, OR	J. I. Haas, Inc.	1409	13.4
Gervais, OR	Robert Coleman	1572	11.2
Toppenish, WA	J. I. Haas, Inc.	916	13.1

Cone yields from commercial plots were judged to be satisfactory, especially since each location had a number of missing hills and a substantial number of replants.

a. Mytoma Ranch, Independence, Oregon (Haas): The field was planted June 10, 1980 from soft wood cuttings produced in the spring of that year. Plants were not trained in 1980, but were double strung in 1981. Of the 1,701 hills planted, 1528 were harvested (173 missing hills). About 15% of all plants were small (replants in 1981), and, therefore, did not materially contribute to yield. The plot was machine harvested on September 11, 1981.

Production: 2781 pounds total = 1409 lbs/acre
15 bales delivered to the dealer
(average bale weight - 190 lbs)
Leaf and stem: 3.0%; Seeds: 1.0%

Quality (dry weight basis): alpha 13.4%; beta 4.4%; CoH 24%

Adjacent Cascade control: 1000 lbs/acre (estimate)

b. Coleman Ranch, Gervais, Oregon: This field was planted May 7, 1980 from rooted soft wood cuttings. Of 1726 hills planted 136 died, leaving 1590 plants for harvest in 1981. Plants were not strung in 1980, but were double strung in 1981. About 15% were small plants (1-2 vines per hill), which adversely affected the yield. The plot was harvested September 11, 1981.

Production: 3230 pounds total = 1572 lbs/acre
19 bales delivered to the dealer
(average weight - 175 lbs)
Leaf and stem: 2.0%; Seeds 13.0%

Quality (dry weight basis): (alpha 12.2%; beta 2.2%; CoH 25%)

Adjacent Cascade control: 1200 lbs/acre (estimate)

c. Toppenish, Washington (Haas): About 1.2 acres was planted from rooted soft wood cuttings in 1980 (7 x 7 ft. spacing). Due to the late planting date plants did not get established well, but most hills could be trained in the spring of 1981. A total of 1049 hills were harvested on September 13, 1981. About 20% of the hills were small plants (1-2 vines/hill) which adversely affected production.

Production: 1081 pounds total = 916 lbs/acre

Quality (dry weight basis): (alpha 13.1%; beta 4.6%)

Alpha acids content in this plot appeared to level off the first week of September as illustrated by the quality data obtained from hand samples: September 4 (12.4% α), September 9 (12.7% α), September 11 (13.9% α), September 13 (12.3% α), September 16 (12.4% α).

d. Mabton, Washington (Haas): A 17 acre field of 21193, planted from rooted soft wood cuttings in mid-May 1981, produced 8 bales total (about ½ bale/acre) with an analysis of 12.8% alpha and 4.4% beta on an 8% moisture basis (13.5% alpha, 4.6% beta, dry weight basis).

e. USDA 21193 maturity series: Hand samples (one lb each) were obtained on seven different dates from our 1981 nursery plots near Corvallis to study the development of hop quality constituents with increasing maturity (Table 4). Yield and quality data of machine harvested 21193 and Bullion controls harvested at optimum maturity are included for comparison.

USDA 21193 produced significantly higher cone yields and alpha acids content than the Bullion or prunus-free Bullion controls.

Table 4. Development of Soft Resins in USDA 21193 during Harvest

	Harvest Date	Yield lbs/α	Alpha	Beta	Alpha Production lbs/α	oil ml/100g	Co-humulone
			%	%			%
Hand Sample							
21193	Aug. 18	-	10.1	4.1	-	0.16	18
21193	Aug. 27	-	14.5	5.0	-	0.80	21
21193	Aug. 31	-	14.0	5.5	-	0.89	24
21193	Sep. 4	-	16.0	4.4	-	1.97	25
21193	Sep. 7	-	13.5	5.5	-	1.32	26
21193	Sep. 12	-	14.3	4.2	-	1.60	28
21193	Sep. 28	-	17.0	4.6	-	2.98	25
Machine Sample							
21193 [1/]	Sep. 12	3033	14.2	4.2	431	-	29
Bullion	Sep. 1	1826	9.3	4.8	170	-	35
prunus-free Bullion 10A	Sep. 1	2295	10.3	5.1	236	-	34

[1/] Average of two locations.

Alpha acids content in 21193 increases rapidly from mid-August and apparently levels off the first week of September. A similar situation was found for oil content and cohumulone content while beta acids seem to level off about ten days earlier. The maximum alpha and oil content on September 28 may be due to sampling error.

INFORMATION SHEET - USDA 21193
(SELECTION NO. 7005-194)

January 1982

Pedigree: 65009 x 63015M
(Br. Gold x Early Green - Unknown) x (Br. Gold^2 x East Kent Golding - Bavarian Seedlg)

Genetic Composition: 5/8 Br. Gold; 1/8 Ea. Green; 1/16 E. Kent Golding; 1/32 Bavarian; 5/32 Unknown.

Maturity: Medium late, about Sept. 5-10 in Oregon. Later pick results in maximum alpha production.

History: Cross made in 1970;
Single nursery plant, 1971 - 1973
2 hill seeded observation plot, 1974 - 1979
To Yakima (J. I. Haas test location); 1976
To Prosser, WA. and Parma, ID., 1976
Seedless test location, Corvallis; 1978 - present
30 hill observation plot, 2 locations, Yakima Valley, 1979
2 ½ acre off-station plots - 2 locations, Oregon, 1980
1 - acre off-station plot - 1 location, Yakima Valley, 1980
1 - acre off-station plot - 1 location, Idaho, 1981
Four 5 - acre plots, WA. 1981
17 acres, near Toppenish, WA. 1981
20 acres, Woodburn, OR. 1981
40 plants, Sloughhouse, CA. 1981

Training: Easy, excellent spring regrowth, abundant shoots; climbs well.

Picking: Excellent, compact cone, no shatter, easy clean up.

Drying & Baling: Very good, no problems encountered. Bales likely to be heavier than average.

Cone Type: Compact, dense, medium heavy. Cones do not fluff up upon drying and do not shatter, even with very late picking (about 25% heavier than Br. Gold).

Lupulin: Plentiful, deep yellow color.

Aroma: Mild, somewhat spicy.

Storage Stability: Very good, retained nearly 80% α acid in 1977, 74% in 1979, 60% in 1980 at 6 months, room temperature.

Essential Oils: range about 1.3 to 2.3 ml/100 g

Oil Composition	1979	1980	1981
Myrcene	50.9	57.8	53.0
Humulene	22.3	18.0	18.0
Caryophyllene	10.4	8.1	8.2
Farnesene	<0.2	0	<0.2
Murollene	1.0	1.8	1.4
Hum/Car. ratio	2.14	2.22	2.20
Total Oil, Average (ml/100g)	1.78	2.30	1.89

Alpha ratio ($\alpha/\alpha+\beta$): 71 - 78 (Over three times more alpha than beta)

Cohumulone: 24 to 27%

Diseases: Crown resistance to downy mildew; no indication of verticillium wilt in Oregon; slight verticillium symptoms in 2 Washington off-station plots. Resistant to downy mildew in 20-can greenhouse tests--1978. Free of PNRSV and hop mosaic in 1978,1979, 1980 and 1981 ELISA tests; occasional yellow fleck on bottom leaves apparently not due to viruses. Off-station plots established with virus-free stock in 1980. Nuclear virus-free stock increased at Corvallis in 1981.

Other Information: Occasionally some white cones when grown seedless. Plants are easily propagated by softwood cuttings or by layering. A 5-acre plot of virus-free nuclear plants scheduled for Oregon planting in 1982.

USDA 21193: Yield and Quality Information. (Quality data on dry weight basis)
HSI_6 = hop storage index, sample stored 6 months @ room temp., calculated % alpha remaining.

Year	Corvallis			Yakima			Prosser			Idaho A = best (to D)		
	α,	β,	Remarks	α,	β,	Remarks	α,	β,	Remarks	α,	β,	Remarks
1972	11.2	4.2	73% remaining HSI_7 0.41									
1973	12.0	3.6	CoH 22, good storage aroma									
1974	-	-	moved from single hill nursery to replicated plots; no data									
1975	11.8	3.7	HSI_6 0.41; CoH 22 no yield data									
1976	12.8 12.6	4.9 4.5	821 lbs/A 6 mo: 83% remaining HSI_6 0.36	13.3 14.4	5.0 5.8	69% remaining good vigor good yield	13.3	5.0	16 lbs/plant, good com. potential, good vigor good yield			
1977	12.3 12.1	4.4 4.5	1429 lbs/A; 6 mo: 78% remaining, 6 mo: 72% remaining vigor, good storage (HSI_6= 0.44)	10.8	4.6	HSI_0 0.29 HSI_6 0.41 73% remaining	10.8 11.4	4.9 4.7	12 ¼ lbs/plant fair vigor 71% remaining good storage	11.1	6.3	74% remaining, arm length A, clustering A, cone size A, vigor A(=best) good storage
1978	11.9 11.0	4.6 4.6	981 lbs/A 1855 lbs/A DM/cones 6 mo(avg.):67%remaining	14.9	5.6		10.1	5.2	Poor/fair comm. potential terminal cone	11.5	4.2	
1979	13.6 14.0 13.3	5.2 4.8 4.9	2045 lbs/A (avg.2 plots) CoH 25 1023 lbs/acre 1589 " 6 mo(avg.):74%remaining	13.3	4.8	Good yield (baby)	12.8	5.2	yield 10-12bales/a	--	--	poor not-harvested
1980	14.9 15.7 14.9	4.7 5.4 5.0	2483 lbs/acre 2687 " 2218 " Co-humulone:24-28% 6 mo(avg.): 76 % rem.	Haas:(Toppenish):Yield like B.Gold 13.6 5.7 14.2 5.5 Brulotte: (Toppenish) 13.8-16: 4.4-5.5			Plants disappeared at Prosser, spring 1980 Commercial location harv. 8/30 13.9 5.1 yield about 9/5 13.8 4.4 10b/A est. 9/12 16.8 5.7		Exptl. yard discontinued			
1981	14.3 14.2	4.2 4.2	3396 lbs/a CoH 28 2670 " CoH 30 Storage test in progress	Brulotte:(babies) 9.3 5.8 CoH 25 Patnode (babies) 9.1 4.5 CoH 23 Haas 13.5 4.6 (babies)						8.1	2.5	1000 lb/a (immature) no data available

2. USDA 21254 (Selection 7312-83): This high alpha selection from a 1973 cross was moved to an off-station plot to obtain bale quantities from commercial brewing trials. This hop appears to mature as early as Bullion in Oregon, is moderately resistant to downy mildew under field conditions, has a low beta acids content, moderately low cohumulene content, and a high humulene/caryophyllene ratio (H/C = 2.9 - 3.7). Brewers interested in aroma hops will hopefully evaluate this hop in commercial brewing trials. An up-to-date information sheet of USDA 21254 is found on the following page.

The yield of 21254 has been variable. The low yield in 1978, probably due to plant injury from pruning, resulted in spotty spring regrowth. The 1980 and 1981 yields were comparable to Brewer's Gold or Bullion at our Willamette test location. The alpha acids content and the six-month hop storage index (room temperature storage) have been remarkebly stable for the past five years. The humulene/caryophyllene ratio in the two preceding years averaged 3.32 and the myrcene content was 47.3%, which is low by U.S. standards.

3. Record, USDA Accession No. 21078: This hop, from a cross of Northern Brewer x Saazer seedling, was obtained from Belgium (the country of origin) in 1974. Besides Belgium, this cultivar is grown on substantial acreage in Germany (900 acres in 1980). Although Germans classify Record as "bitter hop" together with Northern Brewer and Brewer's Gold, it has consistently scored higher aroma points in German trade exhibitions than the other two high alpha hops, sometimes only a few points below "noble aroma hops."

In the overall evaluation (including alpha acids content and aroma) at the 1980 German Hop Variety Exhibition, Northern Brewer obtained 74.2 points, Record 73.0, and Hallertauer mittelfrüh 63.9.

Yields of Record in USDA nursery plots near Corvallis have been variable (1000-1600 lbs/acre). The cultivar appears to have a substantially higher yield potential than Northern Brewer. Alpha acids content during the past five years averaged about 8.4%. The myrcene content of the oil in the past years averaged about 54% and the humulene/caryophyllene ratio was 3.2. In a 1981 seedless trial, Record produced 1370 lbs/acre with 9.3% alpha, 4.6% beta, and a cohumulone of 39. The latter is higher than the 22-26 average of preceding years.

INFORMATION SHEET - USDA 21254
(SELECTION NO. 7312-083)

January 1982

Pedigree: 21055 x 21109M
(Comet x Utah 524-2) x Brewer's Gold x Fuggle-Colorado 2-1)

Genetic Composition: 1/4 Comet; 1/4 Wild American; 1/4 Br. Gold; 1/8 Colo.Wi.Am.

Maturity: Medium early, about Aug. 28 in Oregon.

History: Cross No. 7312 made in 1973
Single nursery plant, 1974 - 1976
5-hill seedless plot, Willamette Yard, 1976 - present
5-hill seedless plot, Smith Yard, 1981
1.5 acres, Hubbard, Oregon, 1981
Used as female parent of crosses 7610, 7611, 7612 to produce high alpha - low beta progenies

Training: Very good spring regrowth, abundant shoots

Picking: Very good, no shatter

Cone Type: Medium, moderately compact

Storage Stability: Very good, retained 82% alpha when stored six months at room temperature (4-year average; range: 77-90% alpha remaining)

Essential Oils: 1.55 ml/100 g (5-year average)

Diseases: Intermediate reaction to downy mildew in 20-can greenhouse test in 1978 (some pith rot). Bottom foliage infection moderately heavy in 1978, 1979, light in 1977. No systemic crown infection. No verticillium or virus symptoms observed.

Quality:

Year	Yield lbs/α	% alpha	% beta	ratio	HSI_6	% Alpha remaining	Cohumulone
1975	-	15.6	4.1	79	0.40	-	-
1976	-	15.6	4.4	78	-	-	-
1977	2076	9.2	2.9	76	0.41	90	-
1978	572	13.5	4.4	75	0.40	80	-
1979	1271	13.5	3.9	77	0.40	82	27
1980	1506	13.3	4.1	76	0.44	77	24
1981	1706	12.4	3.1	79	Not Completed		30
Average	1426	13.3	3.8	77	0.41	82	27

At the request of a major U.S. aroma hop user, we established a one acre plot of Record near Woodburn, Oregon. The first mature crop will be available in 1982. ELISA tests in late spring 1981 showed that Record is completely infected with all five hop viruses known to occur in the United States, a fact that may have adversely affected its performance in past years. Virus clean-up of Record involving heat treatment and meristem tip culture initiated by Dr. Hampton in the summer of 1981 is in progress.

4. Galena (USDA Acc. No. 21182) and Eroica (USDA Acc. No. 21183): The advent of Ridomil for controlling systemic downy mildew infection has been of great benefit for these two high alpha varieties which are moderately susceptible to downy mildew under Oregon conditions. An 18-acre commercial field of Galena (near Woodburn) and a 25-acre field of Eroica (near Mt. Angel) were planted in 1981. Planting stock of Galena was obtained by the grower from Idaho while Eroica planting stock was provided by USDA. The varieties were increased by a commercial root propagator.

In 1981 nursery plots near Corvallis, Galena significantly outyielded Eroica (2100 lbs/acre versus 1200 lbs/acre), but Eroica had a higher alpha acids content (15.4% versus 11.9%). Galena has better storage stability than Eroica and both had high cohumulone content (35-40%), and a low H/C ratio. Commercial bale quantities from both varieties grown in Oregon will be available in 1982.

5. Washington high alpha selections W412-18 (Acc. No. 21224) and W416-02 (Acc. No. 21225): Commercial testing of these selections is concentrated in the Yakima Valley and will be reported by Prosser scientists. Performance of these two lines in nursery plots near Corvallis over the past three years has been disappointing. Prior to 1981 the two lines were severely damaged by downy mildew infection. In 1981 when downy mildew was not a problem (Ridomil protection), yields were better than in previous years (about 1000 lbs/acre; alpha 11.5, beta 5.5, cohumulone 40%). Bullion 10A (free of prunus necrotic ringspot virus) at the same location produced 2200 lbs/acre (10.1% alpha; 5.6 beta, and a cohumulone content of 35).

The two lines are now established at a second seedless location near Corvallis but there are no plants at present to establish commercial off-station plots in Oregon.

6. Washington selection W421-38 (USDA Acc. No. 21226): This selection from the cross of a Petham Golding seedlg(USDA Acc. No. 68052) with a male seedling from a Brewer's Gold-Utah Wild American cross is being tested as a potential high alpha/aroma hop. In mature seedless nursery plots near Corvallis in 1981, the line yielded about 1200 lbs/acre with 15.3% alpha, 3.8% beta and a cohumulone content of 34%. All plants had long sidearms, but sparse cone set and large fluffy cones which adversely affected yields. In previous years, this line was somewhat damaged by downy mildew infection which was not a factor in 1981. At the present time there are no plans to expand testing of this line in Oregon.

AROMA HOPS

The development of new aroma type cultivars is made particularly difficult because in contrast to high alpha hops we lack an objective evaluation procedure that is generally accepted by brewing chemists or brew masters. Higher alpha acid hops have often been rejected by aroma hop users, although there are no scientific reasons why it should not be possible to achieve a combination of high alpha acids content and "Noble European" aroma characteristics. Scientists from Germany and Yugoslavia claim to have achieved this goal with some of their newly released hop varieties, notably, Perle (Germany) and Bobek, Blisk and Buket (Yugoslavia). These cultivars have higher alpha acids content (occasionally exceding 10%), lower beta, lower cohumulone content (20-26), and an above average humulene/caryophyllene ratio.

A large number of potential aroma selections from the USDA Hop Breeding Program are at various stages of field testing. Cascade and Willamette, although recognized as aroma hops, seem to fit only a certain segment of the U.S. brewing industry. Columbia, which combines higher alpha acids content and certain European aroma characteristics (e.g., a high humulene/caryophyllene ratio), is still undergoing brewery evaluation.

1. Established European Aroma Varieties

a. Styrian (Acc. No. 21049): This Yugoslavian aroma hop, developed from Fuggle, has been grown on about 15½ acres in Oregon at two seeded locations. A few acres of Styrian are also grown in a seedless commercial location in

Northern Idaho. Production has been satisfactory, somewhat better than Fuggle. Sryrian was found to be free of prunus necrotic ringspot virus, apple mosaic virus and hop mosiac virus (ELISA testing). Brewery evaluation of U.S.-grown Styrian has not yet been completed.

b. Hallertauer mittelfrüh (Acc. No. 21014): This cultivar reportedly produces acceptable yields in the Yakima Valley and in Northern Idaho (about 5-6 bales/acre) but the variety has been disappointing in Oregon. A 45-hill trial plot of heat-treated Hallertauer mittelfrüh (Acc. No. 21228), (free of prunus necrotic ringspot virus and of apple mosaic virus, obtained originally from Dr. Skotland, Prosser WA) was planted in 1981 at a commercial location in Oregon. Yield and quality data will be obtained in 1982.

In Germany, commercial acreage of Hallertauer mittelfrüh has dropped from 21,411 acres (46% of the total German hop acreage) in 1973 to 7,497 acres (16.9% of total acreage) in 1980. Continued strong demand for this hop in world hop markets, coupled with decreased supplies may force brewers to look for alternatives.

c. Hersbrucker (Acc. No. 21185): The acreage of this aroma hop in Germany has remained relatively stable during the past decade (10,311 acres or 8.8% in 1973, 9,948 acres or 22.4% in 1980). However, the importance of this hop has risen due to its increased acceptance as replacement for Hallertauer mittelfrüh. With the advent of Ridomil, Hersbrucker can probably be grown successfully in Oregon. Two commercial test plots in Oregon (about 2.5 acres and 0.25 acres, respectively) produced yields significantly above those of other European Noble aroma hops. In 1981 nursery plots Hersbrucker produced disappointing cone yields (less than 1200 lbs/acre) with about 5% alpha, 7% beta, and a cohumulone content of 26%. A virus-free strain originally obtained from Germany was found to be infected with hop mosaic virus. The hop is also being evaluated in the Yakima Valley. Brewery evaluation of U.S.-grown Hersbrucker has not yet been completed.

d. Tettnanger (Acc. No. 21015 and 21197, a prunus-free strain): This hop, similar to Hallertauer mittelfrüh, appears to be marginal in the United States. Two commercial locations in Oregon produced yields of about 1200 lbs/acre. At these locations Tettnanger was always harvested about 8-10 days too early since growers wanted to get this hop "out of the way" before they started picking their regular crop. Thus, yield and quality of Tettnanger undoubtedly have suffered.

A limited mass selection program from a commercial Oregon location indicated some differences in yield and quality potential of Tettnanger that may be large enough to warrant commercial exploitation.

2. Perle (Acc. No. 21227): This German higher alpha aroma hop was established on a two-acre plot in Oregon in 1981, and a one-acre plot in Washington. Commercial quantities of this hop will be available in 1982. Production from one-acre in Oregon has already been contracted by a cooperating brewer, but the second acre is still available. In a seedless nursery plot near Corvallis Perle showed good vigor and a good branching pattern in the baby year (the year it was planted). The cultivar was also free of prunus necrotic ringspot virus, apple mosaic virus, hop mosaic virus, and hop virus 24, but gave a positive reaction to hop latent virus, indicating that it is infected with this virus. No conclusions regarding the yield potential of Perle can be drawn from preliminary field observations obtained in 1981. The quality was 7.1% alpha, 2.9% beta, and the cohumulone content was 26%.

3. USDA 21245: This selection from a 1973 cross of Northern Brewer and a male containing Brewer's Gold, Early Green, and a German seedling, has shown remarkable vigor, good yield potential (1200-1900 lbs/acre over a three-year period), early maturity, good quality (alpha 10-11%, beta 4%, cohumulone content 28%, humulene/caryophyllene 2.58), and excellent storage stability. Hand samples from 1981 nursery plots near Corvallis were provided to a cooperating brewer for pilot brewing. At present there are no plans to move this hop into off-station trials.

4. Potential Aroma Selections USDA 21180 and 21181: A cooperating foreign brewer expressed interest in these selections which appear to combine high yield potential, good alpha acids content, a balanced alpha/beta ratio, and desirable aroma characteristics. The yield of the two has consistently averaged over 2,000 lbs/acre. The alpha acids content of 21180 during the past six years averaged from 8 to 9% with a cohumulone content of about 30, while 21181 had about 6-7% alpha with a cohumulone content of about 40. Both have moderate to good storage stability, with 21181 somewhat better than its sister selection 21180. The myrcene content of USDA 21180 during the past two years has averaged 49%, similar to that of U.S.-grown Tettnanger. USDA 21180 had a H/C ratio of 2.08 in 1980 and obtained favorable rating from hand evaluation by the interested brewer in the past.

5. USDA 21202: This selection from a 1969 cross between Yakima Cluster and a German midlew resistant male (64037M) has had excellent yield (over 2,000 lbs/acre), an alpha and beta acids content of about 6%, respectively, and exceptionally high humulene content coupled with low caryophyllene, and above average storage characteristics. The variety matures late in Oregon (mid-September) but shows excellent spring regrowth and heavy cone set. Thus far, this selection seems to fit many chemical characteristics indicative of an aroma hop. Hand samples for brewer evaluation and pilot plant brewing will be available from the 1982 crop.

HOP GENETICS

1. New Seedling Nursery: A new nursery of about 3,000 seedlings from crosses of three females and nine males selected for high yield potential and early maturity was planted in the spring of 1981. The pedigree and quality data of the parents are listed in Table 5. Several male parents, such as 7303-105M, 7306-13M, 7308-09M, and 7314-19M, had excellent storage stability of their soft resins as indicated by the six-month storage index (percent alpha remaining after six months of storage at room temperature). Selections will be evaluated for early maturity, high yield potential and quality characteristics beginning in 1982.

2. Hop Pollen Storage in Liquid Nitrogen: Pollen from four male genotypes (19036M, 19039M, 19172M, and 64103M) stored for two years in liquid nitrogen (-196°C) was used to pollinate a late flowering female cultivar (Acc. No. 21083) in late July 1981. Seed set from liquid nitrogen stored pollen was about half that of the fresh pollen control while pollen stored at -18°C (freezer) produced practically no seeds. The results from the two-year liquid nitrogen study will be summarized for publication in the near future.

3. Germplasm Development: One of the major goals of the USDA Hop Breeding and Genetics Program is to select lines of potential value for future breeding and variety development. We have identified a number of valuable high alpha male and female lines, varying in cohumulone content and storage stability.

A cross between two selected low alpha lines led to zero alpha hops in 1977 where the total soft resin fraction apparently consist of only beta acids.

Table 5. Quality Data of Parents used for 1980 Crosses (New Seedling Nursery Planted 1981)
(CoH = cohumulone; H/C = humulene/caryophyllene ratio)

Accession [1] or Sel. No.	1979					1980				
	% Alpha	% Beta	CoH	H/C	6 month storage % α remaining	% Alpha	% Beta	CoH	H/C	6 month storage % α remaining
Females:										
19185	4.7	2.5	37	-	78	5.1	2.5	36	2.70	-
65013	6.3	6.0	35	2.69	34	6.9	5.7	35	2.55	34
64003	1.5	4.6	32	-	39	-	-	-	-	-
Males:										
7303-105M	47.9	19.7	21	0.75	99	50.4	21.4	20	0.68	82
-135M	62.9	15.1	26	-	41	60.0	20.8	25	0.78	73
-138M	56.7	19.0	29	2.56	49	54.9	19.9	28	2.64	76
7306-13M	55.1	18.8	20	2.34	99	43.8	18.4	21	2.66	69
7308-09M	54.8	19.8	22	3.18	89	50.1	16.3	19	3.13	99
-37M	52.0	22.0	22	2.42	75	41.6	24.7	22	2.55	48
7311-141M	48.6	22.7	28	1.25	75	42.9	18.6	29	1.35	47
-142M	47.6	23.6	25	-	-	49.8	22.0	26	0.10	75
7314-19M	53.3	6.8	26	1.35	-	44.4	17.9	25	1.50	89

[1] Pedigree: 19185 = Late Grape Seedling x Fuggle - Red Vine Seedling
56013 = Cascade
64003 = (Late Grape Seedlg x Fuggle - Fuggle Seedlg) x (Strisselsp - L. Cluster Seedlg)

7303-105M = Comet x Bullion-German Seedling
-135M = "
-138M = "

7306-13M = N.Brew x [(B.Gold x EaGreen-unkn) x Germ.Seedlg]

7308-09M = No.Brew x Bullion - Germ. Seedling
-37M = "

7311-141M= (Comet x (BGxFu-Colo2-1)x(BGxEG-XS)xGermS)
-142M= "

7314-19M = (Comet x (BGxFu-Colo2-1)xBullion-GermS

The opposite, namely 100% alpha acid hops with no beta acids, has not yet been obtained. Recombination of high alpha acid genes from several sources has led to some genotypes with an alpha/beta ratio in excess of 4 (alpha ratio above 80), indicating that selection for minor modifying genes in addition to high alpha genes may be successful in shifting the alpha/beta ratio to the extreme. Table 6 gives an example of this work.

Table 6. Example of Genetic Modification of Alpha/Beta Ratio in Hops

Genotype	Yield [1/]	% Alpha	% Beta	Ratio	Cohumulone
21290 (Sel. 7312-57)	1600	9.2	1.2	88	31
21298 (Sel. 7315-35)	1400	15.2	2.8	84	25
21055 (Mother of above)	590	14.9	4.6	76	47
62013 (Mother of above)	1600	10.2	5.8	63	40

[1/] lbs/acre calculated from 5-hill nursery plots, 1981 data.

Similar progress has been made with male hops that could be used for another cycle of alpha acid recombination. A hop with minimal amounts of beta acids could be of potential value to hop extractors who consider beta acids as an undesirable diluent of the soft resin fraction.

CHEMICAL EVALUATION OF HOP QUALITY

Gail B. Nickerson, OSU
Sam T. Likens, USDA-ARS
February 8, 1982

During the past year we received more samples for analysis than in any other year. We have not completed all of the analyses at this time. By the end of February all of the Oregon and Washington samples will be analyzed for alpha and beta acids and cohumulone ratio. Most of the oil content determinations have been completed. The oil composition is being determined on selected genotypes from Oregon and Washington.

Potential Aroma Types

These three chemical characteristics were the initial considerations in selecting potential "aroma" types: Alpha acids 4.5 to 7.0%; alpha ratio 45-60, and cohumulone ratio less than 30. Twenty-five nursery selections from the first 25 1977 crosses analyzed in 1980 had all of these characteristics. After storage tests, 11 of these had better storage than Cascade. Cascade was the female parent of these selections.

The same criteria were used to identify aroma types from the 1981 crop. Table 1 gives a list of these genotypes, an asterisk indicates that the genotype was in this group two consecutive years. The oil composition will be determined on the bale samples.

Another characteristic which may be indicative of "aroma" type hops is low myrcene content in the oil. Prior to 1979 we did not have access to a gas chromatograph equipped with a capillary column. With a capillary column about 200 peaks are resolved versus 40-50 with a packed column. Through Val Peacock's work most of the peaks have been identified. With improved separation and detection we have much greater confidence in the results. The 1979 Annual Report (pp. 251-255) gives the results of oil composition analyses on the 1979 crop. When the data are arranged according to percent myrcene in the oil, the varieties with low myrcene are mostly aroma types as shown in Table 2. There is a high correlation between percent myrcene in the oil and percent humulene. Table 3 shows the correlation coefficients for the 1979 and 1980 analyses. Statistically all of the relations are significant where large numbers of samples were analyzed,

although the correlation between humulene/caryophyllene ratio and percent myrcene is less than for the other factors. A histogram of the myrcene contents is given in Figure 1. There doesn't seem to be a relationship between cohumulone ratio and percent myrcene.

All of these results seem to indicate that we have several factors to consider when we attempt to imitate aroma types: The composition of the resin and the composition of the oil. When time permits, the percent myrcene, humulene and caryophyllene will be incorporated into our summary files.

Potential Extract Types

Among the factors important in the selection of extract type hops are high alpha acid content, high yield and good storage. Another item which we have not considered in the past is the actual proportion of alpha to beta acids. Two genotypes with the same alpha acid content but differing amounts of beta acids do not furnish the same percent alpha acid in the extract. In other words, the one with less beta acids will have a higher concentration of alpha acids in the extract. From our experience about 75% of an extract is alpha + beta, therefore, a 12% alpha hop with an alpha ratio of 80 will have about 60% alpha in the extract, while one with 12% alpha and alpha ratio of 63 will have 50% alpha in the extract. Table 4 shows the 1980 samples with high alpha and storage results. Table 5 gives the 1981 samples with high alpha, high alpha ratio and good yield. Lower than expected storage values (% α + β remaining) were characteristic of the 1980 crop.

Evaluation of Potential Male Breeding Material

We are continuing our search for superior male germplasm for future breeding. Lupulin was separated from 207 samples of male flowers and analyzed for alpha, beta and cohumulone ratio (CoH). Sixty-four of these had a cohumulone ratio less than 20 and were analyzed for their humulene/caryophyllene ratio (H/C). Of these, 29 had H/C ratios greater than 2.5 and were analyzed for storage stability by determination of safe period and permeability. The complete analyses of these are given in Table 6.

Three of these (21271M, 7312-017M and 7610-024M) are "high alpha" with alpha ratios greater than 67 (i.e., twice as much alpha as beta) combined

with good storage (70% or more alpha + beta remaining after six months at room temperature), low cohumulone and high H/C. These should provide superior males for future high alpha breeding. The other selections show a wide range in both alpha ratio and storageability. Accession number 64033M and others show potential for aroma breeding.

Storageability of Progenies of 1977 Crosses on Cascade

In 1981 we completed the six month storage tests on 656 cone samples and 253 bales from the 1980 crop. The cone samples were from 1977 crosses of different males with Cascade as the female parent. More than 50% of the random selections had better storage than Cascade, indicating that storageability can be incorporated.

Analytical Developments

This year we obtained a variable wavelength detector for HPLC. The new detector enables us to measure alpha and beta acids with greater sensitivity. Measuring at absorbance of 326 nm with this detector gives a ten-times increase in integrator counts than at 340 nm. A different compound, 2,5-Dihydroxybenzoic acid, was used to determine the relationship between absorbance and integrator counts. The 2,5-Dihydroxybenzoic acid has several advantages over Chalcone as a reference compound, it is not light sensitive and it is also readily obtainable.

EXPLANATION OF COLUMN HEADINGS ON COMPUTER PRINTOUT

ACCESSION OR NURSERY NUMBER: The accession no. is a 5-digit number assigned to commercial varieties or advanced material from the breeding program. The nursery number consists of 4-digits (year of cross & cross number), dash, and then plant number in a cross. Selections made in Washington are preceded by a W.

IDENTIFICATION: Name of commercial variety or nursery number.

TYPE: Samples are miniature BALE, loose CONE or LUPulin samples from males.

LOCATION: OSU samples are identified as yard row number: hill numbers, Rows 001-199, seeded main yard; 201-299, seedless Smith yard; 301-399, seedless Willamette yard. Off station Oregon samples have OR-grower abbreviation. In the future, Washington samples from IAREC will be identified with yard numbers and abbreviations for grower yards; B, Brulotte; C, Carpenter, etc.

HARVEST DATE: The picking date as month/day/year.

YIELD LB/AC: Yield data in lbs dry hops/acre.

ALPHA LB/AC: Yield of α-acid (lbs)/acre.

ALPHA (%), BETA (%): Bale samples are analyzed by the spectrophotometric method. Cone and lupulin samples are analyzed by high pressure liquid chromatography (HPLC).

ALPHA RATIO: The ratio of α-acids/(α + β-acids) is linear from 0 to 100 and represents the portion of the total (α + β) that is α-acid. Other laboratories report α/β-ratio or α/β-fraction (β-acids + uncharacterized soft resins) found in German publications.

α	10	20	30	40	50	60	70	80
α/β-Ratio	0.13	0.25	0.43	0.67	1.0	1.50	2.33	4.0

ALPHA + BETA (%): Sum of α- + β-acids.

HOP STORAGE INDEX: The ratio of A_{275}/A_{325} (HSI) from spectrophotometirc analysis of bale samples. Numbers higher than 0.30 indicate some deterioriation has occurred before analysis. Cones and lupulin samples by HPLC are arbitrarily assigned an HSI value of 0.25.

SIX MONTH HSI: The ratio A_{275}/A_{325} after 6 months storage at room temperature.

% A + B REMAIN: The amount of α- + β-acids remaining after 6 months storage at room temperature for bale samples. For cone samples the % remaining is calculated from the HSI (% remain = 100 - 110 log (HSI/0.25)). The storage stability of a genotype is characterized by:

% Remaining	90-100%	80-90%	60-80%	40-60%	Less than 40%
HSI (6 mo.)	0.25-0.31	0.32-0.38	0.39-0.58	0.59-0.88	> 0.89
Rating	Very good	Good	Fair	Poor	Very poor

OIL MLS/100G: Oil content as mls oil/100 g hops.

OIL HUM/CARY: Humulene/caryophyllene ratio from gas chromatographic analysis of hop oil.

COH: Cohumulone ratio from HPLC analysis. Ratio of cohumulone to sum of cohumulone.

SERIAL NUMBER: Laboratory number assigned to each separate sample.

TABLE 1. PØTENTIAL ARØMA TYPE HØPS FRØM 1981 ANALYSES. ALPHA 4.5-7.0%, ALPHA RATIØ 45-60, CØH <30.

SELECTED GENØTYPES AT 8% MØISTURE CØNTENT (BALE) ØR AS IS BASIS (CØNE) SØRTED BY IDENTITY AS ØF 82/01/28.(N= 22)

ACCESSIØN ØR NURSERY NUMBER	IDENTIFICATIØN	TYPE	LØCATIØN	HARVEST DATE	YIELD LB/AC	ALPHA LB/AC	ALPHA (%)	BETA (%)	ALPHA RATIØ	ALPHA +BETA (%)	HØP STØRAGE INDEX	SIX MØNTH HSI	% A+B REMAIN (6 MØ)	ØIL MLS/ 100G	ØIL HUM/ CARY	CØH	SERIAL NUMBER
21014	HALLERTAU MF	BALE	007:01-04	8/19/81	0	0	4.9	4.3	53	9.1	.16	0.00	0	.73	0.00	16	43
21016 *	FUGGLE N VF	BALE	304:01-05	8/20/81	896	45	5.1	3.5	59	8.6	.26	0.00	0	.92	0.00	25	34
21078	RECØRD	BALE	317:01-05	8/28/81	640	41	6.5	4.4	59	10.9	.27	0.00	0	0.00	0.00	30	684
21085	YUGØ VII/23	CØNE	139:01-51	9/16/81	0	0	6.0	4.5	56	10.5	.25	0.00	0	0.00	0.00	22	539
21145	6305-004	CØNE	052:51-52	8/31/81	0	0	6.0	6.8	46	12.8	.25	0.00	0	0.00	0.00	25	189
21179 *	HERSBRUCKER-E	BALE	230:01-10	9/18/81	1143	70	6.1	6.6	48	12.7	.22	0.00	0	.76	3.21	26	713
21180	7003-143	CØNE	034:51-52	8/31/81	0	0	4.6	3.0	60	7.7	.25	0.00	0	0.00	0.00	25	184
21186	SPALTER	BALE	241:01-10	8/26/81	507	32	6.5	5.2	55	11.7	.29	0.00	0	.64	0.00	25	389
21188 *	NP2/55 (S. AFR)	BALE	243:01-10	9/18/81	1109	63	5.7	4.3	56	10.0	.22	0.00	0	1.14	2.03	29	729
21202 *	6903-107	BALE	314:11-15	9/15/81	3114	217	7.0	6.1	53	13.1	.22	0.00	0	.67	0.00	29	670
21239	BØBEK	BALE	323:01-05	8/28/81	114	6	6.0	4.0	60	9.9	.25	0.00	0	0.00	0.00	27	305
61021		BALE	019:01-04	8/19/81	0	0	4.6	4.7	49	9.3	.24	0.00	0	.73	0.00	23	46
64008		CØNE	019:51-52	8/31/81	0	0	4.5	3.5	56	8.0	.25	0.00	0	0.00	0.00	23	172
7007-324		BALE	332:26-30	9/15/81	1954	102	5.3	5.3	50	10.5	.29	0.00	0	1.59	0.00	28	653
7713-030		CØNE	017:46	8/31/81	0	0	6.9	5.2	57	12.2	.25	0.00	0	0.00	0.00	28	275
7719-018		CØNE	025:14	9/01/81	0	0	6.5	7.0	48	13.4	.25	0.00	0	0.00	0.00	24	240
7801-043		BALE	174:45	8/21/81	0	0	4.5	5.1	46	9.7	.26	0.00	0	.48	0.00	26	70
7801-084		BALE	175:33	8/21/81	0	0	5.6	4.7	54	10.3	.28	0.00	0	.49	0.00	30	81
7801-094		BALE	175:43	8/21/81	0	0	5.2	4.3	54	9.6	.27	0.00	0	.40	0.00	29	80
7803-034		BALE	178:34	8/22/81	0	0	5.1	3.4	59	8.5	.29	0.00	0	.62	0.00	23	58
7803-125		BALE	176:21	8/21/81	0	0	5.8	4.8	54	10.6	.25	0.00	0	.75	0.00	26	56

Table 2. Selected Varieties Ranked by Percent Myrcene in the Oil (1979 Analyses)

Variety	% Myrcene	Variety	% Myrcene
Hallertau MF	33.5, 49.0	Shinshuwase	54.5
Hallertau	42.4	Galena	55.1
Tettnang	43.8, 51.7	N. Brewer	55.4
Backa	44.1, 58.8	Brewers Gold	66.4, 68.9
Yugo Golding	47.7	Ahil	67.3
Sav Golding	48.1	Comet	67.5
Wye Challenger	48.6	Aurora	68.1
Stryian	49.4, 57.9	Eroica	68.7
Fuggle	49.6	Wye Target	69.2
S. Brewer	50.2	Cascade	69.2, 73.7
Apolon	50.8	Vojvodina	70.6
Record	51.8	Bullion	71.3
Wye Northdown	52.2	Cluster	73.3
Neoplanta	52.4	Shinshuwase	74.5
Yugo IV/2	54.3	W. American	82.1
Golden Star	54.5		

Table 3. Relations between Oil Constituents and Cohumulone Ratio

	Correlation Coefficient (Number of Samples)	
	1979	1980
% myrcene versus % humulene	-.6875 (183)**	-.7830 (115)**
% myrcene versus % humulene/caryophyllene	-.2509 (183)**	-.3297 (115)**
% myrcene versus oil content	0.4443 (183)**	-
% myrcene versus CoH	0.3040 (19)	0.5762 (19)*
H/C ratio versus CoH	-	-.3424 (131)**

*Significant at the 95% confidence level.

**Significant at the 99% confidence level.

TABLE 4. STØRAGE RESULTS FØR HIGH ALPHA SELECTIØNS ØF 1980.

SELECTED GENØTYPES AT 8% MØISTURE CØNTENT (BALE) ØR AS IS BASIS (CØNE) SØRTED BY IDENTITY AS ØF 82/01/28.(N= 18) PAGE 1

ACCESSIØN ØR NURSERY NUMBER	IDENTIFICATIØN	TYPE	LØCATIØN	HARVEST DATE	YIELD LB/AC	ALPHA LB/AC	ALPHA (%)	BETA (%)	ALPHA RATIØ	ALPHA +BETA (%)	HØP STØRAGE INDEX	SIX MØNTH HSI	% A+B REMAIN (6 MØ)	ØIL MLS/ 100G	ØIL HUM/ CARY	CØH	SERIAL NUMBER
I31-11A		BALE	323:21-25	9/18/80	2414	335	13.9	6.7	67	20.5	.24	.74	45	1.63	.18	37	1205
21050	AHIL	BALE	218:01-10	9/10/80	1783	223	12.6	4.8	72	17.4	.24	.83	38	2.25	0.00	22	984
21056	BULLIØN 10A VF	BALE	308:01-05	9/05/80	2013	254	12.6	5.7	68	18.4	.23	.80	43	1.68	1.98	35	997
21112	WYE TARGET VF	BALE	217:01-10	9/10/80	2016	268	13.3	5.3	71	18.7	.25	.72	49	1.71	1.88	34	823
21112	WYE TARGET VF	BALE	303:06-10	9/17/80	1800	255	14.2	4.9	74	19.1	.23	.76	41	2.32	0.00	37	1068
21182	GALENA, I43-16	BALE	239:01-10	9/10/80	1894	241	12.7	7.6	62	20.3	.23	.47	64	1.17	2.49	29	983
21183	ERØICA, I34-5	BALE	325:21-25	9/18/80	2161	269	12.5	5.4	69	17.9	.26	.79	38	1.25	.05	38	857
21193	7005-194	BALE	315:16-20	9/17/80	2218	328	14.8	5.0	74	19.8	.22	.66	49	2.57	2.25	28	1138
21193	7005-194	BALE	315:16-20	9/17/80	2218	331	15.0	5.0	74	20.0	.24	.62	56	2.54	0.00	28	1090
21195	7006-408	BALE	210:28-32	9/10/80	1655	231	14.0	5.5	71	19.5	.26	.50	66	1.74	0.00	29	1103
21200	7004-075	BALE	221:17-21	9/04/80	2577	321	12.5	4.5	73	17.0	.21	.61	53	2.04	0.00	42	1166
21201	7005-070	BALE	238:17-21	9/12/80	1766	225	12.8	8.5	60	21.3	.23	.65	56	2.73	2.08	35	1072
7005-201		BALE	319:16-20	9/08/80	2048	248	12.1	7.2	62	19.3	.23	.86	38	1.21	2.75	35	996
7301-003		BALE	323:26-30	9/09/80	1888	229	12.1	5.7	68	17.8	.30	1.07	25	2.26	0.00	44	1114
7311-032		BALE	315:31-35	9/18/80	1971	277	14.1	4.6	75	18.6	.27	.56	61	1.75	1.45	35	879
7311-152		BALE	321:31-35	9/08/80	1851	270	14.6	4.4	76	19.0	.27	.54	65	2.23	1.83	29	1012
7313-032		BALE	333:01-05	9/17/80	2670	377	14.1	5.1	73	19.2	.26	.65	51	2.50	0.00	44	1116
7506-253		BALE	221:23-27	9/16/80	1723	248	14.4	7.8	64	22.2	.25	.76	30	2.34	3.74	24	1169

TABLE 5. HIGH ALPHA WITH GØØD YIELD FØR 1981 CRØP.

SELECTED GENØTYPES AT 8% MØISTURE CØNTENT (BALE) ØR AS IS BASIS (CØNE) SØRTED BY IDENTITY AS ØF 82/01/28.(N= 12)

ACCESSIØN ØR NURSERY NUMBER	IDENTIFICATIØN	TYPE	LØCATIØN	HARVEST DATE	YIELD LB/AC	ALPHA LB/AC	ALPHA (%)	BETA (%)	ALPHA RATIØ	ALPHA +BETA (%)	HØP STØRAGE INDEX	SIX MØNTH HSI	% A+B REMAIN (6 MØ)	ØIL MLS/ 100G	ØIL HUM/ CARY	CØH	SERIAL NUMBER
W401-026		CØNE	303:21-25	9/16/81	2000	243	12.2	9.6	55	21.7	.25	0.00	0	0.00	0.00	47	522
W402-030		BALE	211:28-32	9/19/81	2287	315	13.8	8.6	61	22.4	.27	0.00	0	.92	0.00	40	714
W408-010		BALE	330:21-25	9/08/81	2112	278	13.2	6.8	66	20.0	.30	0.00	0	0.00	0.00	33	822
21182	GALENA, I43-16	BALE	239:01-10	9/10/81	2790	346	12.4	8.1	60	20.5	.24	0.00	0	.87	2.00	36	492
21193	7005-194	BALE	315:16-20	9/15/81	2670	378	14.2	4.2	77	18.4	.26	0.00	0	2.18	0.00	30	656
21193	7005-194	BALE	350:26-30	9/14/81	2338	375	16.1	4.4	78	20.5	.24	0.00	0	0.00	0.00	28	616
21193	7005-194	BALE	237:01-10	9/12/81	3396	485	14.3	4.2	77	18.5	.25	0.00	0	1.60	2.18	28	632
21198	7003-038	CØNE	227:12-16	9/16/81	2200	298	13.6	7.7	63	21.3	.25	0.00	0	0.00	0.00	32	507
21221	I31-11A, BGXØP	BALE	323:21-25	9/08/81	2278	305	13.4	5.9	69	19.3	.29	0.00	0	0.00	0.00	43	789
7003-154		BALE	340:21-25	9/17/81	2165	266	12.3	7.8	61	20.1	.25	0.00	0	0.00	0.00	43	608
7301-009		BALE	336:26-30	9/15/81	2278	324	14.3	3.9	78	18.2	.17	0.00	0	2.09	0.00	46	645
7504-073		BALE	215:12-16	9/18/81	2016	254	12.6	7.1	64	19.7	.27	0.00	0	.73	0.00	38	711

TABLE 6.

1981 LUPULIN SAMPLES WITH CØH <= 20, H/C RATIØ >= 2.5 WITH STØRAGE DATA .

SELECTED GENØTYPES SØRTED BY PERM AS ØF 82/01/20. (N= 27)

ACCESSIØN ØR NURSERY NUMBER	IDENTIFICATIØN	LØCATIØN	HARVEST DATE	ALPHA (%)	BETA (%)	ALPHA RATIØ	ALPHA +BETA (%)	HØP STØRAGE INDEX	CRUSH 3 HR HSI	SAFE PERIØD	PERMEA-BILITY	CALC 6 MØNTH HSI	CALC % A+B REMAIN	ØIL: HUM/ CARY	CØH	SERIAL NUMBER
7506-207M		050:59-60	7/08/81	32.1	25.4	55	57.5	.25	1.06	2.30	.99	1.01	33	3.37	1[illegible]	9
7506-235M		051:59-60	7/14/81	33.3	33.6	49	66.8	.25	.45	3.30	.99	.95	36	3.31	18	18
7705-009M		007:43	7/15/81	14.0	25.0	35	38.9	.25	.50	4.00	.99	.91	38	3.01	19	43
7711-010M		015:26	7/09/81	27.8	45.1	38	72.9	.25	1.17	2.40	.99	1.00	33	2.88	18	11
7309-034M		004:59-60	7/08/81	34.3	21.8	61	56.1	.25	.44	3.70	.99	.93	37	2.82	14	3
19172M	CATS TAILX19009	024:53-54	7/24/81	23.7	26.6	47	50.3	.25	.63	2.90	.99	.97	35	2.82	18	149
7506-182M		049:59-60	7/14/81	25.5	46.8	35	72.3	.25	1.84	1.50	.99	1.05	31	3.40	13	17
64033M		030:55-56	7/24/81	17.4	44.6	28	62.0	.25	.85	2.10	.90	.94	36	4.11	16	151
7717-022M		022:31	7/09/81	31.4	36.1	46	67.5	.25	.28	5.30	.83	.70	50	2.73	14	12
19172M	CATS TAILX19009	001:26	7/21/81	24.7	28.8	46	53.5	.25	.48	4.40	.83	.76	47	2.91	18	114
64037M		004:57-58	7/16/81	15.9	43.4	26	59.2	.25	1.14	1.80	.80	.88	39	3.35	10	56
7506-100M		046:59-60	7/20/81	36.4	27.4	57	63.8	.25	.32	4.00	.77	.73	48	3.27	16	84
51114M		005:55-56	7/24/81	12.8	42.1	23	54.9	.25	.39	3.60	.73	.72	49	3.98	,19	173
7507-117M		053:59-60	7/17/81	28.3	49.4	36	77.7	.25	.28	3.70	.70	.69	51	3.54	20	64
7303-159M		036:55-56	7/14/81	33.5	19.2	63	52.7	.25	.33	5.30	.68	.58	59	2.61	12	16
7308-023M		055:55-56	7/17/81	37.3	18.0	67	55.2	.25	.36	5.60	.58	.48	68	2.62	20	79
21271M		053:55-56	7/24/81	43.3	19.1	69	62.4	.25	.37	7.80	.58	.35	83	3.25	20	139
64035M		002:57-58	7/24/81	30.6	28.4	51	59.0	.25	.43	3.10	.50	.56	61	3.85	16	169
7309-004M		003:59-60	7/08/81	42.2	16.7	71	58.8	.25	.41	3.90	.47	.49	68	2.83	17	2
7504-040M		050:57-58	7/24/81	31.0	35.7	46	66.7	.25	1.08	1.80	.40	.55	62	2.70	18	128
21090M	YUGØ 12/17	018:57-58	8/07/81	30.6	28.8	51	59.4	.25	.79	2.00	.40	.54	63	2.92	11	204
7719-002M		024:32	7/10/81	35.9	34.0	51	69.9	.25	.29	4.00	.40	.42	75	3.10	20	14
7312-017M		017:59-60	7/17/81	41.8	18.4	69	60.2	.25	.48	5.30	.38	.33	86	2.72	18	63
7718-025M		023:39	7/15/81	17.1	40.5	29	57.6	.25	.93	1.90	.30	.46	71	3.41	16	20
7613-105M		124:15-16	7/24/81	38.6	21.8	63	60.3	.25	.34	8.00	.28	.09	99	3.46	18	135
7610-024M		124:13-14	7/20/81	32.1	11.7	73	43.9	.25	.62	4.20	.10	.16	99	3.44	19	106
7702-014M		003:34	7/21/81	21.7	48.1	31	69.8	.25	.40	2.10	.01	.21	99	3.14	19	121

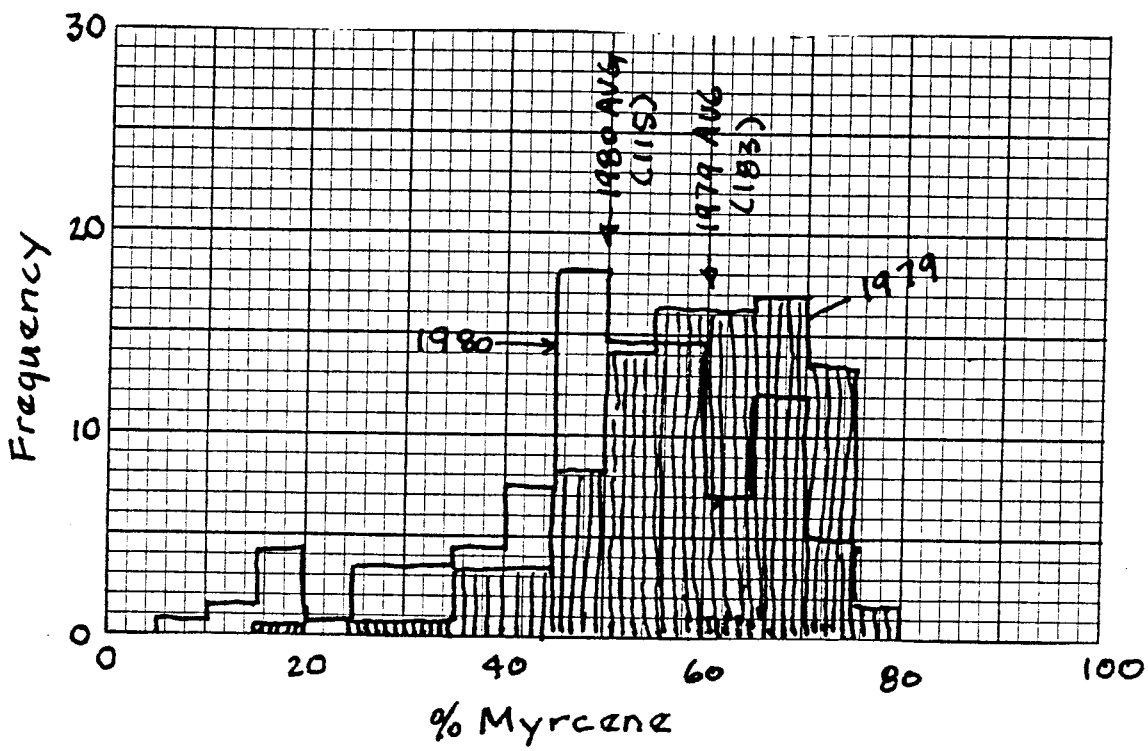

FIGURE I. HISTOGRAM OF % MYRCENE IN OIL

Annual Progress Report to the Hop Research Council
Project Number 036, Oregon State University

"Identification, Characterization, and Control of Phytopathogens Limiting Production of Hops"

Richard O. Hampton

ARS research on hop diseases, comprising effort by 0.4 scientist/year and 1.4 Research-Assistant/years, is dedicated to effectual solutions to prioritized disease problems in the Pacific Northwest Area hop industry. Our goal is to assure success for U.S. growers and industry by facilitating economical production of superior hops of diverse types. During 1981, we have emphasized disease research that directly supports development of high-yielding high-alpha-acid and European-type aroma hops. In this context, we have investigated Humulus germplasm health, disease resistance among germplasm collections, control of pathogens in nuclear sources of cultivars and in germplasm accessions, and monitored diverse hop materials for the presence of hop pathogens common to European hops but not reported in the U.S.A.

1. Humulus germplasm health

Among 116 Humulus germplasm accessions tested for the presence of five viruses, some 60% (70/116) were found to be infected with hop latent virus. These same tests indicated that 23/116 accessions were infected with prunus necrotic ringspot virus, 32/116 were infected with apple mosaic virus, 32/116 with hop mosaic virus, and 35/116 with hop virus 24. From these tests, elite sources of 25 cultivars and three special selections were identified, i.e., individual plants for each accession that contained the fewest viruses were designated elite sources (Table 1). The low incidence of prunus necrotic ringspot virus and apple mosaic virus among elite sources was due either to heat-treating/meristeming at Prosser and Braunschweig, West Germany, or to discovery of plants that were naturally free of these viruses. Again, hop latent virus was the predominant viral pathogen in these elite sources. The Record cultivar, in which interest was expressed at the 1981 HRC meeting, was found to contain all viruses for which we could test. This cultivar has been subjected to thermotherapy and has been meristemmed. Accession 21085 (Table 1), characterized by very low cohumulone content, will also be subjected to thermotherapy/meristeming, as will other virus-infected materials considered strategic to breeding or information development.

A preliminary experiment suggests that prunus necrotic ringspot is transmissible through hop seeds when crosses are made between infected parents, particularly infected female parents. This and other points will be re-tested in follow-up experiments. Such seed transmission would predicate breeding of Humulus parents established to be free of all ilarviruses (PNRSV, ApMV, and other new viruses of this group), known to be seed-transmitted in other plant species, to preclude infected breeding progenies. In extensive studies at East Malling, England, large plantings of PNRSV-free hop cultivars have tended to remain free of this virus for long periods of time. The means of natural spread has never been determined. These results have encouraged the Ministry of Agriculture in England to provide PNRSV control exclusively by controlled propagation from PNRSV-free nuclear sources of each hop cultivar. Thus, eventual dilution of infected plantings with virus-free stocks is the strategy for controlling this important pathogen. This strategy, until developing information suggests otherwise, is being adopted by us for PNRSV control in breeding nurseries and experimental plantings.

The health of male germplasm (male hop plants) differed uniquely from that of female germplasm. At least one male plant of each male germplasm accession was free

of PNRSV, except Accession No. 63016M which contained all five viruses (Table 2). Thus, by simple virus testing (ELISA serology) and plant selection, we were able to derive male germplasm virtually free of this virus. Apple mosaic and hop latent viruses predominated in male germplasm, with 11/24 and 9/24 accessions, respectively, infected with these viruses. Only 3/24 male accessions contained hop mosaic virus and 4/24 contained hop virus 24. Eight accessions, as they were found in the field, were free of all viruses for which we could test.

2. Disease Resistant Germplasm

The cultivar Comet has been considered possibly resistant to PNRSV for several years. Limited attempts to inoculate Comet plants with PNRSV were unsuccessful. Further, no field-grown Comet plant has been found to contain this virus. Such evidence at least suggests the existence of virus-resistant genes in Humulus.

To follow-up this evidence, we have begun evaluations of PNRSV isolates, mechanical inocualtion procedures, and germplasm screening methods. At the same time, we are attempting to determine the incubation period for PNRSV in susceptible hops, with the intention of expanding the study to other virus-Humulus interactions.

Pending development of this information, we have considered the natural absence of viruses in Humulus germplasm as a possible indication of resistance. Certainly, the occurrence of a particular virus in germplasm accession is a reasonable indication of susceptibility to that virus. Thus, candidate accessions for tests of specific virus resistance are being selected by virtue of absence of specific viruses after long periods of exposure to infection. Our initial emphasis on PNRSV-resistance is based on the known deleterious effect of PNRSV infection on both yield and alpha acid, from Dr. Haunold's experiments underway since 1974.

Numerous prior tests indicate that some hop cultivars are quite resistant to infection by the downy mildew fungus, Pseudoperonospora humuli. Our search for downy mildew resistance among Humulus germplasm accessions will now be facilitated by adaptation of methods developed at Wye College, England, by Dr. D. J. Royle. These methods provide for precise, effective, rapid screening of materials for resistance. In the midst of spectacular mildew control with Ridomil, we are enhancing our program of disease resistance development on the assumption that future control measures shoul be based on multiple approaches: a combination of Humulus resistance, cultural-management practices, and available agricultural chemicals.

3. Pathogen control in nuclear sources of cultivars and germplasm

Following the methods of Dr. H. E. Schmidt, Aschersleben, DDR, we are standardizing thermotherapy/meristemming procedures for eliminating viruses from Humulus germplasm accessions and strategic cultivars. This work is complementary to efforts of Dr. Skotland at Prosser, as are other aspects of our research. We will attempt to apply chemotherapy measures developed by Dr. H. Rohloff, Braunschweig, West Germany, to supplement thermotherapy technology for elimination of such viruses as hop latent virus. Our disease control research is based on the premise that maximal effort to produce disease-free germplasm sources and nuclear stocks of cultivars is more economical than attempts to remedy diseases in large plant populations.

Humulus germplasm that may be extremely valuable to long-range breeding objectives but very susceptible to downy mildew or other fungal pathogens will be protected by cultural and chemical means as necessary. Protection of such materials in meristem cultures or containerized plants is also feasible.

In the context of disease-free nuclear stocks, I would like to stimulate the Council's consideration of implementing development of an area-wide code of standards for hop plant certification. Such standards have been developed by Dr. Skotland and others for the state of Washington. A good start has thus been made, and benefits from the Washington program have already been realized. It would now seem timely and appropriate that these efforts be evaluated and expanded to uniformly apply to Idaho, Washington, and Oregon, pooling the efforts of ARS and state scientists and state Departments of Agriculture. Likewise, pathogen-free nuclear stocks from current research efforts would be cataloged and made available to qualified propagators under the control of each state Hop Commission. Certified stocks, in this framework, would have qualified by standards of excellence adopted by the three-state area. Certification standards could be gradually upgraded as it becomes increasingly possible to assure freedom of stocks from all known hop pathogens.

A statement from the Council, as to whether or not this objective should be pursued, would be helpful to future planning on hop improvement for the area.

4. Search for New Pathogens

All the viruses known to occur in hops in the U.S.A. fit neatly into two virus groups: ilarviruses (PNRSV and ApMV) and carlaviruses (HMV, HLV, and HV-24). Viruses within groups share many common characteristics, which enables us to predict with fair accuracy their behavior in nature, even in different plant species. Our knowledge of behavior, especially methods of dissemination, provides a basis ultimately for control. The appearance of any new virus would give reason for concern until its behavior in nature could be understood and a control strategy developed. The same would be true, certainly, for fungal, bacterial or other pathogens.

At least three viruses not known to occur in the U.S.A. have been reported in hops in Europe: arabis mosaic virus, tobacco necrosis virus, and alfalfa mosaic virus. Arabis mosaic virus in particular has been widespread among European hop plantings for many decades. This virus, in Europe, is nematode transmissible, unlike any of the U.S. hop viruses. Because hop propagative materials have been freely exchanged between Europe and America, it is somewhat surprising that arabis mosaic virus has never been detected in hops of this country. We and Dr. Skotland plan to continue surveillance for arabis mosaic and other viruses, particularly in recently introduced materials.

ELISA serological results obtained during 1981 suggest that ilarviruses other than PNRSV and ApMV may occur in Humulus germplasm accessions. Likewise, it appears probable that carlaviruses besides HMV, HLV, and HV-24 have been encountered during ELISA tests. These will be further investigated and, where possible, isolated and characterized.

We are attempting to develop effective diagnostic methods for detection of new, serious strains of Verticillium, Phytophthora, Pythium, Sclerotinia, Phoma, and other reported fungal pathogens of hops.

5. Anticipated projects

In addition to continuation of the above lines of research, we anticipate research defining mechanisms of field spread of carlaviruses particularly, elucidating the effects of specific viruses on yields and hop qualities of newer cultivars, and clarifying the natural ecology of hop virus 24. Attempts will be made to understand the relative freedom of male germplasm from hop viruses.

TABLE 1

HEALTH STATUS OF CULTIVARS IN THE U.S. HOP GERMPLASM COLLECTION

	Cultivars (Elite Sources)	Virus				
		PNRSV	ApMV	HMV	HLV	HV-24
p	Bullion 10A	−	−	+	+	+
p	Brewers Gold	−	−	+	+	+
	Cascade	+	+	−	+	+
* p	Cluster $L_1$4	−	−	−	−	−
	Comet	−	−	+	+	+
	Dunav	−	−	o	o	o
	Elsasser	−	−	+	+	−
* p	Eroica	−	−	−	−	−
	Fuggle H	−	−	−	+	−
*	Galena	−	−	−	−	−
	Golden Star	+	+	−	+	+
p	Hallertauer	−	−	−	+	+
* g	Hersbrucker G	−	−	−	−	−
* p	Huller Bitterer	−	−	−	−	−
	Neoplanta	−	−	o	o	o
g	Perle	−	−	−	+	−
	Precose de Bourgogne	−	+	−	+	−
	Record	+	+	+	+	+
	Saazer	−	+	+	−	−
	Shinshuwase	+	+	−	+	+
	Styrian	−	−	−	+	+
	Tardif de Bourgogne	−	+	−	+	−
	Target (Wye)	−	−	−	+	−
	Vojvodina	−	−	o	o	o
	Willamette	−	−	−	+	−
	Special Selections					
	21193	−	−	−	+	−
	BO R-704	−	−	−	+	+
	21085 (low cohumulone)	+	+	+	+	−

p = Heat-treated at Prosser
g = Heat-treated at Braunschweig, West Germany
* = At least one plant available that is free of all five viruses

TABLE 2

HEALTH STATUS OF MALE HUMULUS GERMPLASM

Male accession (best source)	PNRSV	ApMV	HMV	HLV	HV-24
19005M	—	+	—	+	—
* 19062M	—	—	—	—	—
* 19085M	—	—	—	—	—
* 19173M	—	—	—	—	—
21130M	—	+	—	+	—
60013M	—	—	—	+	+
60023M	—	+	—	—	—
60026M	—	—	—	+	+
* 60028M	—	—	—	—	—
60031M	—	—	+	—	+
63015M	—	—	+	+	—
63016M	+	+	+	+	+
7303-105M	—	+	—	—	—
7303-135M	—	+	—	+	—
7303-138M	—	+	—	+	—
7306-13M	—	+	—	—	—
7308-09M	—	+	—	—	—
7308-37M	—	+	—	—	—
7311-141M	—	+	—	—	—
* 7311-142M	—	—	—	—	—
7314-19M	—	—	—	+	—
* 7705-10M	—	—	—	—	—
* 7723-32M	—	—	—	—	—
* 7727-17M	—	—	—	—	—

* = At least one plant available that is free of all five viruses