Hop Production, Breeding, and Variety Development in Various Countries[1,2]

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ABSTRACT

Only about 30 countries are engaged in commercial hop (*Humulus lupulus* L.) production. The older hop varieties are primarily aroma types, developed locally by selection of superior plants in farmers' fields. Today the relatively few countries with hop breeding programs use mass selection, hybridization, and mutation breeding. Other countries rely primarily on introduction and adaptation of successful hop varieties from these programs. This article presents recent information on hop breeding and variety development as they relate to hop production in various countries.

Key words: *Hybridization, Quality, Selection, Yield*

Hops, one of the indispensable raw materials for beer production, is considered by many economists to be a classic example of a commodity with inelastic demand. Brewers use about the same amount, regardless of supply, in order to avoid changes in the aroma and flavor profile of their beer. If hop supplies fall short of expectations, a substantial increase in price may occur. A relatively small hop surplus on the other hand may drive prices down very quickly, because brewers do not readily change their hopping ratio.

Brewers are afraid of getting caught with inadequate hop supplies. Therefore, they frequently stockpile a supply of hops and purchase future supplies several years in advance. Growers assume an enormous financial risk in growing this labor-intensive and capital-intensive crop. They like to have a certain income guarantee, even in times of high inflation, and are willing to sell at least part of their crop one or more years in advance at guaranteed prices. This in turn helps to insure a stable supply of specific hop varieties. It also assures the brewer that he can maintain a uniform flavor and taste profile of his product, which customers appreciate.

The conservative attitude of brewers and hop growers, which, in part at least, is dictated by the marketplace, made introduction of new varieties difficult for hop breeders in the past. Well-known hop varieties such as Saazer, Tettnanger, Hallertauer Mittelfrüh, Fuggle, Styrian, and Cluster dominated world hop markets over the years, regardless of price, because brewers feared that switching to a new hop variety might adversely affect the flavor profile of their product.

The advent of processed hop products and, particularly, of resin extracts that are frequently not tied directly to a specific hop variety brought drastic changes. New varieties with a significantly higher yield potential than the traditional aroma types were introduced. In Germany, the English high-alpha hops Northern Brewer and Brewer's Gold partly replaced Hallertauer Mittelfrüh, an aroma hop of worldwide reputation. In contrast to Hallertauer Mittelfrüh, the higher yielding English hops were tolerant to verticillium wilt, a hop disease largely unknown in Germany before 1950. American growers partly replaced Fuggle, a low-yielding aroma hop, with higher-yielding varieties that forced Fuggle users to look for alternatives.

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Some brewers became interested in hop varieties with a higher content of α-acids, but their enthusiasm was not always reflected in the marketplace. Others realized that the supply of traditional aroma varieties was inadequate for their projected production volume. In recent years, cooperative efforts by hop breeders, growers, and brewers have resulted in new varieties that have flavor and resin profiles similar to those of existing varieties but are more attractive to growers because of higher yields. Some new varieties developed by English, Australian, German, American, and other hop breeders were accepted in a few years, as compared to the decades necessary for acceptance in years past.

WORLD HOP PRODUCTION

Hop plants need long summer days for maximum production. Therefore, they are primarily grown between 40 and 50 degrees north or south latitude in about 30 countries (Table I). Most major hop-producing countries belong to the International Hop Production Bureau (IHB), which, among other activities, coordinates production and marketing information. An International Hop Congress is held annually in one of the member countries. The activities of the IHB are augmented by an Economic Commission and a Technical Commission, which are composed of representative specialists from member countries.

The 13 members of the IHB in 1978, the last year for which complete data are available, accounted for 79% of the total hop surfaces worldwide and for 89% of the total production (Table I). Production data for all major hop-growing countries except the Soviet Union are readily available. The data in Table I for the Soviet Union are the best estimates available. Only sketchy data were available for some countries that reportedly had commercial hop production in 1978, but their production had no material effect on world hop markets.

West Germany, with 29% of the total world hop production, presently is the most important hop producer worldwide, followed by the United States (24%), Czechoslovakia (9.7%), England (9%), and Yugoslavia (4%). The English hop industry is mainly geared to supplying domestic demands, whereas the other four major producers plus Belgium, Spain, Poland, and Australia, with smaller but still substantial production bases, rely, in part at least, on export markets. Both the United States and West Germany produce more than twice the hops used by their domestic brewing industry in a given year, and competition between these two hop giants for world markets is frequently fierce.

HOP BREEDING AND VARIETY DEVELOPMENT

Plant breeding activities are expensive. After the breeder has assembled a sufficiently broad germplasm base and has familiarized himself with the genetic potential of his collection, he can attempt to combine genetic traits to create superior varieties. Normally it takes at least 10–15 years before a new hop variety can be released for commercial production.

Theoretically, at least, the task should be relatively simple: Suitable male and female parents are selected and crossed; a seedling population is grown; and genotypes for release as new varieties are selected and propagated. Because hop plants are easily propagated vegetatively and new plants are genetically identical to the mother plant, a superior seedling plant can become a new variety in a relatively short time.

The three major techniques for developing new hop varieties are mass selection, hybridization, and mutation breeding.

In mass selection, the breeder simply selects a phenotypically superior plant that may have arisen from a spontaneous mutation. The plant may be propagated and released as a new or improved variety. This technique has developed many successful older and some newer hop varieties such as Fuggle, Fuggle H, Styrian, Early Cluster, E-2, L-1 (also called Yakima Cluster), L-8, and probably also Hallertauer Mittelfrüh, Saazer, and others.

Hybridization is a deliberate attempt to recombine genetic traits from selected parents. In mass selection, a selected clone frequently resembles the variety from which it was selected, but in hybridization, varieties often differ substantially from one or both parents. By choosing the parents carefully, evaluating the progeny in detail, and perhaps backcrossing to the more desirable parent, the breeder can retain desirable traits and improve less desirable ones. The time required to test and evaluate new hybrids normally is much longer than that required to improve hop varieties through mass selection.

Hop is a wind-pollinated (open-pollinated) species, and therefore a breeder may choose simply to collect open-pollinated seeds of a desirable female plant without knowing the identity or the genetic properties of the male parent. Examples of successful hop varieties from open-pollination are Bullion, Brewer's Gold, Cascade, Talisman, Galena, Eroica, Record, Wye Northdown, and others. Successful hybrids from planned crosses of established male and female parents are Comet, Perle, Hüller Bitterer, the four Super Styrians (Ahil, Apolon, Atlas, and Aurora), Dunav, Neoplanta, Vojvodina, Wye Challenger, Wye Target, and others.

Mutation breeding, the third alternative, involves mass selection or hybridization of induced or natural mutations. Mutations normally involve changes in the genetic makeup of the plant that affect certain agronomic or quality traits. The breeder may release a superior mutant as a new variety, or he may use the mutant as parent for new crosses. Examples of hop varieties developed through mutations are Golden Star (a bud mutation of Shinshuwase), Pocket Talisman (a spontaneous mutation from Talisman), and the new triploid varieties Green Bullet, Sticklebract, Harley's Fulbright, Columbia, and Willamette, all of which were obtained by chromosome doubling followed by hybridization.

The final test of a hop variety comes in the marketplace, and usually at the grower or brewer level. The grower must be able to grow the variety and make a profit. The brewer must be able to make good beer with the new hop.

Because hop breeding is expensive, it is done in relatively few countries. Many of the hop-producing countries listed in Table I rely on introduction of successful hop varieties from other countries, perhaps followed by reselection in the new environment. Therefore, a hop variety developed in one country may also be very rewarding for growers in another country who had not contributed at all to its development. Examples are Northern Brewer, Brewer's Gold, Fuggle, Hallertauer Mittelfrüh, Cascade, Late Cluster, and others (Table I). Attempts to artificially restrict hop planting stock to specific areas or individuals normally are futile. In the long run, the

Table I
1978 World Hop Production and Major Varieties

Country	Production (ha)	Production (1,000 kg)	Average Yield (kg/ha)	Important Hop Varieties
International Hop Bureau (IHB) members				
West Germany	17,622	30,330.0	1,721.1	Northern Brewer, Hallertauer Mittelfrüh, Hersbrucker, Brewer's Gold, Hüller, Tettnanger
United States	12,526	24,979.8	1,994.2	Cluster, Bullion, Cascade, Brewer's Gold, Fuggle, Talisman
Czechoslovakia	10,400	10,087.9	970.0	Saazer and selected clones
England	5,837	9,368.7	1,605.1	Wye Target, Northdown, Challenger, Fuggle, Goldings, Bullion, Northern Brewer
Yugoslavia	3,137	4,380.8	1,396.5	Styrian, Bačka, Super Styrians
Poland	2,400	1,942.0	809.2	Lublin, Pulawy, and selected clones
East Germany	2,160	3,610.0	1,671.3	Northern Brewer, Saazer, Bullion, Saladin
Spain	1,803	2,089.8	1,159.1	H-3, H-7, Strisselspalt, Hallertauer Mittelfrüh
Bulgaria	1,390	725.0	521.6	Tettnanger
Australia	1,055	2,372.5	2,248.8	Pride of Ringwood
France	887	1,501.4	1,692.7	Brewer's Gold, Strisselspalt, Northern Brewer
Belgium	800	1,373.7	1,717.1	Brewer's Gold, Hallertauer Mittelfrüh, Northern Brewer, Record
Hungary	550	590.0	1,072.7	Saazer, Saladin, Hallertauer Mittelfrüh, Northern Brewer, Brewer's Gold
Subtotal	60,567	93,351.6		
Not members of IHB				
Soviet Union	13,000	6,900.0	530.8	Zhitomirski and Kalistovo clones and hybrids
Japan	1,270	2,168.2	1,707.2	Shinshuwase, Kirin II, Early Zug
Romania	1,200	1,250.0	1,041.7	Northern Brewer, Brewer's Gold
Canada	329	471.7	1,433.7	Bramling, Kent, Fuggle, Brewer's Gold
Argentina	224	230.0	1,026.8	Spalter, Cascade, Cluster, Pride of Ringwood
South Africa	210	217.7	1,036.7	Southern Brewer, Pride of Ringwood, Cluster
New Zealand	142	210.0	1,478.9	Sticklebract, Green Bullet, Harley's Fulbright, Super Alpha
Austria	117	136.0	1,162.4	Styrian
China		125.0		H641, H644
India	60	80.0	1,333.3	Cluster, Hybrid-2, Talisman
Switzerland	12	20.9	1,741.7	Tettnanger
Subtotal	16,564	11,809.5		
World total	77,131	105,161.1		

marketplace and specific microclimatic conditions make the final decision, no matter what restrictions are placed on release and distribution of hop planting stock.

HOP BREEDING AND PRODUCTION BY INDIVIDUAL COUNTRIES

West Germany

The Federal Republic of Germany, the largest hop-producing country of the world, has a long tradition of hop growing that dates back to the ninth century (18,22). Today, the most important hop-growing areas in West Germany are: Hallertau (15,012 ha), Tettnang (1,109 ha), Spalt (797 ha), Jura (512 ha), Hersbrucker Mountains (169 ha), Rheinpfalz (12 ha), and Baden (11 ha) (17). Germany has had an active hop research program since 1926, when the German Society for Hop Research was created. The Hans Pfülf Institute for Hop Research, supported by the government and the brewing industry, was established in 1962 in Hüll near Wolnzach, Bavaria. Originally only aroma hop varieties were grown in Germany. Initial research efforts by Professor Zattler were directed primarily at improving the resistance to downy mildew (*Pseudoperonospora humuli* Miy. et Tak., G. W. Wils.) of German hops, primarily the dominant Hallertauer Mittelfrüh variety, which occupied the total hop area of the Bavarian district from which it got its name. More than 25 years of efforts to develop new aroma hop varieties with downy mildew resistance culminated in the release of Hüller Anfang, Hüller Start, and Hüller Fortschritt in the 1960s (21,23).

The appearance of verticillium wilt fungi, to which Hallertauer Mittelfrüh and the new varieties were susceptible, forced a redirection of the research. In the late 1950s, the English variety Northern Brewer was introduced to the Hallertau district, where it showed surprising resistance to verticillium wilt. Another English hop, Brewer's Gold, also found its way to Bavaria via Belgium at about the same time and was found to be tolerant to verticillium wilt. Both Northern Brewer and Brewer's Gold had sufficient tolerance to downy mildew and produced higher yields and higher α-acids content in Bavaria than did traditional German hop varieties. Record, a Northern Brewer seedling developed as a high-alpha hop in Belgium, was introduced from the Alsace to the Hallertau area in the early 1960s (23). The decline of the Hallertau hop area and, with it, the reputation of the world's premier producer of aroma hops appeared to be unstoppable.

Efforts by the Hans Pfülf Institute for Hop Research to develop verticillium-tolerant lines, based primarily on Northern Brewer germplasm, resulted in several new varieties with higher α-acids content, good aroma properties, and improved resistance to downy mildew and verticillium wilt. Hüller Bitterer (also called Hüller), from a cross between Northern Brewer and a German male hop (21), was initially introduced as an aroma hop with moderately high α-acids content. After several successful years, Hüller became infected with viruses, particularly prunus necrotic ringspot virus, that adversely affected yield and α-acids content. Efforts by German hop researchers to remove the viruses reportedly have been successful, and virus-free planting stock of Hüller is now available to German growers.

Perle, another seedling from a Northern Brewer cross made in Germany (21), was released for commercial production in 1978. It has α-acids levels up to 9%, pleasant aroma, and good yield potential (31,46).

Another new aroma hop, Emerald, is in the final stages of commercial field trials. It reportedly has pleasant aroma and high α-acids content. Its pedigree has not yet been fully disclosed. The male parent of this variety is the same as that of Perle, and their aroma and resin profiles are similar (21).

The Hallertau district also grows substantial quantities of Hersbrucker Spät, a long-established, late-maturing hop that somewhat resembles the Czechoslovakian Saazer in its aroma profile. The other German hop-producing areas primarily grow local varieties with breeding histories largely unknown.

Presently the German hop-producing area is divided nearly evenly between aroma hops and high α-acids hops (Table II). Hüller Bitterer is an aroma hop with medium levels of α-acids and good aroma. Perle and Emerald to date have not had a significant impact on the marketplace, but efforts are being made to expand Perle, which has recently been accepted by the German brewing industry as an aroma hop equivalent to Hallertauer Mittelfrüh (9).

United States

Hop production in the United States started with the early settlers on the eastern seaboard (3,42) and gradually shifted west for various economic and production reasons. Presently hops are grown in the United States near Sacramento, CA; near Grants Pass and in the Willamette Valley in Oregon; and in the Yakima Valley in Washington and the Boise Valley in Idaho. After World War II the United States become the most important hop producer worldwide and held this position until the late 1960s. Overproduction coupled with poor prices and efforts to stabilize domestic hop production resulted in establishment of a Federal Hop Marketing Order, which placed production limits on hop growers. Prices have now improved considerably, and U.S. hop production during the past several years has averaged about 25 million kilograms annually, about one-fourth of the total world production, and is increasing steadily.

The Yakima Valley of Washington, with 8,637 ha of hops in 1978, is the most important hop-growing area in the United States, followed by Oregon with 2,214 ha, Idaho with 1,081 ha, and California with 593 ha (10) (Table III). The most important U.S. hop varieties are Early Cluster, Late Cluster, English (a collective trade name for the English varieties Bullion and Brewer's Gold), Cascade, Talisman, Fuggle, and Comet (Table III).

Systematic hop research in the United States started at Oregon State University in 1931 when most U.S. hops were grown in that state. The threat of downy mildew similar to that in Germany stimulated a crash program to combat this disease. The Cluster variety was too susceptible to this fungus, and most of Oregon's Cluster acreage shifted to the Yakima Valley in the 1940s, to be replaced by downy-mildew-tolerant varieties such as Fuggle, Bullion, and Brewer's Gold. Fuggle-H, an improved selection of Fuggle, was released for commercial production in 1967 (14), followed by Fuggle-T, a colchicine-induced tetraploid Fuggle for breeding purposes (12). Cascade, an open-pollinated seedling with Fuggle and the Russian Serebrianka in its pedigree, was released as an aroma hop in 1972 (4). In 1975 Comet, a high α-acids selection from a cross between a seedling of the English Sunshine and an indigenous American male hop from Utah (47), was released. Two triploid aroma varieties, Columbia and Willamette, which originated from crosses between the tetraploid Fuggle-T and selected male parents, were released in 1976 (11,13).

Table II
Major Hop Varieties Grown in West Germany in 1978

Variety	Hectares
Low alpha-aroma	
Hallertauer Mittelfrüh	3,545
Tettnanger (German Early Hop)	838
Spalter	293
Hersbrucker Spät	2,974
Medium alpha	
Hüller Bitterer	1,563
High alpha	
Northern Brewer	5,741
Brewer's Gold	2,286
Record	382
Total	17,622

Scientists at the Irrigated Agriculture Research and Extension Center at Prosser, WA, concentrated on improving the Cluster variety through mass selection in the 1950s. The hop trade has not differentiated between various Cluster selections, but growers have distinguished lines differing in maturity and harvest dates. The high-yielding early-maturing E-2 (Early Cluster selection), the medium-early L-1 (also called Yakima Cluster), and the late-maturing L-8, a Late Cluster selection, were readily accepted by brewers and today have become the most important Washington hop varieties (6).

An open-pollinated seedling of Late Cluster selected in Idaho resulted in Talisman (37), which now occupies over 360 ha in Oregon and Washington (Table III). Pocket Talisman, a high-yielding short-internode mutant of Talisman released in 1978 (38), has not yet been grown commercially. Galena and Eroica, two open-pollinated seedlings of Brewer's Gold, have recently been released as high α-acids hop varieties in Idaho (36).

United Kingdom

The English hop industry dates to the Middle Ages when Flemish weavers brought hops across the Channel (5). The number of hop varieties grown commercially today in England exceeds that of any other country (Table IV).

Several English research institutions are presently working on hops. Most of the breeding work is done at the Institute for Hop Research, Wye College (University of London), near Ashford, in the center of the Kent hop-growing district. English hop research and particularly Salmon's work at Wye College has had the greatest influence on the hop industry worldwide. Salmon first recognized the genetic potential of high α-acids genes from native North American hops. Some of his hybrids, notably Brewer's Gold (39) and Bullion (40), both of which originated from open-pollinated seed collected in 1919, and Northern Brewer (41), were successful hop varieties in their own right. In addition, hop breeders in many other countries used them to develop their own high α-acids hops.

Figure 1 is a simplified diagram of English hop breeding activities, drawn after Neve (34). The wild Manitoba BB1, a native Canadian female hop open-pollinated by English male plants in Salmon's hop gardens, resulted in several male and female breeding lines and in Bullion and Brewer's Gold, two sister selections with high α-acids content and high yield potential. Two additional crosses with Brewer's Gold and English and American parents resulted in Northern Brewer, a high α-acids hop with pleasant aroma and brewing characteristics. Alliance and Janus are direct

Table III
Hop Areas (ha) and Varieties of the United States in 1978

Variety	Washington	Oregon	Idaho	California	Total
Low alpha-aroma					
Fuggle	0	854.7	0	0	854.7
Cascade	995.6	374.3	170.0	0	1,539.9
Columbia and Willamette[a]	0	64.3	0	0	64.3
Hallertauer and Tettnanger	18.6	2.0	73.7	0	94.3
Experimental	0	1.0	13.4		14.4
Medium alpha					
Early Cluster	5,515.3	0	134.4	0	5,649.7
Late Cluster	1,052.2	35.2	350.1	0	1,437.5
California Cluster	0.0	0.0	0.0	586.8	586.8
Talisman	0.0	37.2	324.2	0.0	361.4
High alpha					
English[b]	822.4	843.4	14.6	0	1,680.4
Comet	232.7	2.4	0.8	6.5	242.4
Total	8,636.8	2,214.5	1,081.2	593.3	12,525.8
Average yield (kg/ha)	2,105.0	1,670.0	2,030.0	1,560.0	1,994.2

[a] New triploid varieties.
[b] Collective trade term for Bullion and Brewer's Gold.

Table IV
English Hop Production in 1978 by Growing Area and Varieties

Growing Area	Production (ha)	Production (1,000 kg)	Average Yield (kg/ha)	Variety	Hectares
Weald of Kent	1,647	2,429.1	1,474.8	Wye Target	997
Herfordshire	1,620	2,756.5	1,701.5	Wye Northdown	940
Mid Kent	836	1,280.8	1,532.1	Wye Challenger	744
East Kent	688	1,260.6	1,832.3	Fuggle	588
Worcestershire	586	989.7	1,688.9	Goldings	478
Sussex	251	379.2	1,510.8	Bramling Cross	453
Hants, Surrey, Berkshire	209	273.0	1,306.2	Bullion	400
				Northern Brewer	342
				Whitbread's Golding Variety	332
				Wye Saxon	197
				Keyworth's Midseason	163
				Progress	142
				Others	61
Total	5,837	9,368.9	1,605.1		5,837

descendents of an unnamed sister selection of Brewer's Gold, whereas Bramling Cross arose from a Brewer's Gold brother. Wye Northdown and Wye Target, two high α-acids hops with pleasant aroma properties, are direct descendents of Northern Brewer (32,33,35). Downy mildew resistant germplasm introduced in the 1950s from the German hop-breeding program at Hüll, was combined with Northern Brewer to produce Wye Challenger. Additional crosses involving Northern Brewer with continental European and English germplasm gave rise to Wye Saxon and Wye Viking (35), the two most recent releases from the English hop breeding program. Some varieties released from Wye during the past 25 years, such as Alliance, Janus, Density, and Defender, are no longer grown commercially. Newer hop varieties with higher α-acids content have become more attractive to English brewers.

The only important English hop variety missing from Fig. 1 is Fuggle, an early midseason variety found as a seedling about 1861 in Kent (5). In England, Fuggle is susceptible to verticillium wilt and virus diseases. In the United States this variety is grown mostly in Oregon, where it is early maturing and has been used as a source of breeding for downy mildew resistance.

The scope and success of the English hop-breeding program is probably due to several factors. Early in his career Professor Salmon concentrated on using diverse germplasm for breeding. Hop research in other major hop-growing countries at that time was primarily aimed at saving existing varieties by breeding for disease resistance, mainly downy mildew. The English brewing industry has also apparently been more willing than European or American brewers to experiment with new hop varieties. The availability of diverse germplasm from the English hop-breeding program, the broad adaptation of some of Salmon's earlier selections, and the higher yield and α-acids content of some English varieties have benefited many other hop-breeding programs worldwide.

Yugoslavia

Yugoslavian hop production and research is concentrated in two geographical areas: the Savinja Valley of Slovenia (2,135 ha) in the Northwest and the Bačka region of Serbia in the East (1,002 ha).

The dominant Slovenian hop variety at present is Savinski Golding (1,376 ha). This variety, also called Styrian or Styrian Golding, is a direct descendent of Fuggle, which was introduced to Slovenia in the late 1800s (24). Styrian is resistant to downy mildew and is widely exported as an aroma hop.

In the Bačka region of Serbia, an old native variety of the same name occupies about 952 hectares. This variety has a different quality profile than Styrian, but it is used as an aroma hop both domestically and for exports.

Hop-breeding efforts at the Hop Research Institute at Žalec, Slovenia, resulted in four new high-alpha varieties collectively known as Super Styrians or A-varieties.[4] Their total area has increased rapidly, and in 1978 they occupied about one-third of the total Slovenian hop area. Three of them, Atlas (255 ha), Ahil (1 ha), and Apolon (131 ha) originated from a cross between Brewer's Gold and a native Yugoslavian male hop (45). The fourth and most widely grown, Aurora (357 ha), originated from a cross between Northern Brewer and another native Yugoslavian male hop (45) Aurora reportedly produces yields of up to 2,000 kg/ha, with high α-acids content and a pleasant aroma that has prompted Wagner and Kralj[4] to state that "it is absolutely unscientific to divide hops into aroma and bittering categories solely on the ratio of the alpha acid to beta fraction." They have stressed the fact that "aroma varieties may be either high or low in resin content," with the implication that the Super Styrians, with resin content higher than that in the traditional Styrian Golding, have comparable aroma properties that should be advantages to brewers.

Three additional hop varieties from the "B-series," Bobek, Blisk, and Buket, were released recently.[5] Their breeding and production record has not yet been published.

The Serbian hop research activities are centered at the Institute for Hop Research, Bački Petrovac, which is associated with the Institute for Agricultural Research, Novi Sad. Efforts are being made to replace Bačka, the prominent variety, with new hybrids that have higher yield and greater quality potential plus improved resistance to downy mildew. Dunav, Vojvodina, and Neoplanta,

[4] T. Wagner and D. Kralj. Paper presented at 27th Cong. European Union of Hop Trade, Dubrovnik, Yugoslavia, 1979.
[5] T. Wagner. Personal communications. 1980.

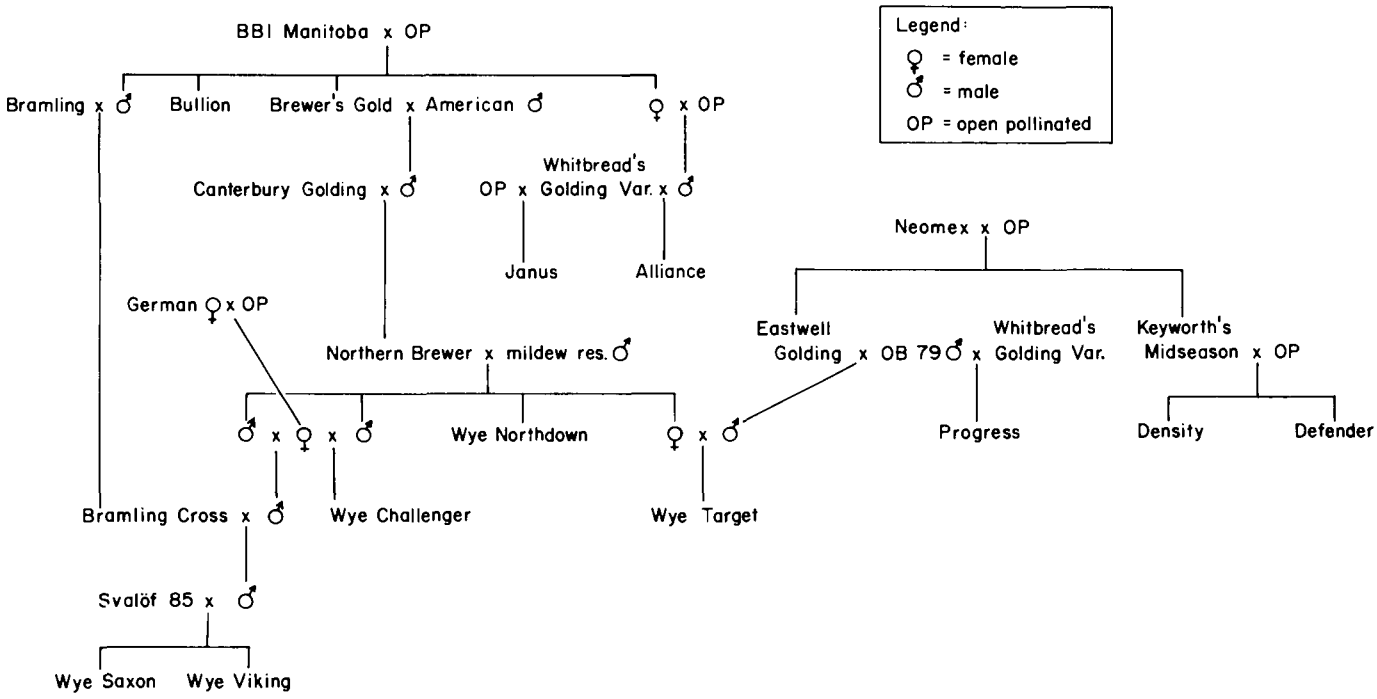

Fig. 1. English hop breeding activities (after Neve, 34).

unrelated to Bačka, were introduced in the 1970s (27). They presently occupy about 50 ha. All three originated from a cross between Northern Brewer and a male plant obtained from a cross between Savinski Golding (Styrian) and a native wild male seedling. All three have more resistance to downy mildew than does Bačka, produce better yields, and have substantially higher α-acids content.

Czechoslovakia

The 10,400 ha of Czechoslovakia's 1978 hop production are divided among four major growing districts. Most hops are grown in the Žatec (Saaz) area (7,020 ha), followed by Úštěk (1,795 ha), Pieštany (950 ha), and Tršice (615 ha). Total hop production in 1978 exceeded 10,000 metric tons (Table I), with average yields of about 970 kg/ha, well below world standards (Table I) (15,17). Žatecky Medium Early Red Hop, also called Saazer or Bohemian Red Hop, and various improved Saazer clones obtained by mass selection accounted for practically all of the production.

Hop-breeding and research activities are centered at the Institute for Hop Research, Žatec. Aromat and Sirem, released for commercial production in 1969, are two improved Saazer clones probably obtained by mass selection (2,44). Records of commercial hop production show about 400 ha planted to these new clones in 1974 but none recently. Zlatan, a hop variety introduced in 1976 (16), is probably also a clone of Saazer, but it has not appeared in recent production records. Žatecky Sladek (Žatec Brewer) appears to be the only new Czechoslovakian hop variety obtained by hybridization. It is derived from a cross between Northern Brewer and a male plant of Saazer background (44). Žatec Brewer reportedly has higher yields and higher α-acids content than does Saazer, but again it appears to have been eliminated from commercial production.

If any of these Czechoslovakian clones or breeding lines are still in commercial production, they are probably marketed under the well-known Saazer name. This obviously would avoid confusion on export markets, to which three-quarters of the country's total production is sold annually.

Poland

Hop production in Poland dates to the ninth century. In the Middle Ages hops were widely grown to support a flourishing native brewing industry. The Polish hop industry was almost completely destroyed during World War II, but it has been rebuilt to the present 2,400 ha (15). Polish hops frequently enter international trade channels, where a distinction is made between the varieties Lublin (1,858 ha) and Pulawy (524 ha), even though they appear to have similar quality profiles.

Hop-breeding and improvement efforts at the Institute for Hop Research, (IUNG), Pulawy, and at other agricultural research centers appear to be primarily directed toward improving existing varieties by clonal selection (30). At present, two major groups of clones are grown, the early-maturing clones No. 7, 8, 22, 34, which resemble the variety Lubelska (also called Pulawy), and the late-maturing clones No. 12 and 18.

East Germany

The German Democratic Republic now grows about 2,160 ha of hops, primarily near Magdeburg-Halle (955 ha), Erfurt (542 ha), Leipzig-Dresden (615 ha), and Gera-Karl Marx Stadt (48 ha). The country shows total production at about 3,610 metric tons and average yields at about 1,671 kg/ha.[6] Northern Brewer (1,180 ha) is the dominant variety, followed by Saazer (760 ha), which is not recommended anymore, and Bullion (176 ha). Saladin, released for commercial production in 1976, is an aroma hop with about 5–6% α-acids content. Oswald reportedly developed it in Czechoslovakia from a clonal selection of Fuggle.

Spain

The Spanish hop industry was started in 1945 with the formation of the SAE Fomento Lupulo Company in the Leon Province (7). Clonal selections, partly involving the English Brewer's Gold, appear to be the main hop-breeding effort for the 1,800 ha in production. The clones H-3 (907 ha) and H-7 (596 ha), reportedly derived from Brewer's Gold; the old French variety Strisselspalt (221 ha); and the German Hallertauer Mittelfrüh (74 ha) were grown in 1978 (20), with a total production of about 2,090 metric tons annually (7,15).

Australia

The Australian hop research station at Ringwood, near Melbourne, has recently been closed, at least partially because the variety Pride of Ringwood has been so successful. Released in 1958, it was developed at this station, which was largely supported by the brewing industry.[7] This high-yielding, high-alpha variety is from a cross between an open-pollinated seedling of the English variety Pride of Kent and a Tasmanian male. Today it occupies nearly all of Australia's hop areas. Of the 1,055 ha of commercial Australian hop production, 43% are grown on the mainland in Victoria, primarily in the district of Myrrhea (320 ha) and in the Ovens Valley (148 ha) (25). The remaining 587 ha are grown in Tasmania, around Hobart near the southern tip of the island (362 ha), and near Scottsdale in the north (225 ha).

Pride of Ringwood is also grown commercially in South Africa and in India, but the variety matures too late in the United States to be of commercial value there.

Belgium

In 1978 Belgium had 800 ha of hops under cultivation, of which 602 ha were grown in the Poperinge area, 176 ha in Alost-Asse, and 22 ha in other areas (17). Total production was 1,373.7 metric tons, with an average yield of 1,717 kg/ha (Table I). The dominant variety, more than one-third of the total production, was Brewer's Gold, followed by Northern Brewer, Hallertauer Mittelfrüh, Record, and Saazer. Record, a high α-acids hop, was developed in Belgium about 25 years ago from a cross between Northern Brewer and a male plant obtained from an open-pollinated Saazer. Record is also grown on nearly 400 ha in West Germany, where it produces good yields with relatively high α-acids content.

Soviet Union

Official data on Russian hop production are available only sporadically. Estimates of the total hop area in the Soviet Union vary between 12,000 and 16,000 ha, an area second only to that of West Germany (Table I), (1,15).

The 1978 Russian hop production amounted to about 10,900–11,500 metric tons, with average yields of 681–958 kg/ha, depending on which hop area and production estimates are used for the calculations. More recent estimates place Soviet yield levels at about 1,000–1,400 kg/ha. The total hop area is expected to be expanded to about 30,000 hectares, nearly doubling the present production potential (1).

Hops are grown mainly in two Russian Republics, the Ukraine (7,050 ha), with commercial hop production near Zhitomir, Rowno, Lvov, and Wolhynia, and the Russian Soviet Federated Republic, with hop production in the Moscovska area (3,945 ha), in Chuvashija (1,800 ha), and in the Altaj (63 ha) (43). The hop-production area in Chuvashija reportedly was expanded to about 3,600 ha in 1979.

Russian hop research is centered at the Institute of Hop Research at Zhitomir (Ukraine) and at the Hop Research Station Kalistovo near Moscow. Hop-breeding activities appear to be focused on mass selection with the old Serebrianka variety. They have resulted in a number of improved clones, notably clone No. 16, and the medium-early Zhitomirski Red Hop No. 18 (43). Other clonal

[6] K. Borde. Personal communication. 1980.

[7] A. S. Nash. Personal communication. 1980.

selections are the Early Moscovskii, the medium-late Brjansky, the Kalistovo Medium Early Hop, the Medium Early Wolhynia Hop, and the Ivano Red Hop. The emphasis on "medium early" and "red" in the variety names perhaps indicates a relationship to the Czechoslovakian variety Saazer, which officially is called Žatecky Medium Early Red Hop.

Names of other Russian hop varieties have occasionally appeared in various trade publications in recent years, notably Aromatinyi, Anievskii, Malymysh, Nadeshdinski, Gibridnyi, Smolistyi Resinour, Yubleniyi, and Gibrid 11-35, but no Soviet breeding histories or production records are available.

Japan

Japan imports large quantities of European aroma hops, but its own hop industry dates to 1872 (19). Hop-breeding and production research is supported largely by breweries. Of the 1,270 ha of commercial hop production in 1978, all but 17 ha were located on the island of Honshu (15,19).

The dominant Japanese hop variety, Shinshuwase, which occupied 95% of the total hop area in 1978, was developed in Japan from a cross between Saazer and a male hop of unknown European ancestry. Other Japanese varieties developed more recently include Kirin II (a selection from Shinshuwase), Golden Star (a bud mutation from Shinshuwase) (29), and two as yet unnamed high α-acids selections from a cross between Brewer's Gold and Japanese male plants of European origin (28). Early Zug, an old European aroma variety introduced in 1911, is grown only on the northern island of Hokkaido.

South Africa

The Republic of South Africa, a hop importer, is trying to grow more of its own hops through industry-supported breeding and production research near George on the southern coast. Southern Brewer, an aroma hop with medium-high α-acids content, developed in South Africa from a cross between two open-pollinated Fuggle seedlings,[8] is now the dominant variety (105 ha), followed by the Australian variety Pride of Ringwood (84 ha) and the American Late Cluster (21 ha). Hybrid-2, another South African hop variety developed a number of years ago from an open-pollinated Golden Cluster seedling, was discontinued in 1947 because of low yields. This variety reportedly grows very well in Northern India. Another, as yet unnamed, selection (NP2/55) from a cross involving Pride of Ringwood reportedly produces up to 11% α-acids content and good yields.[9]

New Zealand

Brought to New Zealand by the early settlers (8), hops are grown today on about 140 ha near Nelson on the Waimea Plains, in Upper Moutere, and in the Motueka-Riwaka area near the Riwaka Hop Research Station (8,26). Three hop varieties developed at this station and released to New Zealand growers in the 1960s have quickly become the dominant varieties of the country. First Choice and Smooth Cone originated from open-pollinated seed collected in New Zealand on California Cluster, a Late Cluster hop originally introduced from the United States. A third, CaliCross, came from a California Cluster crossed to a male plant of Fuggle and unknown parentage. All three varieties are resistant to Phytophthora root rot, the prevalent hop disease in New Zealand, and produce good yields with α-acids content ranging from 6 to about 9%.

Another goal of the New Zealand hop-breeding program is the development of high α-acids, high yielding, naturally seedless hop varieties through polyploid breeding. Three naturally seedless triploid varieties, introduced in the early 1970s, reportedly produce yields of up to 4,000 kg/ha with an α-acids content frequently in excess of 11%. They now account for about 80% of the total New Zealand hop-growing area[10] (8). Sticklebract originated from an open-pollinated cross of a colchicine-induced tetraploid First Choice, whereas Harley's Fulbright and Green Bullet came from open-pollinated seed collected on a tetraploid Smooth Cone. Another new variety, Super Alpha, reportedly produces high yields with an α-acids content of up to 15%. It is a tetraploid hop from an open-pollinated cross on tetraploid Smooth Cone. Super Alpha regularly exceeds the minimum New Zealand goal of 336 kg of α-acids production per hectare. Because New Zealand's hop production now exceeds domestic needs, efforts are directed toward developing export markets.[11]

China

Chinese hops have recently appeared on world markets at very competitive prices. They appear to be aroma hops, but little is known abroad about the Chinese hop industry.

Other hop-producing countries such as Argentina, Canada, Romania, Bulgaria, France, Hungary, Austria, and India do not have specific hop-breeding programs. They rely on foreign introductions and, occasionally, on native varieties of local origin (Table I). Ireland, North Korea, Portugal, Mexico, and Turkey reportedly also grow small amounts of hops, but detailed information from these countries is unavailable.

[8] B. M. Robinson. Personal communication. 1979.
[9] Refer to note 8 above.
[10] A. A. Frost. Personal communication. 1980.
[11] Refer to note 10 above.

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