New Japanese Hop Varieties with High α-Acid Content

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ABSTRACT

Kirin Brewery Co. Ltd. (Japan) developed three new high α-acid hop varieties: Toyomidori, Kitamidori, and Eastern Gold. Their α-acid contents were 12.2, 15.4, and 17.3%, respectively. The α-acid contents of these new varieties were comparable to those of the high α-acid varieties previously reported. Eastern Gold might be referred to as an excellent high α-acid variety. In addition to high α-acid content, the oil composition of Kitamidori was similar to that of Saazer. These varieties had Wye male OB 79 as a common genetic composition, and their genetic potential for α-acid content could be predicted.
Keywords: Hop, Breeding, Variety

The principal objectives of breeding to improve hop quality are to develop new varieties with highly α-acid content or aroma properties similar to highly reputable European aroma varieties (13). Breeding for high α-acid content has also been combined with high yields to raise α-acid productivity per unit area in various countries (3,5). Olympic (7) and Nugget (4), developed in the United States, contain more than 12% α-acid. Along with high yields, breeding has resulted in significantly increased α-acid production.

The Hans Pfülf Institute for Hop Research in Germany has tried to develop new aroma-type varieties with *Verticillium* tolerance, such as Hallertauer Tradition and Spalter Select (1). Breeding for aroma properties in the United States has aimed at the development of higher yielding aroma-type varieties to replace imported European varieties such as Hallertauer Mittelfrüh or Hersbrucker (5). Mt. Hood (5), a recently developed variety, was selected from progeny of a cross between the tetraploid Hallertauer Mittelfrüh and a U.S. Department of Agriculture male. It has the potential for high yield as well as aroma properties similar to European aroma varieties.

The Kirin Brewery initiated a hop breeding program in the 1930s to develop new varieties with high α-acid content and aroma properties. The three major approaches for developing new varieties are introduction, hybridization, and mutation breeding. We attempted to introduce different varieties from foreign countries, but most of those tested had not achieved a high enough yield to be used in commercial cultivation because of their poor adaptation to Japanese environmental conditions. Therefore, the breeding program has progressed by selecting plants that arose from hybridization or mutation. This article describes in detail the characteristics of the new high α-acid varieties Toyomidori, Kitamidori, and Eastern Gold, which were developed by hybridization breeding.

EXPERIMENTAL

Seeds treated with natural low temperature for a defined time period were sown in a soil bed, germinated, raised as seedlings in the greenhouse, and then transplanted to the experimental plot in the same year. Within two years after planting, initial selections were made on the basis of agronomic and chemical evaluation. Selected plants were immediately propagated, and evaluation of their agronomic and chemical characteristics was continued in detail for three to five years in experimental plots at Iwate or Fukushima (39 and 38° north latitude, respectively). Brewing properties were evaluated concomitantly. The final stages of the breeding program were usually conducted at the grower level to confirm that the new selection would truly benefit growers.

A chemical evaluation of each variety was performed for α- and β-acid content (9,16), α-acid composition (14), essential oil content by steam distillation (6), and oil composition using Shimadzu GC-6A gas chromatography (9). Carbowax 20*M*, 60–200°C, 3°C/min and field ionization detector were used in all evaluations with gas chromatography.

Brewing evaluations were conducted on a small scale (200 L–50 hl) or on a plant scale (1,000 hl). Sensory evaluation (11) of beers hopped with 100% of each variety was conducted with highly trained panels.

RESULTS

All varietal characteristics described below were compared with those of the present leading variety, Kirin No. 2, as a control.

Toyomidori

Toyomidori originated from a cross between Northern Brewer and Wye male OB 79 (Table I). It was registered under the Japanese Seeds and Seedling Law in 1981 and was released for commercial production. In 1990 it was grown in 58 ha of cultivated area and produced 153 t of dried cones.

The average α-acid content (dry basis) over a three-year investigation of Toyomidori was 12.2% (more than twice that of the control), while cohumulone content, essential oil content, and oil composition were all similar (Table II).

Toyomidori matured on August 11 (Table III), 14 days earlier than the control and produced 3,391 cones per vine (Table III). The number of cones in Toyomidori was 20–30% less than the that in the control. Because of its heavier cone weight, Toyomidori had a higher commercial yield than that of the control (Table III).

Four brewing evaluations using pellets were done on a small scale (200 L) in 1981 and on a plant scale in 1982 and 1983. In the sensory tests, Toyomidori was free from off-flavor and was evaluated as equal or slightly superior to the control with regard to bitterness and hop flavor.

Kitamidori

Kitamidori, registered in 1989, originated from a cross between C-79-27-01 (female parent with high α-acid content and many cones) and C-79-64-110 (male parent) (Table I). The chemical data of Kitamidori cones during 1984–88 are shown in Table IV. Kitamidori had high α-acid content (13.4–17.0%; average, 15.4%). The α-acid contained 19% cohumulone. Myrcene and humulene contents were 26 and 37%, respectively, of the essential oil of Kitamidori. Farnesene, which was not detected in the essential oil of the control, was 9% in Kitamidori, a value close to that associated with Saazer. Kitamidori matured on August 8 (Table III), seven days earlier than the control. It produced 1,299 cones and weighed 15.3 g/100 cones, resulting in an estimated yield almost equal to that of the control (Table III). Two 50-hl brewing evaluations with baled Kitamidori were conducted in 1984 and 1985. In the sensory tests, Kitamidori was free of off-flavor and was comparable to the control in bitterness and hop flavor.

Eastern Gold

Eastern Gold was bred from a cross between C-76-64-17 (female parent with high α-acid content and many cones) and Wye male OB 79 (male parent) (Table I). The application for registration of Eastern Gold is in process.

During the investigations conducted between 1986 and 1988, the α-acid content of Eastern Gold averaged 17.3% (range, 14.6–19.9%). This was the highest value among the three varieties tested (Table V). The content of cohumulone was 22% of the α-acid content (Table V). As with Kitamidori, farnesene was detected in the essential oil (Tables IV, V). Eastern Gold matured on September 6, 18 days later than the control (Table III). The number of cones per vine averaged 4,276; the weight of 100 cones was 20.9 g. The estimated yield was approximately twice that of the control (Table III). In spite of two years of crops harvested from immature plants, a preliminary small-scale (200 L) brewing evaluation was conducted in 1984. In the sensory tests, Eastern Gold was evaluated as comparable to the control in bitterness and hop flavor.

DISCUSSION

Hallertauer Magnum (1), Olympic (7), Nugget (4), Chinook (8), Wye Target (12), Aurora (15), and Vojvodina (15) have all been reported as high α-acid hop varieties. The α-acid content of these varieties was approximately 9–15%, while the α-acid contents of Toyomidori and Kitamidori apparently were comparable. Furthermore, Eastern Gold had higher α-acid content than did these varieties and could be referred to as an excellent high α-acid variety.

α-Acid production could be estimated from the commercial yield and its α-acid content. According to the data on commercial production of Toyomidori in 1990, the average yield was 2.66 t/ha, and the average α-acid content was 11.7%. Consequently, the α-acid production of Toyomidori was 311 kg/ha, which was approximately equal to that of Olympic (7) or Nugget (4).

Kitamidori appeared to have an oil composition similar to that of Saazer in terms of myrcene, farnesene, and β-caryophyllene content (Table IV). The humulene content of Kitamidori's essential oil was much higher, resulting in a higher ratio of humulene to β-caryophyllene than that of the control (Table IV). Maier (10) demonstrated that the outstanding feature of aroma varieties was a high humulene content, and a high ratio of humulene to β-caryophyllene concerning oil composition. Therefore, Kitamidori could be thought to have aroma properties, at least in part.

TABLE I
Parents and Genetic Composition of Three Hop Varieties

	Toyomidori	Kitamidori	Eastern Gold
Female parent	Northern Brewer	C-79-27-01	C-76-64-17
Male parent	Wye male OB 79	C-79-64-110	Wye male OB 79
Genetic composition	1/2 Northern Brewer	10/64 Kirin No. 2	5/64 Kirin
	1/2 Wye male OB 79	16/64 Wye male OB 79	48/64 Wye
		2/64 New Zealand	1/64 New Zealand
		36/64 Open pollinated	10/64 Open pollinated

TABLE II
Chemical Composition of Toyomidori and Kirin No. 2[a]

	Toyomidori				
	1977	1978	1979	Average ± SD	Kirin No. 2[b]
α-Acids, % db	11.8	12.9	12.0	12.2 ± 0.6	5.8 ± 0.5
β-Fraction, % db	7.5	7.1	6.9	7.2 ± 0.3	7.0 ± 0.4
Cohumulone content, %	41	38	42	40 ± 2	43 ± 2
Essential oil, ml/100 g, db	0.77	0.82	0.47	0.69 ± 0.19	0.72 ± 0.33
Oil composition, %					
Myrcene	23	32	25	27 ± 5	32 ± 13
β-Caryophyllene	12	12	12	12 ± 0	12 ± 3
Farnesene	...	...	...	...	...
Humulene	24	21	28	24 ± 4	25 ± 9
Ratio of humulene to β-caryophyllene	2.00	1.75	2.33	2.03 ± 0.29	2.08 ± 0.30

[a] Analyses were done with a mixture of cones on two or three plants cultivated in Iwate experimental field.
[b] Kirin No. 2 was cultivated in the same experimental plot as that of Toyomidori and analyzed during investigation.

TABLE III
Physiological and Agronomic Characteristics of Four Hop Varieties

Variety	Year	Location[a]	Date of Maturing	No. of Cones per Vine[b]	Cone Size/(mm)[c] Length	Cone Size/(mm)[c] Width	Weight of 100 Cones (g)	Yield[d] (tons/ha)
Toyomidori[e]	1977–1979	Iwate	Aug. 11	3,391	30.0	21.0	28.5	2.33 ± 0.43
Kirin No. 2[e]	1977–1979	Iwate	Aug. 24	4,023	29.0	21.0	11.8	1.95 ± 0.25
Kitamidori	1984–1988	Fukushima	Aug. 8	1,299 ± 413	29.0 ± 3.8	18.7 ± 1.1	15.3 ± 3.5	1.53 ± 0.25
Kirin No. 2	1984–1988	Fukushima	Aug. 15	2,098 ± 809	31.5 ± 3.2	20.2 ± 3.7	11.8 ± 2.2	1.78 ± 0.73
Eastern Gold	1987-1989	Iwate	Sept. 6	4,276 ± 244	34.1 ± 1.8	19.3 ± 3.2	20.9 ± 4.7	6.38 ± 0.11
Kirin No. 2	1987–1989	Iwate	Aug. 19	3,155 ± 97	37.1 ± 3.5	20.4 ± 2.8	13.6 ± 2.2	3.09 ± 0.50

[a] Iwate and Fukishima experimental plots (39 and 38° north latitude, respectively).
[b] Values for each year were the average (± SD) of three vines.
[c] Values for each year were the average (± SD) of 20 cones.
[d] Average values of commercial cones ± SD in Toyomidori and Kirin No. 2 in 1977–79 were obtained from total production in a 0.1-ha plot each year. The values of Kitamidori and Eastern Gold are shown as averaged yields ± SD, which were estimated each year using the following formula: (Number of cones per vine) × (100 dried cones weight/100) × (7,200 vines)/10^6.
[e] The number of cones, cone size, and weight of 100 cones were investigated only in 1977.

TABLE IV
Chemical Composition of Kitamidori, Kirin No. 2, and Saazer[a,b]

	Kitamidori							
	1984	1985	1986	1987	1988	Average ± SD[c]	Kirin No. 2[c]	Saazer
α-Acids, %, db	13.4	15.6	17.0	15.1	15.7	15.4 ± 1.3	7.0 ± 0.6	3.5
β-Fraction, %, db	7.5	7.7	8.9	7.4	10.3	8.4 ± 1.2	8.9 ± 1.7	7.0
Cohumulone content, %	20	17	21	18	20	19 ± 2	48 ± 1.1	26
Essential oil, ml/100 g	0.99	1.22	2.61	1.76	1.79	1.67 ± 0.63	0.96 ± 0.20	0.38
Oil composition, %								
Myrcene	22	17	32	29	32	26 ± 7	47 ± 6	27
β-Caryophyllene	13	13	10	10	10	11 ± 2	8 ± 1	8
Farnesene	10	8	10	10	9	9 ± 1	...	11
Humulene	43	43	34	34	32	37 ± 5	16 ± 2	22
Ratio of humulene to β-caryophyllene	3.31	3.31	3.40	3.40	3.20	3.32 ± 0.08	2.00 ± 0.22	2.75

[a] Analyses were done with a mixture of cones on two or three plants cultivated in Iwate experimental plot.
[b] 1988, imported Saazer.
[c] Kirin No. 2 was cultivated in the same experimental plot as was Kitamidori and analyzed during investigation.

TABLE V
Chemical Composition of Kitamidori, Kirin No. 2, and Saazer[a,b]

	Eastern Gold				
	1986	1987	1988	Average ± SD	Kirin No. 2[b]
α-Acids, %, db	19.9	14.6	17.3	17.3 ± 2.7	6.9 ± 0.6
β-Fraction, %, db	9.7	9.8	9.8	9.8 ± 0.1	9.4 ± 2.2
Cohumulone content, %	23	22	21	22 ± 2.1	48 ± 0.6
Essential oil, ml/100 g	1.93	1.89	2.35	2.06 ± 0.25	1.02 ± 0.21
Oil composition, %					
Myrecene	36	29	41	35 ± 6	44 ± 6
β-Caryophyllene	10	12	9	10 ± 1	7 ± 2
Farnesene	5	6	6	6 ± 1	...
Humulene	26	27	22	25 ± 3	16 ± 3
Ratio of humulene to β-caryophyllene	2.60	2.25	2.44	2.43 ± 0.18	2.29 ± 0.12

[a] The analysises were carried out with a mixture of cones on two or three plants cultivated in Iwate experimental plot.
[b] Kirin No. 2 was cultivated in the same experimental plot as was Eastern Gold and analyzed during investigation.

The estimated yield of Eastern Gold was more than twice that of the control (Table III). However, we could not deny the possibility that the value was considerably affected by specific environmental or sampling methods. The yield will be clearly identified when Eastern Gold is grown in commercial production. We expect higher α-acid production, which will largely depend on the α-acid content of Eastern Gold, even though its cone yield is close to that of the control.

All three varieties were evaluated favorably with regard to bitterness and hop flavor and would not be expected to have a negative effect on beer taste. However, we must emphasize the necessity of further brewing evaluations of Eastern Gold.

The female parents of the new varieties are Northern Brewer in Toyomidori, C-79-27-01 in Kitamidori, and C-76-64-17 in Eastern Gold. Their α-acid contents under Japanese conditions were 7.3, 10.3, and 9.7%, respectively. All the new varieties apparently had higher α-acid content than that of their female parents. Since the varieties had Wye male OB 79 as a common genetic composition, which arose from the parents either directly or indirectly, we can assume that Wye male OB 79 significantly contributed to the increased α-acid content in the new varieties.

Hartley and Neve (2) reported on an investigation of the relationship between the α-acid content of female progeny and their male parents, and between female cones and male flowers in intersexual plants. They found no correlations in either group. They suggested that the breeding values of males were indicated far better by the α-acid contents of their female parents than by the contents of their own flowers.

The potential for α-acid content associated with Wye male OB 79 could be predicted by the α-acid content of its female parent. Furthermore, it would be clearly evaluated by the differences of mean values of α-acid contents in progenies, which arose from controlled crosses between some female and male parents as well as Wye male OB 79.

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