



# Evaluation of Czech hop varieties in beer

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## Abstract

New hop varieties were evaluated in brewing tests in the years 2020 and 2021. The Saaz Comfort, Saaz Shine, Saaz Late and Saaz fine aroma hops were compared in lager style beers. Saaz Comfort has the best evaluation in terms of overall popularity. With a 95% probability, its evaluation is different from that of Saaz Shine. Saaz Comfort has a considerably different evaluation of bitterness than Saaz Late and Saaz Shine. The results show that fine aroma hop varieties have different characteristics and thus do not compete with each other. Kazbek and Cascade were compared in lager and ale beer styles. No significant difference was determined in the lager style. However, a significant difference between Kazbek and Cascade was established in ale. Gaia has a considerably better evaluation in the lager style than in ale. Gaia has the best evaluation of aroma and bitterness in lagers with dry hopping.

**Key words:** hops, *Humulus lupulus* L., bitterness, drinkability, hop varieties, beer, sensory analysis

## 1 Introduction

Hop breeding is a very demanding and complicated process. A high heterozygosity, which is due to the allogamy of hops, makes hop breeding difficult (Neve and Lewis, 1978). It is not possible to gain a homozygous plant because hops demonstrate a high growth depression as a result of inbreeding. Hybridization always leads to a considerable splitting of characteristics in descendents (Nesvadba et al., 1999). The difficulties are also due to the long process of hop breeding (the development of new hop varieties takes from 15 to 25 years), high costs and extensive material requirements (greenhouses, laboratories, breeding areas, brewing tests, zoning experiments etc.). New hop varieties must show numerous qualities required for hop growing under different cultivation conditions for at least 15 years. A hop variety is registered because of its uniformity, stability and unchanging quality and quantity parameters (Nesvadba et al., 2020). A low variability of its characteristics and good agrotechnical aspects are important as well.

Currently, a broad range of breeding objectives are being pursued. They can be divided into two basic areas:

I. Agrotechnical objectives – These objectives went through a long-term development, depending on the changing trends in hop growing (e.g. transition from hop fields with poles to wire trellises, machine harvest, mechanized cutting, low trellises). The current agrotechnical requirements in hop breeding are divided into the following objectives: resistance to biotic and abiotic factors, high yields, required content and composition of hop resins, stability of performance and quality characteristics, sensitivity to agrotechnical interventions, etc.

II. Brewing objectives – They are very important for hop breeding because new hop varieties cannot be grown without being utilized in beer brewing. In terms of beer brewing, hop varieties are currently divided into three groups: aroma hops, bitter hops and other hop varieties (IHGC hop variety list, 2018). Unfortunately, the

category of aroma hops comprises both Saaz and hop varieties such as Premiant, Perle and Marynka. Therefore, from the beer brewing perspective, it is better to divide hop varieties into the following groups according to Vent (1999):

1. Fine aroma hops. Hop varieties falling into this group provide traditional fine aroma hops, the world's standard of quality, guaranteeing excellent taste and aroma of brewed beers. This group includes Saaz and the German Spalt and Tettnang hop varieties. These hops show a lower content of hop resins.

2. Aroma hops. This group consists of the original hop varieties or ecotypes of the individual countries, e.g. Hallertauer and Hersbrucker from Germany, Fuggle from United Kingdom, Willamette from the United States, Lublin from Poland and Savinjski Golding from Slovenia, as well as new hybrid hop varieties characterized by the same composition of hop resins and hop oils as aroma hops (e.g. Sládek, Hallertau Tradition and Spalter Select). The content of alpha acids is about 3–6%. Hop cones preserve their intensive aroma.

3. Dual purpose hops. This group comprises hop varieties which were recently developed by hybridizing bitter hops with regional aroma hops in order to achieve a higher content of alpha bitter acids (around 6–9%), increase yields and preserve the hoppy aroma of hop cones. They are characterized by a combination of these characteristics, and therefore they can be used either as aroma hops or bitter hops in beer brewing. Both foreign hop varieties (Perle, Marynka, Aurora, etc.) and Czech hops (Bor and Premiant) fall within this group.

4. Bitter hops. This group consists of traditional hop varieties that are remarkable for a higher content of alpha bitter acids (6–10%) and lack of an acceptable hoppy aroma. It is a category of older foreign hop varieties such as Northern Brewer, Brewers Gold, Golding and Cluster.

5. High alpha hops. They are hybrid hop varieties with a high content of alpha bitter acids, ranging from 12 to 16%. The harvested hop cones are primarily used for the production of hop extracts. These hop varieties have a sharp aroma with different components. The group includes primarily foreign hops such as Target, Magnum, Taurus, Herkules and Columbus (CTZ) as well as the Czech Agnus, Vital and Gaia hop varieties.

As suggested above, hop breeding in the Czech Republic is also divided into several areas. The newly registered Saaz

Brilliant, Saaz Comfort and Saaz Shine hop varieties rank among fine aroma hops. In terms of hop resins, the content of alpha and beta acids is a priority. In aroma hops, it is desirable to achieve a balanced alpha/beta ratio. In high alpha hops, the ratio should be about 2. It is necessary to mention that the development of hop varieties is the result of long-term breeding efforts (Nesvadba and Krofta, 2002). In recent years, preference has been given to flavour hops. Kazbek was registered in 2018 (Krofta, 2013) and Mimosa in 2019 (Nesvadba and Charvátová, 2020). Additional genotypes are going through registration tests. They have citrusy, fruity, spicy or woody aromas. When a new hop variety is registered, it is necessary to present it to breweries. Therefore, brewing tests and seminars are organized during which brewers from Czech breweries and microbreweries can participate in the evaluation of quality parameters.

The aim of this work was to evaluate beers that are hopped with Czech varieties. The achieved results reflected the preferences of selected Czech brewers.

## 2 Material and methods

Three series of tests were performed in cooperation between the Hop Research Institute in Žatec and Arix a.s. Žatec in the years 2020 and 2021. The objective of beer tasting was to establish brewing characteristics of the tested hop varieties.

The content of alpha acids was determined by using liquid chromatography (EBC 7.7, 2012). The content and composition of hop oils was determined from dry hop cones by using gas chromatography (Krofta, 2008).

All brewing tests were performed in the microbrewery of the Hop Research Institute in Žatec. The following traditional method was used to produce lagers: mashing, one-mash decoction, lautering, hop boiling for 90 minutes (1<sup>st</sup> hopping after the beginning of boiling, 2<sup>nd</sup> hopping after 30 minutes, 3<sup>rd</sup> hopping 10 minutes before the end of boiling), open fermentation and secondary fermentation in a lager cellar. Hopping of ale style top fermented beers: 1<sup>st</sup> dose at the beginning of boiling, 2<sup>nd</sup> 10 minutes before the end of boiling and 3<sup>rd</sup> in the whirlpool.

All beers were filtered with a plate filter and bottled into 0.33 l bottles. Bottling took place 3 days before beer tasting. Beers were stored at the temperature of 2 °C and tasted at 7–9 °C.

1<sup>st</sup> series: testing of fine aroma hop varieties.

**Saaz** was developed by clonal selection from the original vegetation in the Žatec and Ústěk regions. In 1952, Osvald's clones were registered under designations 31,

72 and 114. The content of alpha acids is 4.5–7.0%, beta acids 4.5–7.0%, share of cohumulone 33–40% rel. and weight of hop oils 0.7–1.6 g/100 g.

**Saaz Comfort** was developed by selection from the descendants of the Russian Serebrjanka mother plant and the Saaz male plant (found in the production vegetation in Liběšice near Žatec). It was registered in 2019.

**Saaz Late** was developed by selection from descendants of parental combination of semi-finished breeding material with Saaz in its origin. It was registered in 2010.

**Saaz Shine** was developed by selection from descendants of the Sládek mother plant and the Saaz male plant. It was registered in 2019.

**Table 1 shows the hopping method and basic beer analyses. The evaluation focused on two aspects:**

1. Overall popularity
2. Agreeability of bitterness

Based on the evaluation, the compared beer samples were given a ranking (1–4).

In 2021, ale was evaluated. Each hop variety was used for 100% of hopping, for whirlpool and dry hopping in a dose of 3 g/l. The beer hopped with Kazbek had an EPM of 11.9% and an IBU of 45.0. The beer hopped with Cascade had an EPM of 12.0% and an IBU of 46.8.

**The evaluation focused on two aspects:**

1. Identification of the correct pair.
2. If samples were identified correctly, preference was evaluated.

**3<sup>rd</sup> series:** application of the new Gaia variety in top fermented and bottom fermented beers.

**Gaia** was developed by selection from hybrid descendants of the Agnus hop variety and a male plant originating from the Yeoman hop variety and breeding material resulting from hybridization of Czech and foreign hop varieties. It was registered in 2017. Gaia ranks among bitter hops (Nesvadba, 2018). It has a sharp hoppy aroma and its content and composition of hop resins is typical of a Czech bitter variety (Nesvadba and Krofta, 2002).

**Table 1** Hopping and basic beer parameters for the 1<sup>st</sup> series of testing

Sample	1 <sup>st</sup> hopping	2 <sup>nd</sup> hopping	3 <sup>rd</sup> hopping	EPM	IBU
1	Agnus 33%	Agnus 11% Saaz 22%	Saaz 33%	12.3%	42.5
2	Agnus 33%	Agnus 11% Saaz Comfort 22%	Saaz Comfort 33%	11.9%	42.3
3	Agnus 33%	Agnus 11% Saaz Late 22%	Saaz Late 33%	11.9%	37.3
4	Agnus 33%	Agnus 11% Saaz Shine 22%	Saaz Shine 33%	12.3%	39.0

**2<sup>nd</sup> series:** a comparison of the Kazbek and Cascade hop varieties in a triangle test (two identical samples and one different sample) – they were evaluated in the lager beer style.

**Kazbek** was developed by hybridizing the Bor hop variety and a male plant with Russian wild hops in its origin. It was registered in 2008.

**Cascade** was developed from descendants resulting from hybridization of Fuggle, Serebrjanka and American breeding material. It was registered in 1971. The content of alpha acids was 4.5–7.0%, beta acids 4.5–7.0%, the share of cohumulone was 33–40% rel. and the weight of hop oils was 0.7–1.6 g/100 g (USA Hops, 2009).

Lager beers were evaluated in this series. Each hop variety was used for 100% of hopping. Beer hopped with Kazbek had an EPM of 11.4% and an IBU of 39.9. Beer hopped with Cascade had an EPM of 11.3% and an IBU of 39.2.

The content of alpha acids was 12.0–15.0%, beta acids 5.0–10.0%, the share of cohumulone was 20–39% rel. and the weight of hop oils 1.5–2.5 g/100 g (Nesvadba et al., 2017).

Gaia was tested in lagers (the technology was the same as in previous lager beers) and in ale with and without dry hopping (3 g/l). The beers were produced as lager and ale with or without dry hopping.

**The evaluation focused on three parameters:**

1. Character of aroma
2. Character of bitterness
3. Overall impression after drinking (popularity)

They were all evaluated with points on the scale from 1 (the lowest evaluation) to 5 (the highest evaluation).

Pilsner malt and yeast imported from the Krušovice brewery were used for lager beers. Pilsen malt, Pale Ale and caramel malt, Fermentis US05 yeasts, were used for the ale type. Hop pellets were used for all beers. All beer samples were evaluated by Czech brewers. A sensory panel was formed by 45 evaluators. Beer samples were in 0.33 l bottles.

The significance of difference between hop varieties was determined based on the t-test. The difference of sets was determined on the basis of significance level  $\alpha$ , which shows the probability of difference of the tested sets (Meloun and Militký, 1994). For example, if the significance level is determined as  $\alpha = 0.01$ , it means there is a 99% probability that the sets under review are different.

### 3 Results and discussion

All 3 series were tasted on the same day in intervals needed by the beer tasters. Different questionnaires were used in each series, depending on the purpose of the beer tasting.

#### 1<sup>st</sup> series – testing of fine aroma hop varieties

Table 2 shows that Saaz Comfort has the lowest average ranking in the overall popularity of beer (2.22). It is followed by Saaz (2.51) and Saaz Late (2.60). Saaz Shine has the highest average ranking in popularity. The statistical significance of the difference between hop varieties was determined by using the t-test (Table 3). With a 95% probability, Saaz Comfort has a significantly lower average ranking in popularity than Saaz Shine. No statistical

significance of difference was established between other hop varieties. Saaz Comfort received the best evaluation. It ranked as the first 13 times and as the second 17 times, which corresponds to almost two thirds of evaluators. Saaz ranked as the first 11 times and as the second 13 times, which means a half of evaluators. Overall, Saaz Late can be characterized as neutral. It ranked as the second and third most frequently. Saaz Shine has the highest average ranking, namely 2.71. Nevertheless, it came first 11 times. This hop variety either received excellent evaluation or the opposite – it was evaluated as almost the worst one. It looks as if no average evaluation existed for Saaz Late. It is the type of hop variety that will be very popular in many breweries whereas in other breweries it will not be suitable for their type of beer. As for the statistical significance, it can be stated that the new hop varieties do not show a significant difference from older hop varieties – Saaz and Saaz Late. However, there is a statistical significance when comparing Saaz Comfort and Saaz Shine. This difference is important because it expresses the objective of breeding – to develop such hop varieties that are not identical and do not compete with each other. The results suggest that they are not significantly different from Saaz because they are fine aroma hops. Evaluation and ranking also included intensity and aftertaste of bitterness.

In addition, agreeability of bitterness was evaluated by 39 beer tasters. Table 4 shows that Saaz Comfort received the best evaluation. This hop variety has the lowest average ranking (2.00). 27 beer tasters evaluated the beer brewed from this hop variety as their first or second choice. Saaz has an average ranking in agreeability of bitterness of 2.26. No significance of difference was

**Table 2** Average ranking in popularity of evaluated beers brewed from the tested hop varieties

Hop variety	Frequency of ranking				Average ranking	Ranking of samples
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>		
Saaz	11	13	8	13	2.5	2
Saaz Comfort	13	17	7	8	2.2	1
Saaz Late	8	11	17	9	2.6	3
Saaz Shine	11	5	15	14	2.7	4

**Table 3** Significance of difference in ranking in popularity of the evaluated beer samples based on the t-test

Hop variety	Saaz Comfort	Saaz	Saaz Late
Saaz	-	-	-
Saaz Late	-	-	-
Saaz Shine	0.05	-	-

determined in comparison with any of the tested hops (Table 5). In contrast, Saaz Comfort shows a significantly better evaluation than Saaz Shine and Saaz Late. The Saaz Shine and Saaz Late hop varieties were evaluated by 22 beer tasters as number three or four in the ranking, and therefore their average ranking in agreeability of bitterness is 2.51 or 2.54, respectively.

the increase and decrease in bitterness are identical. The bitterness ends 30 seconds after drinking. The Saaz Shine hop variety has very similar times of beginning and maximum intensity of bitterness as Saaz but is different in the character of aftertaste. It is clear that this hop variety preserves a higher intensity of bitterness for the longest time and the aftertaste gradually diminishes after 21 sec-

**Table 4** Average ranking in agreeability of bitterness of the evaluated beers brewed from the tested hop varieties

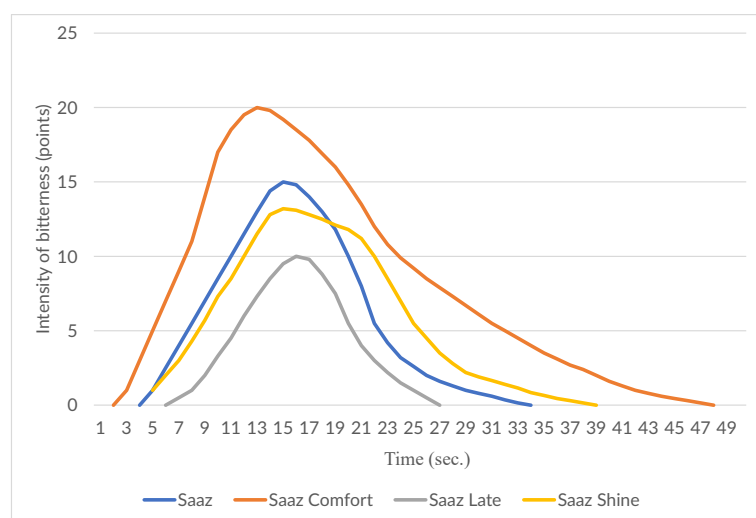
Hop variety	Frequency of ranking				Average ranking	Ranking of samples
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>		
Saaz	12	10	12	5	2.3	2
Saaz Comfort	17	10	7	5	2.0	1
Saaz Late	9	8	14	8	2.5	3
Saaz Shine	11	6	13	9	2.5	4

**Table 5** Significance of difference in agreeability of bitterness of the evaluated beer samples based on the t-test

Hop variety	Saaz Comfort	Saaz	Saaz Shine
Saaz	-	-	-
Saaz Shine	0.01	-	-
Saaz Late	0.05	-	-

Figure 1 shows that there is a difference in the time of reaching the highest intensity. Saaz Comfort reached the maximum intensity of bitterness after 12 seconds, Saaz and Saaz Shine after 15 seconds and Saaz Late after 16 seconds. It is evident that Saaz Comfort has the highest intensity (20 points) and Saaz Late the lowest intensity (10 points). In Saaz, the perception of bitterness begins after 5 seconds and the maximum bitterness at the level of 15 points is reached after 15 seconds. It is clear that the increase and decrease in intensity are similar. However, after 22 seconds, the aftertaste gradually diminishes until after 34 seconds. In Saaz Comfort, the first perception of bitterness begins as early as 3 seconds after drinking. The maximum bitterness at the level of 20 points is reached after 12 seconds. The aftertaste decreases more gradually until after 48 seconds. It can be stated that Saaz Comfort demonstrates an intensive but fine bitterness with a slowly diminishing aftertaste. Saaz Late has a bitterness perception after 9 seconds. This hop variety also has the lowest sensory intensity of bitterness (10 points) after 16 seconds. The figure shows that

onds. After this period of time, the character of aftertaste is identical with that of Saaz. This phenomenon could probably influence the evaluation of beers since the opinions of evaluators differed considerably. In conclusion, it is necessary to note that this evaluation is subjective. Furthermore, different levels of bitterness in beers can lead to different results. The objective was to describe the development of bitterness in graphic representation.



**Figure 1** Intensity and character of bitterness aftertaste in fine aroma hops

### 2<sup>nd</sup> series – a comparison of the Kazbek and Cascade hop varieties in a triangle test

The objective of beer tasting was to determine the difference between lager beers hopped with Kazbek or Cascade. The beer tasters evaluated 3 samples of beers in the following sequence:

- A Kazbek
- B Cascade
- C Cascade.

Only 16 out of 42 beer tasters determined the correct pair (Table 6), which is statistically insignificant. As part of this beer tasting series, beers hopped with Kazbek or Cascade were recognized. Out of 16 correct identifications, Kazbek was preferred 11 times and Cascade only 5 times. The t-test was used to determine that Kazbek is preferred over Cascade with a 95% probability.

**Table 6** A comparison of Kazbek and Cascade in lagers

Determination of the correct pair of beers		Preferred ranking	
Yes	No	Kazbek	Cascade
16	26	11	5

The second beer tasting of these hop varieties took place in 2021. The objective of the beer tasting was to determine the difference between ale beers hopped with Kazbek or Cascade again. The beer tasters evaluated 3 beer samples in the following sequence:

- A Kazbek
- B Kazbek
- C Cascade.

**Table 7** A comparison of Kazbek and Cascade in ale

Determination of the correct pair of beers		Preferred ranking	
Yes	No	Kazbek	Cascade
30	15	18	12

Only 30 out of 45 beer tasters determined the correct pair (Table 6), which is statistically significant with a 99% probability. It means that in this beer tasting round the beers hopped with Kazbek or Cascade were recognized. Out of 30 correct identifications, Kazbek was preferred 18 times and Cascade 12 times. The t-test was used to determine that Kazbek is more frequently preferred over Cascade with a 90% probability.

### 3<sup>rd</sup> series – application of the new Gaia variety in top fermented and bottom fermented beers

The Gaia hop variety was tested in lager beer and in ale with or without dry hopping. The average points are specified in Table 8.

Gaia has the highest average evaluation of aroma character in the lager with dry hopping (2.86 points). The lager and the ale have almost the same evaluation – 2.66 and 2.65 points, respectively. Gaia has the lowest average evaluation in the ale with dry hopping (2.29 points). The t-test was used to determine the statistical significance of the difference between the evaluated beers in terms of their aroma character (Table 9). A significant difference (95% significance) was determined only between the lagers with dry hopping and the ale with dry hopping.

Evaluation of bitterness character suggests the highest average evaluation in the lagers with dry hopping (2.61 points). The lager and the ale with dry hopping have almost the same average evaluation – 2.37 and 2.30 points, respectively. Gaia has the lowest average evaluation in the ale beer style (2.13 points). Statistical significance with a 95% probability was determined only between the lager with dry hopping and the ale (Table 10).

The overall impression after drinking (popularity) is the most important parameter. Gaia is a Czech bitter hop variety and its results suggest that it could be used in the Bohemian type of lager beer (Table 11). Within the results achieved, it received the highest score in the lager with dry hopping (2.98 points) and in the lager (2.90 points). The lowest average evaluation of the overall impression after drinking was given to Gaia in the ale (2.56 points) and the ale with dry hopping (2.10 points). With a 99% probability, the lager with dry hopping has a significantly higher evaluation than the ale with dry hopping. With a 90% probability it has a significantly higher evaluation than the ale (Table 8). The lager has a significantly higher evaluation than the ale with a 90% probability and than the ale with dry hopping with a 99% probability. Significance of the difference between the lager and the lager with dry hopping as well as between the ale and the ale with dry hopping was not established.

**Table 8** Average scores of Gaia

	Character of aroma		Character of bitterness		Impression after drinking	
	Average score	Ranking	Average score	Ranking	Average score	Ranking
Lager	2.7	2	2.4	2	2.9	2
Lager + dry hopping	2.9	1	2.6	1	3.0	1
Ale	2.7	3	2.1	4	2.6	3
Ale + dry hopping	2.3	4	2.3	3	2.1	4

**Table 9** Significance of difference in aroma character based on the t-test

	Lager + dry hopping		
Lager	-	Lager	
Ale	-	-	Ale
Ale + dry hopping	0.05	-	-

**Table 10** Significance of difference in bitterness character based on the t-test

	Lager + dry hopping		
Lager	-	Lager	
Ale + dry hopping	-	-	Ale + dry hopping
Ale	0.05	-	-

**Table 11** Significance of difference in overall impression after drinking based on the t-test

	Lager + dry hopping		
Lager	-	Lager	
Ale	0.1	0.1	Ale
Ale + dry hopping	0.01	0.01	-

The results achieved can be viewed as a statement of results presented by a certain group of beer tasters. For example, the Gaia hop variety shows the lowest popularity in ale with dry hopping but 10 beer tasters evaluated it with 4 points and 13 evaluators with 1 point. Lager beers were evaluated with 4 or 5 points by 12 beer tasters but only 1 or 3 beer tasters, respectively, gave 1 point to these beers. It shows that Gaia in ale with dry hopping receives very low or high evaluations. It is interesting that ale with dry hopping does not have an average evaluation – it either tastes good or it is unpleasant.

#### 4 Conclusion

Brewing tests with Czech hop varieties are very important for breweries. New knowledge makes it possible to identify additional applications for both existing and newly registered hop varieties. The results show that the newly registered Saaz Comfort and Saaz Shine hop vari-

eties have a different evaluation than Saaz and Saaz Late. However, the differences are not statistically significant. In contrast, there is a statistically significant difference between Saaz Comfort and Saaz Shine. This phenomenon shows that new hop varieties are not a substitute for the existing hop varieties. On the contrary, thanks to their characteristics they extend the variability of Czech aroma hops. Every brewery uses a particular hop variety depending on their beer character. This also applies when Kazbek and Cascade are being compared. Beer tasters did not provably recognize the correct pair of tested beers. However, it is interesting that those who did recognize it preferred Kazbek. This shows that the Kazbek hop variety is also suitable for bottom-fermented beers even though it has a citrusy hop aroma. Many Czech breweries are testing this hop variety in lager beers. The results of beer tasting also show that Gaia is suitable for lagers. It receives a better evaluation in lagers, with or without dry hopping, than in ale. The Gaia hop variety is not likely to be used as a single hop but the evaluation shows clearly

in which beer style it has found its place. Nevertheless, it needs to be mentioned that some beer tasters preferred this hop variety in ale with dry hopping. This leads to an unambiguous conclusion: hop varieties can be recommended but breweries decide for themselves where and for which beer style they will be used.

In 2021, the new Saaz Comfort, Saaz Shine and Saaz Brilliant fine aroma varieties were grown on an area of at least 0.5 hectares. A harvest at the level of 1 ton of dry hops can be expected if full fertility is assured. Gaia is already being grown on 0.4 hectares. Depending on the breweries' interest, the growing areas will be expanded later.

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