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Annual Report 2023

Special Crop: Hops

Bavarian State Research Center for Agriculture

- Institute for Crop Science and Plant Breeding -

and

Society for Hop Research

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Annual Report 2023

Special Crop: Hops

Foreword

After an exceptionally weak world hop harvest in 2022, hopes for hop production focused on the 2023 crop year. Unfortunately, the growing conditions in Central Europe in the summer of 2023 were disappointing, with many long periods of hot days and not enough precipitation. We are observing advancing and extreme climate change, which is upon us much faster than the various climate models have predicted. The consequences have a decisive influence on hop production in Central Europe. Especially a long dry period from mid-May to the end of June 2023 affected the hop plants severely in terms of both quality and, more so, quantity, all the way until harvest time.

To counter the diverse effects of climate change decisively in the future and still be able to produce German hops competitively and of high quality for the brewing industry, it is necessary to optimize what we do in many areas. This involves questioning tried and tested methods and making room for new techniques and innovative thinking. Thus, our research goes in two directions: On the one hand, we are developing models and practices to improve sustainability in hop production, which also help to blunt the forces of climate change. On the other, we are strategically repositioning ourselves, which should allow us to master the challenges of tomorrow's hop cultivation and to ensure a sufficient hop supply.

One fundamental but very lengthy solution is the breeding of new, climate-adapted, and healthier hop varieties. This path will take some getting used to in the brewing industry. However, we have already made great strides with the introduction of several new varieties, including the high-alpha variety Titan and the aroma variety Tango. Further work at the Hop Research Center Hüll (IPZ5) on optimizing hop kilning, for instance, helps to save primary energy, reduce CO2 emissions, and preserve hop quality. Novel approaches in the field of plant protection rely on the hop plant's natural defense mechanisms to combat spider mites, while at the same time contributing to the preservation of biodiversity. The challenges facing German hop cultivation are complex and can only be overcome if everyone involved in the entire hop value chain works together. My thanks therefore go to the staff members who contributed to the research results presented in this 2023 Annual Report, either as partners of the Society for Hop Research or as employees of the Hüll Hop Research Center.

In 2002, we started to place the annual reports online in both German and English. This means that plenty of valuable information can now be accessed quickly, easily, and worldwide. Creativity and innovation do not come out of nowhere. Rather, they are the result of interdisciplinary exchanges between scientists around the world. It is therefore important to us to consolidate the current state of knowledge, to make what we have learned available, and to continue to cooperate to ensure the sustainable and successful evolution of both hop production and the brewing industry.

Dr. Michael Möller
Chairman of the Board
Society for Hop Research

Dr. Peter Doleschel
Head of the Institute for
Crop Science and Plant Breeding

Table of Contents

Page

1 Statistical Hop Production Data

Managing Director (LD) Johann Portner, Dipl.-Ing. agr.

1.1 Acreage data

1.1.1 Structure of hop production

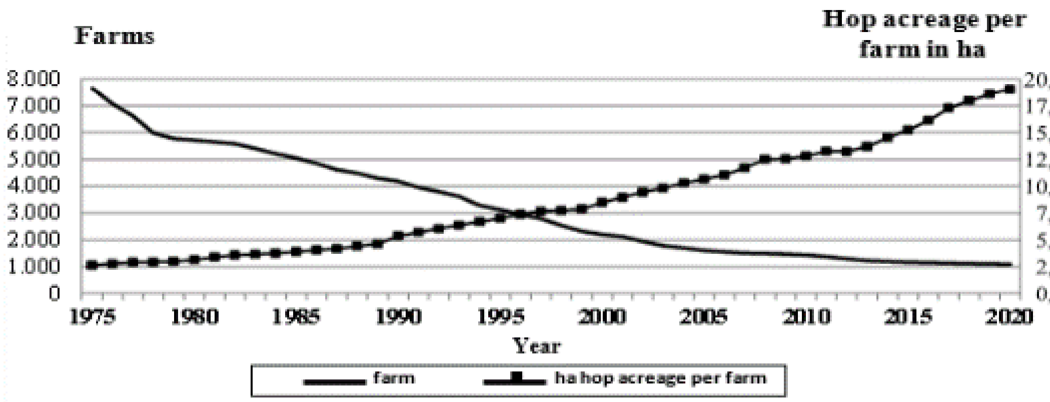


Table 1: Number of hop farms and their acreages in Germany

Year	Number of Farms	Hop acreage per farm in ha	Year	Number of Farms	Hop acreage per farm in ha
1975	7,654	2.64	2010	1,435	12.81
1980	5,716	3.14	2015	1,172	15.23
1985	5,044	3.89	2020	1,087	19.05
1990	4,183	5.35	2021	1,062	19.42
1995	3,122	7.01	2022	1,053	19.57
2000	2,197	8.47	2023	1,041	19.82
2005	1,611	10.66			

Figure 1: Number of hop farms and their acreages in Germany

Table 1: Area under hop cultivation, number of hop farms, and average acreage per farm in each of the German growing regions

Growing area	Hop acreage				Hop growers				Hop area per farm in ha	
	in ha		Increase + / Decrease - 2023 to 2022				Increase + / Decrease - 2023 to 2022			
	2022	2023	ha	%	2022	2023	Farm	%	2022	2023
Hallertau	17,111	17,129	18	0.1	854	841	- 13	- 1.5	20.04	20.37
Spalt	409	403	- 6	- 1.5	44	44	± 0	± 0	9.30	9.16
Tettnang	1,497	1,517	20	1.3	124	124	± 0	± 0	12.07	12.23
Baden, Bitburg, Rhein-Palatinate	12	18	6	47.5	2	2	± 0	± 0	6.00	8.85
Elbe-Saale	1,575	1,563	- 13	- 0.8	29	30	1	3.4	54.33	52.09
Germany	**20,605**	**20,629**	**24**	**0.1**	**1,053**	**1,041**	**- 12**	**- 1.1**	**19.57**	**19.82**

Figure 2: Hop cultivation areas in Germany and in the Hallertau

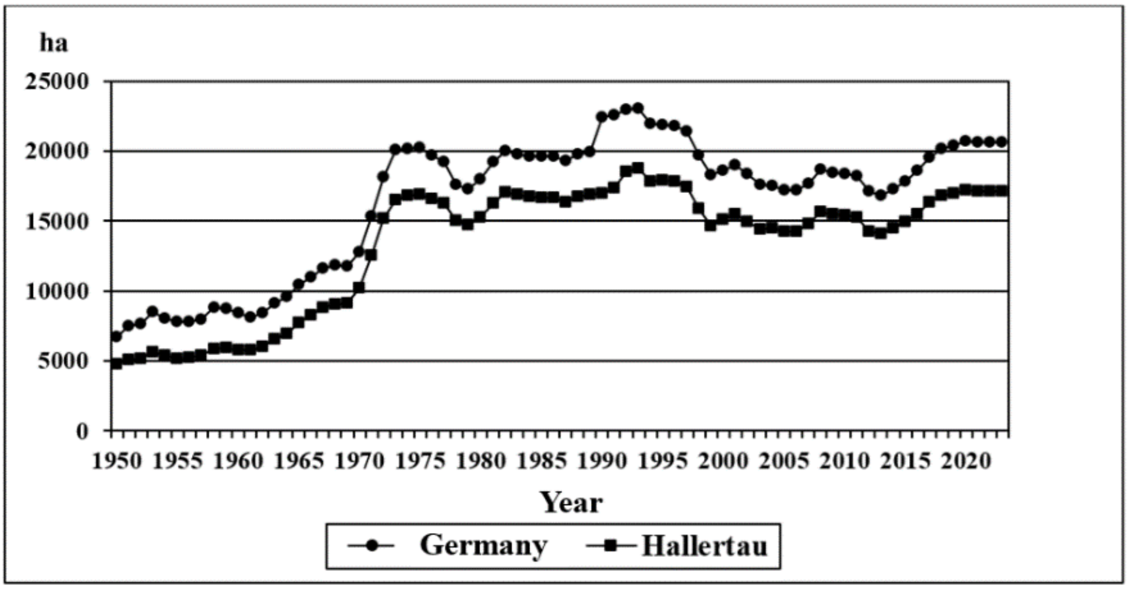


Figure 2: Hop cultivation areas in Germany and in the Hallertau

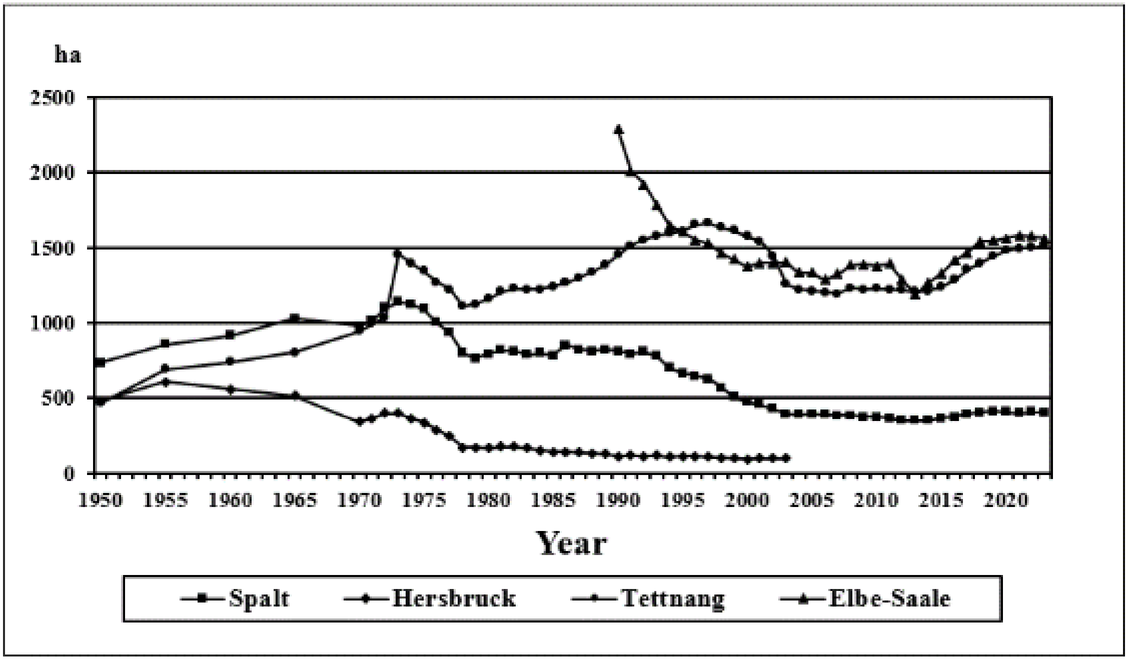


Figure 3: Hop cultivation areas in the Spalt, Hersbruck, Tettnang and Elbe-Saale areas

Statistically, since 2004, the Hersbruck growing area has been counted as part of the Hallertau.

1.1.2 Hop varieties

In 2023, the hop acreage in Germany has remained virtually unchanged at 20,629 ha, which represents a mere 24 ha drop from the previous year.

The share of aroma varieties fell further by 428 ha to 50.3%. The statistics show a total of 37 different aroma varieties planted on 10,374 ha. Most aroma varieties lost area. The key varieties Perle (-119 ha) and Hallertau Tradition (-84 ha) recorded the largest area decline in this segment. There was also significant clearing of Amarillo, several local varieties, finer aroma varieties, as well as so-called "flavor varieties." On the other hand, there were notable increases in area for such newer aromatic varieties as Tango and Akoya.

The bitter hop acreage increased again, this time by 451 ha, and now accounts for 49.7% or 10,255 hectares. Again, the older bitter varieties Hallertauer Magnum (- 43 ha), Hallertauer Taurus (-14 ha), and Nugget (- 9 ha) have seen a decline in area, while the high-alpha varieties Herkules (+ 356 ha) and Polaris (+ 67 ha) gained area. This makes Herkules by far the most plentiful hop variety cultivated in Germany (7,498 hectares). It is now grown on more than one-third of the total hop area. A new arrival in this segment is the high-alpha variety Titan with a cultivation area of 94 hectares.

Table. 2: Hop varieties in the German growing regions in hectares in 2023

Aroma Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Akoya	112		5	14		**131**	**0.6**	**8**
Amarillo	89			2		**90**	**0.6**	**-48**
Amira	2					**2**	**0.0**	**2**
Ariana	48	4	2			**54**	**0.3**	**-18**
Aurum	0		4			**4**	**0.0**	**0**
Brewers Gold	14					**14**	**0.1**	**0**
Brokat	0					**0**	**0.0**	**0**
Callista	33	1	8	14		**56**	**0.3**	**-4**
Cascade	55	4	3	3	1	**65**	**0.3**	**3**
Chinook						**0**	**0.0**	**0**
Comet	5					**5**	**0.0**	**0**
Diamant	11	9				**20**	**0.1**	**4**
Hallertau Blanc	92	2	13	5		**112**	**0.5**	**-15**
Hallertauer Gold	5	2				**7**	**0.0**	**0**
Hallertauer Mfr.	448	27	138	2		**615**	**3.0**	**-21**
Hallertauer Tradition	2,486	40	107	67	2	**2,702**	**13.1**	**-84**
Hersbrucker Pure	1	1				**2**	**0.0**	**-1**
Hersbrucker Spät	778	6	0			**785**	**3.8**	**-25**
Hüll Melon	36	5	7			**48**	**0.2**	**-9**
Lilly						**0**	**0.0**	**0**
Mandarina Bavaria	170	3	10	4		**187**	**0.9**	**-8**
Monroe	9		2			**11**	**0.1**	**-7**
Northern Brewer	83			109		**192**	**0.9**	**-38**
Opal	133	1	3			**137**	**0.7**	**2**
Perle	2,765	42	143	280	7	**3,235**	**15.7**	**-119**
Relax	2					**2**	**0.0**	**-2**
Rottenburger			1			**1**	**0.0**	**0**
Saazer	5			151		**156**	**0.8**	**-5**
Samt						**0**	**0.0**	**0**
Saphir	255	18	41	16		**330**	**1.6**	**-44**
Smaragd (Emerald)	43	1	14			**57**	**0.3**	**-9**
Solero	9		2			**11**	**0.1**	**-2**
Sarachi Ace						**0**	**0.0**	**0**
Spalter		106				**106**	**0.5**	**0**
Spalter Select	417	79	27	4		**528**	**2.6**	**-10**
Tango	55	1	2	3	0	**62**	**0.3**	**30**
Tettnanger			646			**646**	**3.1**	**-8**
Total (ha)	**8,161**	**352**	**1,178**	**673**	**10**	**10,374**	**50.3**	**-428**
Percentage (%)	**39.6**	**1.7**	**5.7**	**3.3**	**0.0**	**50.3**		**-2.1**

Bitter Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Eureka (EUE05256)	6					**6**	**0.0**	**4**
Hallertauer Magnum	1,159	1		610		**1,770**	**8.6**	**-43**
Hallertauer Merkur	2	3		1		**6**	**0.0**	**0**
Hallertauer Taurus	143	1	0	3		**147**	**0.7**	**-14**
Herkules	7,002	44	309	134		**7,498**	**36.3**	**356**
Nugget	100			1		**101**	**0.5**	**-9**
Polaris	410		25	126		**561**	**2.7**	**67**
Record	1					**1**	**0.0**	**0**
Titan	87	1	2	3		**94**	**0.5**	**94**
Xantia	16					**16**	**0.1**	**6**
Others	42		2	12		**56**	**0.3**	**-10**
Total (ha)	**8,968**	**51**		**890**	**8**	**10,255**	**49.7**	**451**
Percentage (%)	**43.5**	**0.2**		**4.3**	**0.0**	**49.7**		**2.2**

All Varieties

	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Total (ha)	**17,129**	**403**	**1,517**	**1,563**	**18**	**20,629**	**100.0**	**24**
Percentage (%)	**83.0**	**2.0**	**7.4**	**7.6**	**0.1**	**100.0**		**0.1**

1.2 Volumes, yields, alpha acid values

The 2023 hop harvest in Germany amounted to 41,234,230 kg, almost 20% more than the poor harvest of 34,405,840 kg of the previous year. However, compared to the excellent 2021 harvest (47,862,190 kg), there was still a decline of 16%.

With an average yield of 1,999 kg/ha based on the total area, the yield this season is 329 kg/ha above that of the previous year, but below the average of recent years.

A very different picture emerges for alpha acid contents. Some varieties had even lower values than the previous year's poor result. Herkules in particular had an average alpha acid content of only 13.9% (as sampled after the harvest in the Hallertau). This is the lowest average value ever measured for this variety. Multiplied by the harvest quantity, this amounted to only two-third of the alpha quantity of the very good 2021 harvest. Many varieties, however, had alpha acid contents above the poor previous year's level or even exceeded the long-term average. Examples are Hersbrucker, Spalter Select, and Nugget. Overall, the amount of alpha acids produced in Germany is expected to be 4,170 t. This exceeds the previous year's value by 12%.

Table 4: Harvest volumes and yields per hectare of hops in Germany

	2018	2019	2020	2021	2022	2023
Yield kg/ha	2.075	2.374	2.264	2.321	1.670	1.999
Cultivated area in ha	20,144	20,417	20,706	20,620	20,605	20,629
Total harvest in kg	41,794,270	48,472,220	46,878,500	47,862,190	34,405,840	41,234,230
Ø Alpha Acid content in %	9.6	10.9	11.6	13.0	10.8	10.1
Generated Alpha amount in MT	4,000	5,260	5,460	6,240	3,720	4,170

MT = metric ton

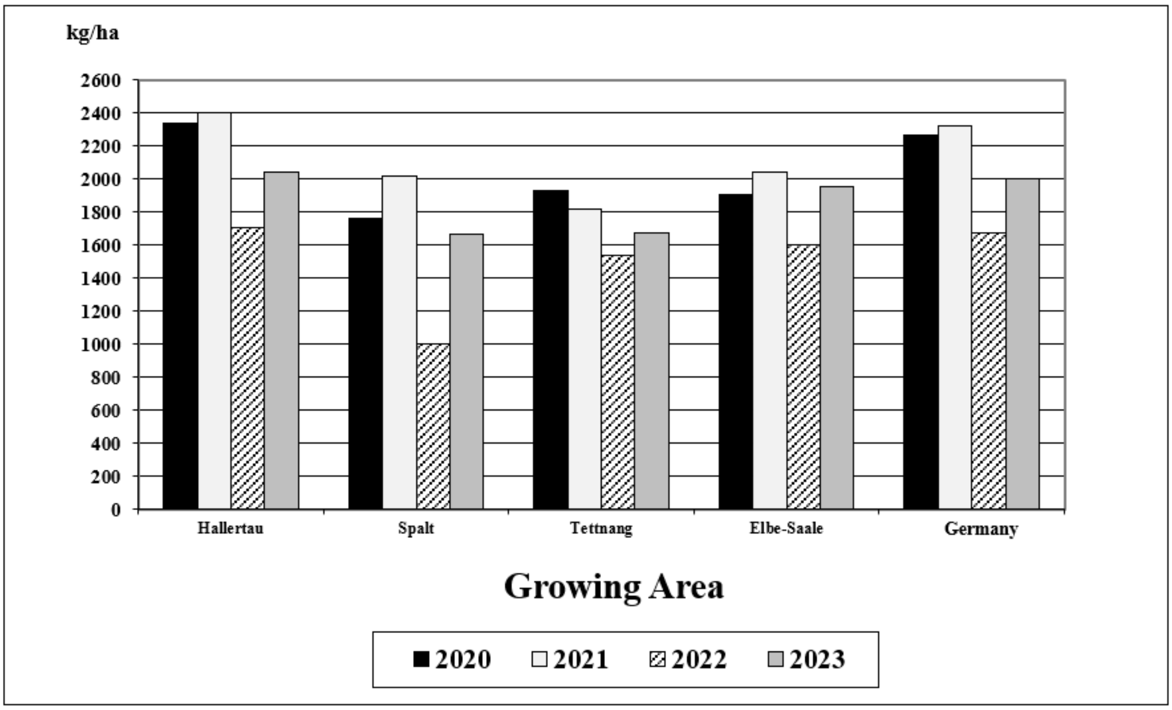
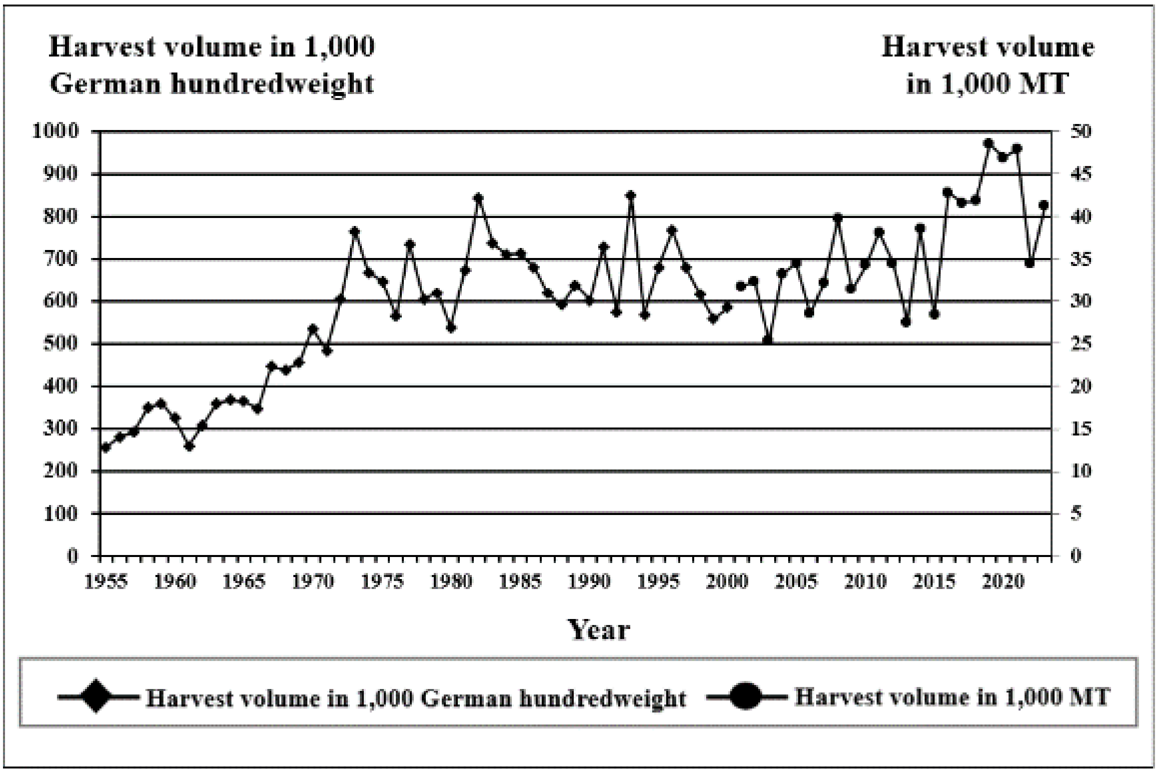
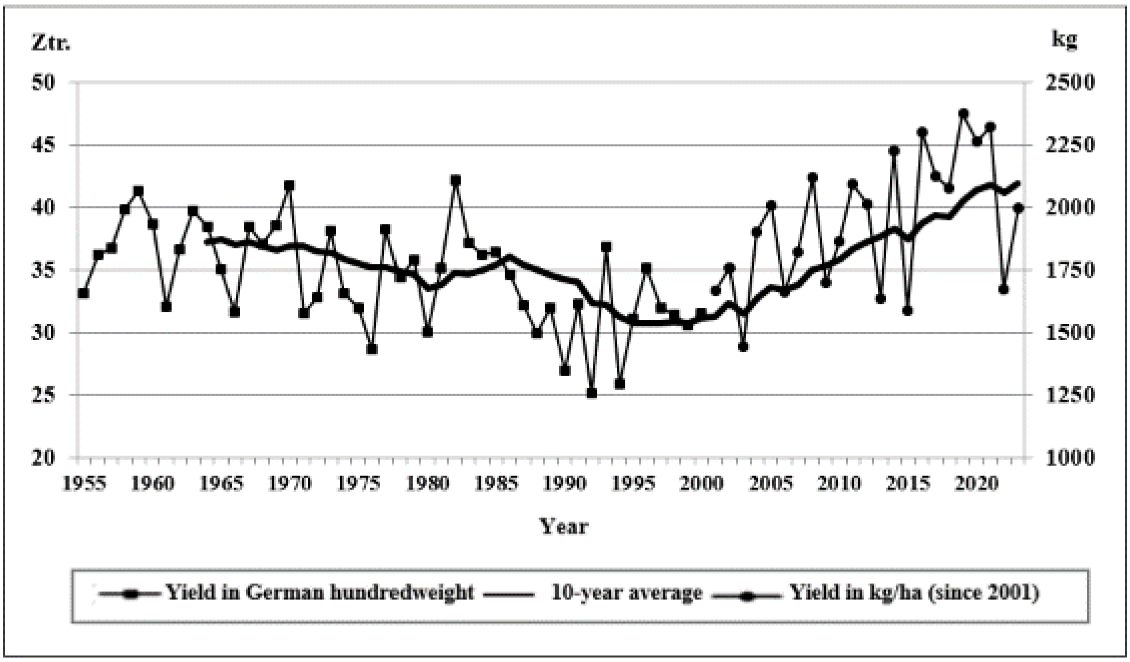


Figure 4: Average yields of individual growing areas in kg/ha



* 1 German Zentner (Ztr.) = 1 German hundredweight = approx. 50 kg

Figure 5: Total harvest volume in Germany



* 1 German Zentner (Ztr.) = 1 German hundredweight = approx. 50 kg

Figure 6: Average yield per hectare in Germany

Table 5: Yields per hectare in the German growing regions

Growing area	Yields in kg/ha total area								
	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Hallertau	1,601	2,383	2,179	2,178	2,441	2,338	2,400	1,704	2,040
Spalt	1,038	1,942	1,949	1,564	1,704	1,759	2,020	1,005	1,668
Tettnang	1,370	1,712	1,677	1,486	2,024	1,927	1,818	1,538	1,670
Rhineland-Palatinate/ Bitburg	1,815	1,957	1,990	1,985	2,030	2,003	973	1,017	1,299
Elbe-Saale	1,777	2,020	2,005	1,615	2,150	1,906	2,038	1,704	1,956
∅ Yield/ha Germany (kg)	**1,587**	**2,299**	**2,126**	**2,075**	**2,374**	**2,264**	**2,321**	**1,670**	**1,999**
Total harvest Germany (MT)	28,337	42,766	41,556	41,794	48,472	46,879	47,862	34,406	41,234
Cultivated area Germany (ha)	17,855	18,598	19,543	20,144	20,417	20,706	20,620	20,605	20,629

Table 6: Alpha acid values of select hop varieties in Germany

Growing area/variety	2014	2015	2016	2017	2018	2019	2020	2021	2022	**2023**	**Ø 5 Year**	**Ø 10 Year**
Hallertau Hallertauer	4.0	2.7	4.3	3.5	3.6	4.1	4.5	5.2	3.1	**2.9**	**4.0**	**3.8**
Hallertau Hersbrucker	2.1	2.3	2.8	2.3	2.0	2.5	3.3	4.6	1.9	**3.0**	**3.1**	**2.7**
Hallertau Hall. Saphir	3.9	2.5	4.0	3.0	3.3	3.3	4.2	4.3	2.6	**3.1**	**3.5**	**3.4**
Hallertau Opal	7.3	5.9	7.8	7.2	6.4	7.3	8.5	8.7	6.1	**6.7**	**7.5**	**7.2**
Hallertau Smaragd	4.7	5.5	6.2	4.5	3.0	5.0	5.8	7.6	4.0	**5.4**	**5.6**	**5.2**
Hallertau Perle	8.0	4.5	8.2	6.9	5.5	6.7	7.4	9.0	4.9	**6.0**	**6.8**	**6.7**
Hallertau Spalter Select	4.7	3.2	5.2	4.6	3.5	4.4	5.2	6.4	3.3	**4.7**	**4.8**	**4.5**
Hallertau Hall. Tradition	5.8	4.7	6.4	5.7	5.0	5.4	6.3	6.1	5.2	**4.9**	**5.6**	**5.6**
Hallertau Mand. Bavaria	7.3	7.0	8.7	7.3	7.5	7.9	9.0	9.9	8.2	**7.9**	**8.6**	**8.1**
Hallertau Hall. Blanc	9.0	7.8	9.7	9.0	8.8	9.0	10.9	9.9	8.1	**8.7**	**9.3**	**9.1**
Hallertau Huell Melon	5.4	5.8	6.8	6.2	5.8	6.6	7.2	8.4	6.3	**6.9**	**7.1**	**6.5**
Hallertau North. Brewer	9.7	5.4	10.5	7.8	7.4	8.1	9.1	10.5	6.4	**7.5**	**8.3**	**8.2**
Hallertau Polaris	19.5	17.7	21.3	19.6	18.4	19.4	20.6	21.5	18.5	**18.0**	**19.6**	**19.5**
Hallertau Hall. Magnum	13.0	12.6	14.3	12.6	11.6	12.3	14.2	16.0	12.2	**11.8**	**13.3**	**13.1**
Hallertau Nugget	9.9	9.2	12.9	10.8	10.1	10.6	12.0	11.1	9.9	**11.9**	**11.1**	**10.8**
Hallertau Hall. Taurus	17.4	12.9	17.6	15.9	13.6	16.1	15.5	17.8	14.6	**13.8**	**15.6**	**15.5**
Hallertau Herkules	17.5	15.1	17.3	15.5	14.6	16.2	16.6	18.5	15.4	**13.9**	**16.1**	**16.1**
Tettnang Tettnanger	4.1	2.1	3.8	3.6	3.0	3.8	4.3	4.7	2.6	**2.6**	**3.6**	**3.5**
Tettnang Hallertauer	4.6	2.9	4.4	4.3	3.8	4.3	4.7	5.0	3.2	**3.3**	**4.1**	**4.1**
Spalt Spalter	3.4	2.2	4.3	3.2	3.5	3.9	4.7	5.2	2.8	**3.0**	**3.9**	**3.6**
Spalt Spalter Select	4.5	2.5	5.5	5.2	2.9	4.1	4.7	6.4	2.8	**5.4**	**4.7**	**4.4**
Elbe-S. Hall. Magnum	11.6	10.4	13.7	12.6	9.3	11.9	11.9	13.8	12.0	**14.2**	**12.8**	**12.1**

Source: Arbeitsgruppe Hopfenanalyse (AHA) (Hop Analytics Working Group)

2 Weather and Growth Development

Managing Director (LD) Johann Portner, Agricultural District Administrator (LAR) Stefan Fuß, and Diplome Engineer, Agriculture, A. Baumgartner

2.1 Weather and growth development 2023

The hop year 2023 started unusually warm and dry, with a rainfall deficit that was compensated only in March and April. While conditions were still good for the initial growth phase and pruning in March, budding and hop growth was delayed by 5-8 days as a result of a cold and wet period in April. That made further pruning and the training of the bines possible again only in late April. The first half of May was also cool and rainy, but by the middle of the month the weather became significantly warmer every day, and it stopped raining. As the soil dried out, necessary tillage and maintenance measures could be carried out again starting in mid-May. The warm and dry weather continued into June. In the northern part of the Hallertau, fewer than 20 mm of precipitation fell throughout the entire month. Because of thunderstorms in the southern Hallertau, this region fared better, receiving up to 70 mm of rain in some places, in June. With 22 summer days (≥ 25 °C) and 5 hot days (≥ 30 °C), June turned out to be warmer than average and the hop plants managed to make up for their earlier development deficit by the end of the month. On marginal sites, however, and on structurally damaged soils, first growth abnormalities as a result of the persistent heat and drought began to appear, including unusually short horizontal shoots in the upper portions of the bines. Needed precipitation arrived only in July, but temperatures remained high and dropped slightly only in the last third of the month. There was significant rainfall, but it came too late for many plants, and losses in yield became already apparent.

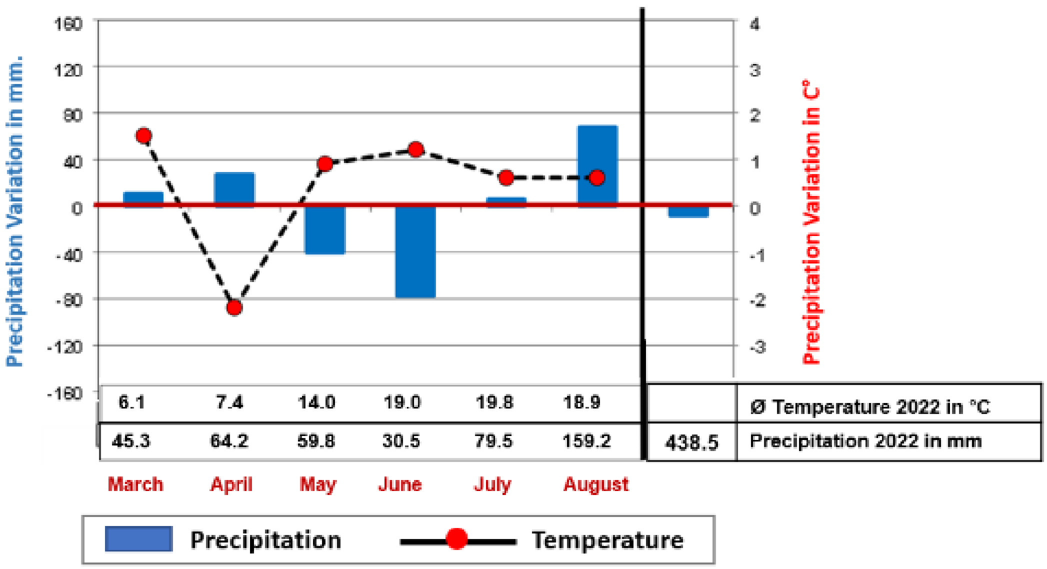


Figure 7: Weather during the 2023 growing season in Hüll by months as a deviation from the 10-year average

The cooler and rainy periods in August managed to limit further damage and yield losses. The hop plants took their time to develop cones and to mature, causing the harvest to start exceptionally late in the season, in early September, when a warm and dry spell helped to accelerate a final ripening. Overall, the Hallertau experienced relatively few heavy precipitation events in the summer of 2023; and there was only local erosion damage. The 438 mm of precipitation at the Hüll site between March and August was almost average. Nonetheless, there were great regional and timing variations in precipitation which made the situation very difficult in many locals, even though the aggregate amounts seemed to be sufficient. This uneven distribution had a fatal impact on hop yield and quality. In gardens with irrigation, the plants' needs could be taken into account, especially where the infrastructure for a balanced supply of nutrients via irrigation water (fertigation) existed. For the second year in a row, these plots clearly demonstrated the advantages of the technology in terms of yield and alpha acid content. As climate change advances, these new methods will become indispensable for the future of hop cultivation.

2.2 Problems resulting from disease and hop infestations

Alfalfa Snout Weevils/Lovage Weevils (*Otiorhynchus ligustici*) appeared only locally and could be controlled with the pesticide Exirel, which was approved for emergencies. Hop Flea Beetles (*Psylliodes attenuatus*), on the other hand, caused considerable damage to shoots and mature plants in several areas.

Primary downy mildew (*Pseudoperonospora humuli*) infections occurred only sporadically during the cold spring. However, stronger outbreaks of primary downy mildew infections were recorded after temperatures rose starting in mid-May that. The lack of precipitation and high temperatures subsequently prevented an increase in zoosporangia as well as the spread of secondary infections, so that the number of spores remained below damaging wave levels throughout the entire summer. Only the heavy rainfalls from mid-July onwards increased the downy mildew risk, meaning that 3-4 control measures were necessary, depending on the ripeness stage of the crop.

There were also several occurrences of powdery mildew (*Sphaerotheca macularis*). However, the extent of the damage remained below that in previous years. Thanks to the emergency approval of the broad-spectrum fungicide Luna Sensation, farmers had a good opportunity to combat the disease and were able to keep the pathogen at bay. The dry and hot summer weather also prevented greater damage from the dreaded *Verticillium* wilt.

The animal pathogens hop aphid (*Phorodon humuli*) and common spider mite (*Tetranychus urticae*) also caused a few problems. However, a single application of the plant protection product Movento was often sufficient to completely control the aphids; and no acaricide measures were necessary because of the additional effect of Movento against spider mites.

The spread of the Citrus Bark Cracking Viroid (CBCVd), which was first detected in the Hallertau in 2019, was once again examined in voluntary monitoring, in Bavaria, in 2023. The infestation still appears to be very limited and the spread is progressing only slowly. It seems that it can be controlled by adhering to strict hygiene measures.

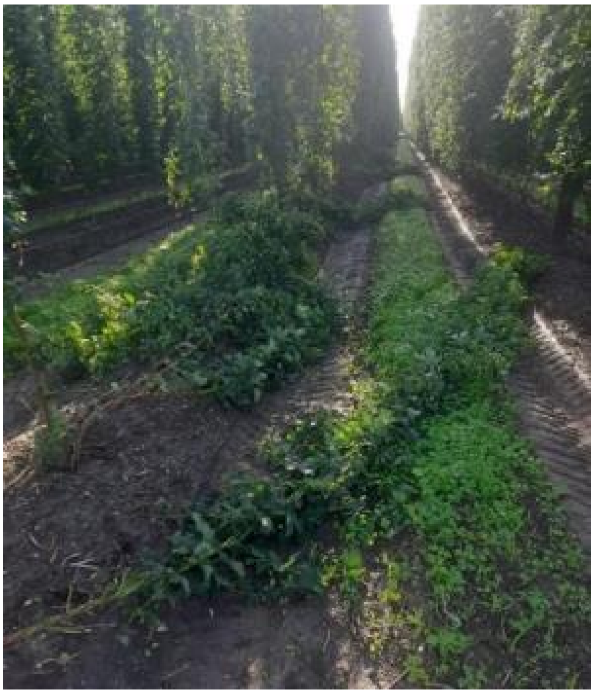
2.3 Out-of-the-ordinary events 2023

The unusual oscillations between intense phases of rain and extended periods of dry weather will probably be characterized as the key feature the 2023 German crop year. The results were low yields in large parts of the Hallertau and especially poor alpha acid values in the high alpha variety Herkules. The low disease pressure and the resulting excellent visual appearance of the crop could neither compensate for nor hide these deficiencies.

Also noticeable were visible symptoms of sunburn on the leaves, which occurred more frequently in August during hot weather, as well as some intense sunlight after periods of rain.

Figure 8: Sunburn on hop leaves (Photo: J. Portner)

The change in weather in August was often accompanied by strong thunderstorms, which caused local hail damage. When combined with strong winds, it also resulted in the downing plenty of bines before the harvest. Sometimes, these forces even led to the collapse of entire hop gardens in the southern Hallertau.



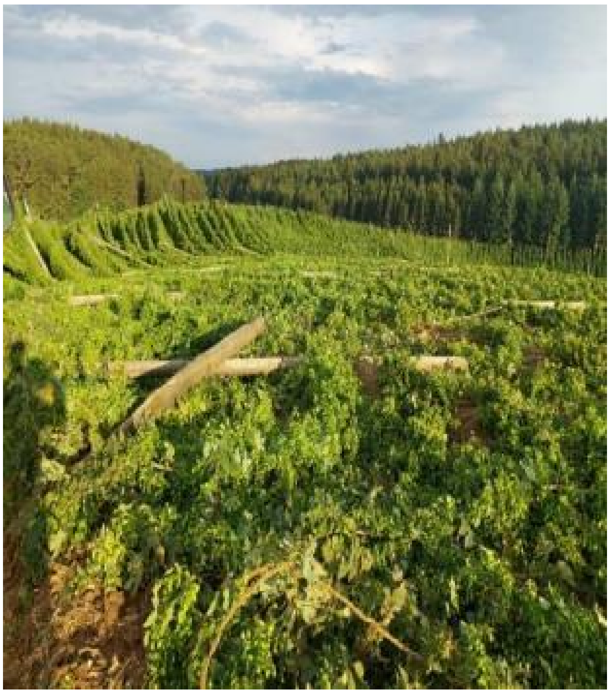


Figure 9: Fallen bines (Photo: J. Lechner)

Figure 10: Collapsed hop garden after a storm (Photo: Hopfenring)

Table 7: Weather data for 2023 (monthly averages or monthly totals) compared to the 10 and 30** year averages in Hüll*

Month		Temperature at 2 m elevation Mean (°C)	Min.∅ (°C)	Max.∅ (°C)	Relative Humidity (%)	Precipitation (mm)	Days w/ Precip. ≥0.2 mm	Sunshine (hours)
January	2023	2.5	-0.7	5.7	98.6	20.2	18.0	16.0
∅	10-y	0.2	-3.3	3.6	94.7	61.4	16.9	34.7
	30-y	-2.3	-5.9	1.1	86.7	50.8	14.8	47.1
February	2023	2.3	-1.5	6.8	94.4	30.9	11.0	77.0
∅	10-y	1.5	-3.0	6.2	89.0	46.4	12.4	76.8
	30-y	-1.0	-4.9	3.1	81.4	46.8	13.3	72.1
March	2023	6.1	1.1	11.8	91.2	45.3	14.0	122.0
∅	10-y	4.6	-1.1	10.5	80.8	34.9	12.1	162.2
	30-y	2.8	-1.7	7.8	78.9	47.7	13.8	132.2
April	2023	7.4	2.6	12.6	90.6	64.2	15.0	131.0
∅	10-y	9.6	2.8	15.3	75.6	37.5	9.9	203.5
	30-y	7.1	1.9	12.8	73.8	60.8	14.1	164.3
May	2023	14.0	8.1	20.3	84.0	59.8	9.0	219.0
∅	10-y	13.1	7.4	18.8	79.3	100.1	15.6	196.2
	30-y	11.9	6.1	17.7	73.9	82.3	15.4	203.6
June	2023	19.0	10.5	27.1	74.2	30.5	9.0	282.0
∅	10-y	17.8	11.4	24.0	78.1	107.9	12.6	243.0
	30-y	15.1	9.0	20.8	74.6	103.5	15.3	212.3
July	2023	19.8	12.4	27.6	82.2	79.5	17.0	236.0
∅	10-y	19.2	12.4	26.1	77.4	74.3	11.7	254.3
	30-y	16.7	10.5	23.1	74.3	90.5	14.1	236.8
August	2023	18.9	13.5	25.8	90.9	159.2	16.0	194.0
∅	10-y	18.3	11.9	25.3	82.3	91.9	11.3	235.3
	30-y	16.0	10.2	22.6	78.2	91.7	13.8	212.4
September	2023	16.7	10.0	25.1	91.6	16.0	5.0	239.0
∅	10-y	13.9	8.1	20.2	87.6	57.7	11.3	167.8
	30-y	12.7	7.4	19.1	80.7	67.9	11.6	175.0
Oktober	2023	11.6	5.8	18.5	93.4	45.6	13.0	125.0
∅	10-y	9.6	4.8	14.9	92.7	56.1	11.7	110.5
	30-y	7.6	3.2	13.1	84.2	51.1	11.0	117.2
November	2023	5.4	2.2	9.3	98.6	154.1	21.0	53.0
∅	10-y	4.4	1.0	8.4	95.5	48.6	12.8	50.6
	30-y	2.6	-0.6	6.1	85.5	57.5	14.4	52.9
December	2023	2.6	-0.8	6.4	98.4	126.0	19.0	43.0
∅	10-y	1.9	-1.3	5.8	96.1	48.6	14.7	36.0
	30-y	-0.9	-4.3	1.8	86.5	52.2	15.0	38.7
∅ Year	**2023**	**10.5**	**5.3**	**16.4**	**90.7**	**831.3**	**167.0**	**1,737.0**
10 – Year Mean		**9.5**	**4.3**	**14.9**	**85.8**	**765.4**	**153.0**	**1,770.9**
30 – Year Mean		**7.4**	**2.6**	**12.4**	**79.9**	**802.8**	**166.6**	**1,664.6**

* The 10-year mean covers the period between 2013 and 2022

** The 30-year mean covers the period between 1961 and 1990

3 Research and Permanent Technical Tasks

3.1 IPZ 5a – Technology in hop cultivation

Ongoing research projects of IPZ 5a (hop cultivation, production technology) funded by third parties

Working Groups Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5a J. Portner	Production and quality initiative for agriculture and horticulture in Bavaria – TS and alpha acid monitoring – Aphid and spider mite monitoring – Chlorophyll measurements to estimate the N-supply status	2019-2023	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (StMELF) *(The Bavarian State Ministry for Food, Agriculture and Forestry)*	Hopfenring e.V. *(Hop Circle)*
IPZ 5a J. Portner	Obtaining and testing the suitability of hop plant fibers for the production of nonwovens (6907)	2022-2023	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (StMELF) *(The Bavarian State Ministry for Food, Agriculture and Forestry)*	Service orders issued to various cooperation partners
IPZ 5a J. Portner A. Schlagenhaufer	Studies measuring soil moisture and irrigation control for resource-saving hop irrigation	2023	Erzeugerorga-nisation HVG e. G. *(HVG Hop Processing Group)*	P. Razavi, Fa. Irriport GmbH

Permanent tasks: Production-technical trials

Working Group	Project	Duration	Collaborators
5a	Training and continued education of hop growers	Permanent task	
5a	Specialized production engineering and business management consulting in hop production	Permanent task	
5a	Development and updating of documents for consulting services	Permanent task	
5a	Dissemination of advisory strategies and exchange of information with group advisory services	Permanent task	Hopfenring e.V. *(Hop Circle)*
5a	Generation of *Peronospora* infestation forecasts and warning messages	Permanent task	
5a	Generation of business data for contribution margin calculations and operational calculations	Permanent task	
5a	Optimization of PS applications and device technologies	Permanent task	

Working Group	Project	Duration	Collaborators
5a	Optimization of techniques and processes to prevent soil erosion and promote soil fertility in hop cultivation	Permanent task	IAB Soil: constant
5a	Testing various materials as a replacement of plastic cords on the “string wire”	2022-2023	Miscellaneous cord wire suppliers; Hop farms
5a	Optimization of drying processes in belt dryers	2022-2023	Hop farms
5a	Fertilizer trials with organic fertilizer in hops	2022-2025	Hop farms
5a	Tactile test on agro-PV systems on hops with regard to the occurrence of pathogens, yield, and quality (Bachelor thesis)	2023	Hop farm, Manuel Riedel
5a	Fertilizer trials to minimize nitrogen in the hop varieties Herkules and Perle	From 2023	

3.2 IPZ 5b – Crop protection in hop production

Ongoing research projects of IPZ 5b (crop protection in hop cultivation) funded by third parties

Working Groups Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5 S. Euringer, C. Krönauer F. Weiß	Establishment of a method for determining Dislodgeable Foliar Residue (DFR) values in hops	2023-2025	Bundesamt für Verbraucherschutz und Lebensmittel-sicherheit (BVL) *(The Federal Office of Consumer Protection and Food Safety)*	BfR, BVL, DLR RP
IPZ 5b S. Euringer, C. Krönauer F. Weiß	CBCVd-Monitoring	2023	Erzeugerorganisation Hopfen HVG e.G. *(HVG Hop Processing Group)*	IPZ 5c, IPS 2c
IPZ 5b S. Euringer, C. Krönauer, F. Weiß	CBCVd Research project	2023-2026	Erzeugerorganisation HVG e. G. *(HVG Hop Processing Group)*	IPZ 5a, IPZ 5c, IPZ 5d, IPS 2c
IPZ 5b S. Euringer, K. Lutz	Fighting hop wilt	2023-2026	Bayerisches Staats-ministerium für Ernährung, Landwirtschaft und Forsten (StMELF) *(The Bavarian State Ministry for Food, Agriculture and Forestry)*	IPZ 5c, AL 1c, KU Eichstätt, Dr. Radišek *(The Slovenian Institute of Hop Research and Brewing)*

Working Groups Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5 S. Euringer, C. Krönauer F. Weiß	Establishment of a method for determining Dislodgeable Foliar Residue (DFR) values in hops	2023-2025	Bundesamt für Verbraucherschutz und Lebensmittel-sicherheit (BVL) *(The Federal Office of Consumer Protection and Food Safety)*	BfR, BVL, DLR RP
IPZ 5b S. Euringer, C. Krönauer F. Weiß	CBCVd-Monitoring	2023	Erzeugerorganisation Hopfen HVG e.G. *(HVG Hop Processing Group)*	IPZ 5c, IPS 2c
IPZ 5b S. Euringer, C. Krönauer, F. Weiß	CBCVd Research project	2023-2026	Erzeugerorganisation HVG e. G. *(HVG Hop Processing Group)*	IPZ 5a, IPZ 5c, IPZ 5d, IPS 2c
IPZ 5b S. Euringer, K. Lutz	GfH *Verticillium* Research project	2017-2023	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	IPZ 5c, Dr. Radišek *(The Slovenian Institute of Hop Research and Brewing)*
IPZ 5b S. Euringer, K. Lutz	*Verticillium* selection gardens Niederlauterbach (2015-2021) Engelbrecht Minster (2016-2022) Gebrontshausen (2020-2024)	2015-2024	Erzeugerorganisation Hopfen HVG e. G. *(HVG Hop Processing Group)*	IPZ 5c
IPZ 5b S. Euringer, F. Weiß	Hyperspectral measurements in hops	2023	Wissenschaftliche Station München e.V. *(Scientific Station Munich e.V.)*	KU Eichstätt *(Catholic University of Eichstätt)*
IPZ 5b S. Euringer, F. Weiß	Evaluation of alternative methods for chemical-synthetic plant protection in hops	2023	Wissenschaftliche Station München e.V. *(Scientific Station Munich e.V.)*	Interessengemeinschaft Niederlauterbach e.V. (IGN) *(Niederlauterbach Interest Group)*

Permanent tasks: Plant protection experiments

Working group	Project	Duration	Collaborators
5b	Official means check	Permanent task	
5b	Execution and supervision of residue analyses in hop cultivation (GEP field part)	Permanent task	
5b	Spray tower experiments to monitor the potential development of resistance in hop aphids	Permanent task	
5b	Aphids fly monitoring	Permanent task	
5b	ELISA-Testing for ApMV and HpMV of hops for breeding purposes	Permanent task	
5b	Monitoring of the plant protection product approval situation in hop cultivation	Permanent task	
5b	Preparation of emergency applications in accordance with Art. 53	Permanent task	Verband dt. Hopfenpflanzer, Hopfenring e.V. *(Association of German Hop Growers)*
5b	Technical commentary on individual company emergency approvals in accordance with Article 22	Permanent task	Verband dt. Hopfenpflanzer, Hopfenring e.V. *(Association of German Hop Growers)*
5b	Viroid monitoring (CBCVd and HSVd)	Permanent task	IPZ 5c, IPS2c
5b	Technical support for the implementation of “plant passports” in hops	Permanent task	
5b	Implementation of the Eppo guideline PP 1/239 (Leaf Wall Area) in hop cultivation	2018-present	
5b	Maintenance of the reporting address, hop.pfla@lfl.bayern.de, for special fertilizers, plant nutrients, bio-stimulants, and pesticides in hop cultivation	2019-present	

3.3 IPZ 5c — Hop breeding research

Current research projects of IPZ 5c (hop breeding research) funded by third parties

Working Groups Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5c A. Lutz Dr. S. Gresset	Development of high-performance, healthy high-alpha varieties that are particularly suitable for cultivation in the Elbe-Saale region	2016-2024	Thüringer Ministerium für Infrastruktur und Landwirtschaft; *(Thuringian Ministry of Infrastructure and Agriculture);* Ministerium f. Umwelt, Landwirtschaft und Energie des Landes Sachsen-Anhalt *(Ministry for Science, Energy, Climate Protection and the Environment of the State of Saxony-Anhalt);* Sächsisches Staatsministerium für Energie, Klimaschutz, Umwelt und Landwirtschaft *(Saxon State Ministry for Energy, Climate Protection, Environment and Agriculture);* Erzeugergem. Hopfen HVG *e.G. (HVG Hop Processing Group)*	IPZ 5d: Dr. K. Kammhuber & Team; Hopfenpflanzerverband Elbe-Saale e.V. (*Hop Growers Association Elbe-Saale e.V.*); Betrieb Berthold, Thüringen *(Hop Farm Berthold, Thuringia);* Hopfengut Lautitz, Sachsen (*Hop Farm Lautitz, Saxony*); Agrargenoss. Querfurt, Sachsen-Anhalt *(Agricultural Cooperative Querfurt, Saxony-Anhalt)*
IPZ 5c Dr. S. Gresset	Research and work on *Verticillium* wilt in hops — molecular detection of presence	2015-2023	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Processing Group)*	IPZ 5c: A. Lutz; IPZ 5b: S. Euringer, K. Lutz; Dr. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia
IPZ 5c Dr. S. Gresset	Validation of genomic selection in hops	2023-2024	Wissenschaftliche Station für Brauerei in München e.V. *(Scientific Station for Brewery in Munich e.V.)* Gesellschaft für Hopfenforschung e.V. *(Society for Hop Research, e.V.)*	IPZ 5c: A. Lutz, Dr. B. Büttner, R. Enders, B. Forster, P. Hager, B. Haugg IPZ 1a: Dr. R. Seidenberger IPZ 1d Dr. Albrecht
IPZ 5c Dr. S. Gresset	Development of a high-throughput marker system for sex determination in hop breeding	2022-2023	Wissenschaftliche Station für Brauerei in München e.V. *(Scientific Station for Brewery in Munich e.V.)* Gesellschaft für Hopfenforschung e.V. *(Society for Hop Research, e.V.)*	IPZ 5c: A. Lutz, Dr. B. Büttner, R. Enders, B. Forster, P. Hager, B. Haugg IPZ 1a: Dr. R. Seidenberger IPZ 1d Dr. Albrecht

Permanent tasks: IPZ 5c

Working Group	Task	Duration	Collaborators
5c	Development and analysis of methods for healthy planting material	Permanent Task	IPZ 5b, IPS 2c
5c	Optimization of resource allocation in the hop breeding process	Permanent Task	
5c	Development of classic aroma varieties with fine typical aroma characteristics	Permanent Task	Gesellschaft für Hopfenforschung e.V. (GfH) *(Society for Hop Research, e.V.)*
5c	Development of robust, powerful high-alpha varieties with excellent alpha acid quality	Permanent Task	Gesellschaft für Hopfenforschung e.V. (GfH) *(Society for Hop Research, e.V.)*
5c	Development of high-throughput phenotyping methods	Permanent Task	
5c	Large plot testing of breeding lines and monitoring of brewing trials	Permanent Task	Gesellschaft für Hopfenforschung e.V. (GfH) *(Society for Hop Research, e.V.)*

3.4 IPZ 5d – Hop quality and hop analytics

Permanent tasks: Hop quality and hop analytics

Working Group	Project	Duration	Collaborators
5d	All analytical investigations in support of the Working Groups of the hop division, especially of those involved in hop breeding	Permanent task	IPZ 5a, IPZ 5b, IPZ 5c, IPZ 5e
5d	Development and optimization of a reliable method for the analysis of aromas using gas chromatography-mass spectroscopy	Permanent task	
5d	Establishment and optimization of NIRS-methods for analyses of hop bitter substances and water content	Permanent task	
5d	Development of methods for analyzing hop polyphenols	Permanent task	Arbeitsgruppe für Hopfenanalytik (AHA) *(Hop Analytics Working Group)*
5d	Organization and evaluation of chain analyses for hop contracts	Permanent task	Labore der Hopfenwirtschaft (*Laboratories in the hop industry*)
5d	Analysis, evaluation, and dissemination of follow-up and control examinations for hop contracts	Permanent task	Labore der Hopfenwirtschaft (*Laboratories in the hop industry*)
5d	Administrative assistance in the analyses of hop varieties for food safety authorities	Permanent task	Lebensmittelüberwachung der Landratsämter *(Food safety monitoring by district offices)*
5d	IT and Internet support for the Hop Research Center Hüll	Permanent task	AI ITP
5d	Alkaloid analysis in lupins	2023-2027	IPZ 1b, IPZ 4a

3.5 IPZ 5e – Ecological issues in hop cultivation

Current IPZ 5e research projects of (ecological issues in hop cultivation) funded by third parties

Working Groups Project Management Project Operations	Project	Duration	Cost Allocation	Collaborators
IPZ 5e Dr. F. Weihrauch M. Obermaier	Further development of culture-specific strategies for organic crop protection with the help of divisional networks - Hop Division.	2017-2023	Bundesanstalt für Landwirtschaft und Ernährung (BLE), BÖLN-Projekt 2815OE095 (*Federal Agency for Agriculture and Food BLE)*	Bund Ökologische Lebensmittelwirtschaft (BÖLW e.V.) *(Organic Food Production Alliance; BÖLW e.V.)*
IPZ 5e Dr. F. Weihrauch Dr. I. Lusebrink M. Obermaier	Development of a catalog of measures to promote biodiversity in hop cultivation	2018-2026	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Processing Group)*	IGN Nierderlauterbach *(Hops Niederlauterbach);* AELF PAF, FZ Agraökologie *(Center of Expertise for Agroecology)* UNB am Landratsamt PAF *(Nature Conservation Authority, District of Pfaffenhofen and Ilm)* LBV, KG PAF
IPZ 5e Dr. F. Weihrauch Dr. I. Lusebrink M. Obermaier	Induced resistance in hops to spider mites	2021-2026	Deutsche Bundesstiftung Umwelt (*German Federal Foundation for the Environment)* (FKZ 35937/01-34/0)	20 commercial farms practicing integrated hop cultivation; AG IPZ 5d

4 Hop Cultivation, Production Techniques

Managing Director (LD) Johann Portner, Dipl.-Ing. agr.

4.1 N_{min}-Investigation 2023

Soil analyses to determine the available amounts of nitrogen and N_{min} are central components of calculating fertilizer requirements. Thewy are also a mandated requirement for hop growers in the so-called "red areas."

In 2023, more than half of the hop growing enterprises in the Hallertau and Spalt, in Bavaria, participated in an N_{min} study. A total of 2,590 hop gardens (2022: 2,959) were examined for N_{min} content. The average N_{min} content in the Bavarian growing areas was 53 kg N/ha, which was 4 kg above the previous year's value. As is the case every year, there were large fluctuations from one farm to the next, as well as among individual hop plots and different varieties cultivated by the same farm.

According to the German Fertilizer Ordinance (DüV), every hop farm must calculate its nitrogen fertilizer requirements (N) annually, while considering the amount of N that is already in the soil before the first round of fertilization. This applies to all plots or management units, according to defined specifications.

Farms with hop areas in the so-called **“green” or non-nitrate-prone areas** are not obliged to carry out N_{min} assessments; and many did not collect N_{min} results for all plots. Instead, they were permitted to use regionalized, provisopnal averages listed in Table 8 in their reporting.

Table 8: Number of sample, preliminary and final N_{min} values for 2023 in the various hop growing districts and regions (current as of April 12, 2023)

County/Region	Number of tests	Preliminary N_{min}-value (As of March 22, 2023)	**Final N_{min}-value**
Eichstätt (including Kinding)	147	72	64
Freising	332	50	48
Hersbruck	75	-	39
Kelheim	1,041	49	52
Landshut	153	69	61
Pfaffenhofen (and Neuburg-Schrobenhausen)	752	50	52
Spalt	90	64	64
Bavaria	**2,590**	**52**	**53**

Hop growers without their own N_{min} values were permitted to calculate their nitrogen requirements using the provisional N_{min} averages for their district or growing region. They needed to correct these values if the final, empirically determined N_{min} value is more than 10 kg N/ha higher than the provisional N_{min} value in the table.

In districts where the final value is lower than the provisional one (e.g., Eichstätt and Landshut), an adjustment is recommended because after correction a higher fertilizer requirement was calculated.

There was no provisional N_{min} value for farms in the Hersbruck region last year, so the fertilizer requirement determination had to be calculated using the final N_{min} value.

Farms in the **"red areas"** had to test at least 3 plots for N_{min} in 2023. If additional hop areas were in the red area, the average N_{min} values had to be transferred to these as well! The above table values were not allowed to be used to calculate the N fertilizer requirement for these areas because of a nitrate risk!

The figure below shows the number of N_{min} tests and N_{min} amounts in Bavaria over several years of testing.

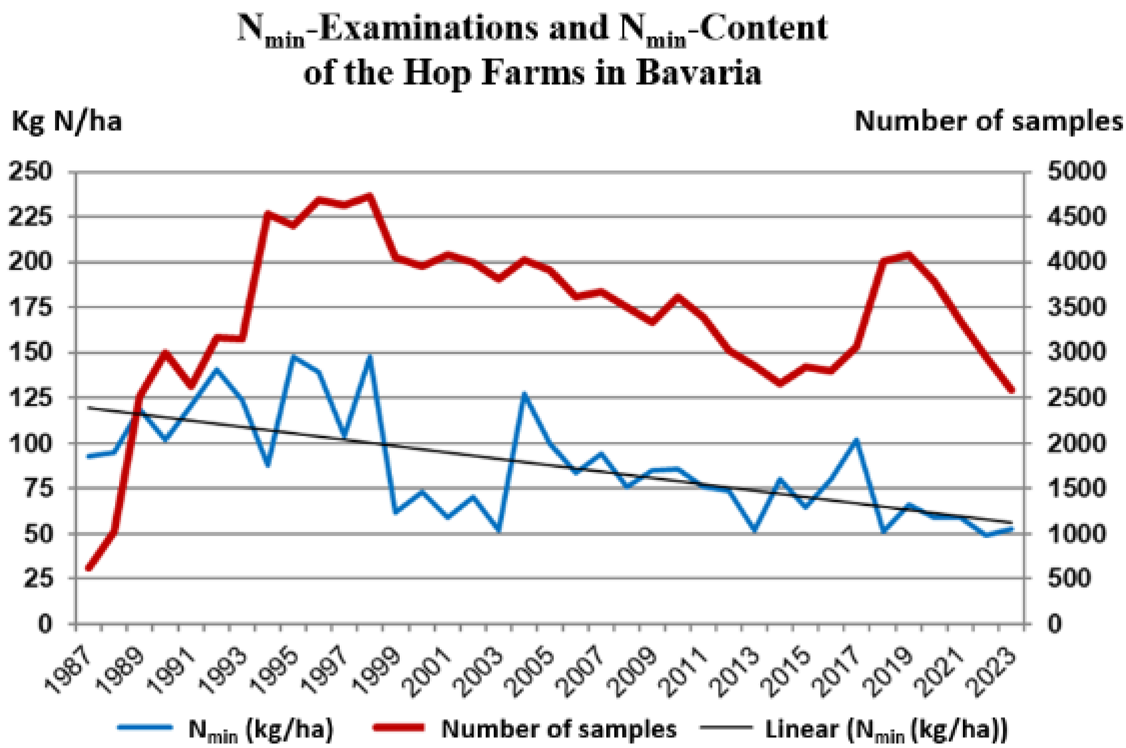


Figure 11: N_{min} investigations, N_{min} amounts and the trend line for N_{min} values in hop gardens in Bavaria over the years

4.2 Summary of research work on nitrogen dynamics in hop soils (ID 6054)

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)* AG Hopfenbau, Produktionstechnik *(Working Group Hop Cultivation and Production Technology)*
Financing:	Erzeugergemeinschaft HVG e. G. *(HVG Hop Processing Group)*
Project Management:	J. Portner
Editing:	A. Schlagenhaufer
Collaboration:	Hop farms in the Hallertau
Duration	March 1, 2018 to February 28, 2021

In the Hallertau, the hops are grown as a special crop in a high-density area. Such an intensive cultivation of a single crop, of course, comes with a high demand for nutrients, especially of older landraces. Thus, the fertilization level for nitrogen is relatively high. This can result in increased nitrate levels in the soil, especially on farms that applicational amounts of organic fertilizer. After the harvest, any residual nitrogen in the soil can, of course, no longer be absorbed by the plants. These nitrogen loads can be skimmed off to some degree with cover crops. The left-over nitrogen, on the other hand, is subject to displacement and can lead to nitrate leaching.

Objectives

As part of the project, the nitrogen dynamics in hop soils from 21 hop farms were examined. For this purpose, intensive N_{min} investigations were carried out in spring, autumn and winter. In addition, the necessary nitrogen requirement for these areas was determined, the actual N fertilization was recorded, and an operational nutrient comparison was created. In this way, the nitrogen shift and the loss potential over the course of the vegetation period can be estimated for different farm types, fertilizer systems, and soil types. In addition, possible approaches for optimizing nitrogen management in hop cultivation should be developed. The aim was to optimize operational nitrogen management in such a way that optimal yields and qualities can be achieved while observing and complying with the requirements of the German Fertilizer Ordinance, as well as with water protection requirements.

Method

Three subareas were selected for each of the 21 farms. The 63 sub-areas reflected the actual variety spectrum grown in the Hallertau and included a wide variety of operating strategies and fertilization systems. The N_{min} sampling was carried out at the beginning of the vegetation period in March and after the harvest in October to record the remaining amounts of nitrogen in the soil, as well as during the dormancy period in winter in order to determine a possible shift during dormancy. As a standard, the available nitrogen in the form of ammonium and nitrate was examined up to a soil depth of 90 cm. The sample was divided into three 30 cm sections to better determine the different displacements in different soil layers. Each farm received individual advice on fertilization. All nitrogen fertilizer applications were recorded in terms of timing and quantity.

During the first harvest in 2018, cones and plant remains were sampled in order to calculate the exact nitrogen removal. This was intended to determine an area-specific nutrient balance and establish the connection to the N_{min} contents in the soil. Since the exact amounts of cones and bine shredding during harvest on the different farms could be determined with only limited accuracy, sampling was not carried out in the following two years. Instead, various areas with the most important Hallertau varieties were harvested in Hüll. This made it possible to determine the following parameters separately for the cones and bine shreds as well as for the entire plant for different varieties at different yield levels:

Figure 12: Soil sampling device

- Fresh matter and dry matter per ha
- DM contents
- N contents
- N removal by cones and bine shreds
- Ratio of cone and bine shred production (main crop product/secondary crop product ratio = HNV)

With the help of this data, the nitrogen withdrawals and the amount of bine shredding can be determined and possibly re-evaluated for the now greatly expanded range of varieties depending on the cone yield.

Results

The experimental years 2018-2021 allowed for the acquisition of extensive insights into the nitrogen dynamics of hops. Using 10 samples, the distribution of the N_{min} contents between the respective layers are shown based on the sampling date (Figure 13). One striking fact is the relatively and absolutely higher N_{min} contents in the upper 30 centimeters in the fall. The decline until spring can be explained by the N uptake of the cover crops. However, one cannot rule out nitrogen shifts into deeper soil layers — especially during high fall and winter precipitation. In addition, strong annual fluctuations in the N_{min} contents were evident.

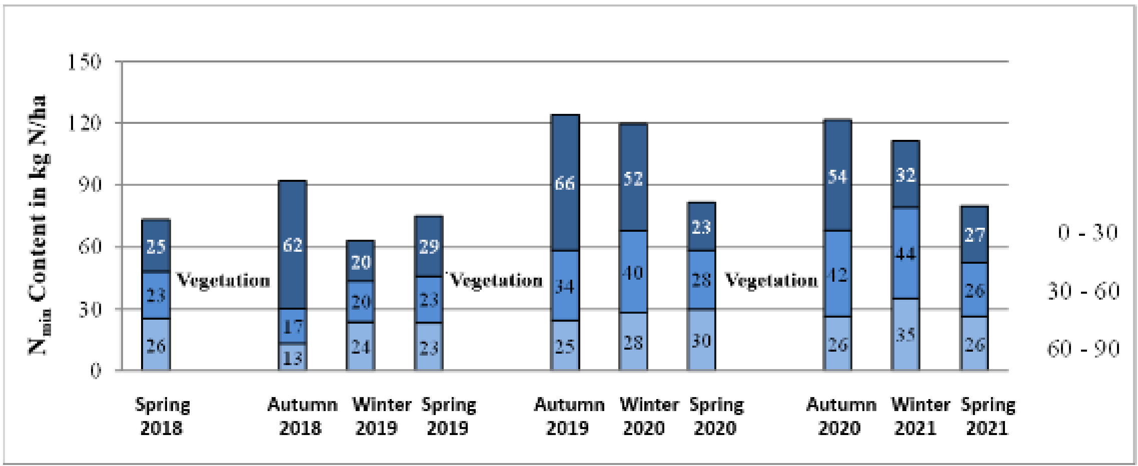


Figure 13: N_{min} contents across all sampling dates, divided into soil layers (0-30, 30-60, 60-90), 2018-2021

A comparison of the N_{min} contents by varieties shows that aroma varieties have higher N_{min} contents than bitter varieties. The acreages planted with only recently released Hüll aroma varieties and with old landraces is still too small to allow for N_{min} contents assessment and comparisons between different variety groups (Figure 14). The data shows that differences in N_{min} content between aroma and bitter varieties is particularly pronounced in the fall. The differences can be explained by a more developed root system and higher N removals of the bitter varieties around harvest time. In addition, it was found that N fertilizer documentation, does not always differentiates between different variety groups or yield levels.

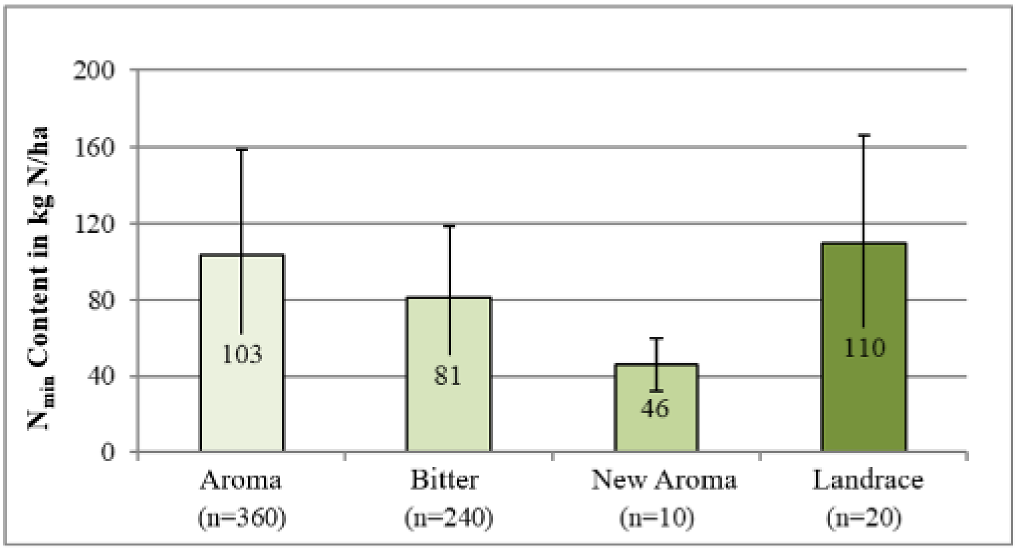


Figure 14: N_{min} contents on average across all sampling dates, broken down by variety groups (2018-2021)

Therefore, a differentiated N fertilization depending on the variety and the location-related yield level is conserved an optimization approach for N fertilization in hops.

As part of the project, the organic fertilization of all farms was also recorded and categorized according to the tuype of N_{min} contents. Three of 21 farms fertilized their hop areas without any organic fertilizer; 4 farms fertilized with an organic fertilizer (except bine shreds); 7 farms applied organic fertilizer exclusively in the form of bine shreds; and 7 farms used other organic fertilizers in addition to the bine shreds in the fall. When looking at the spring N_{min} contents in conjunction with organic fertilizers, a clear trend emerges (Figure 15). The more organic fertilizer was used, the higher was the average the N_{min} content. The long-term fertilizing effect of the organically bound nitrogen in the organic matter is reflected in the N_{min} content. The subsequent supply of nitrogen from organic fertilizers must therefore be taken into account when applying mineral supplementary fertilization.

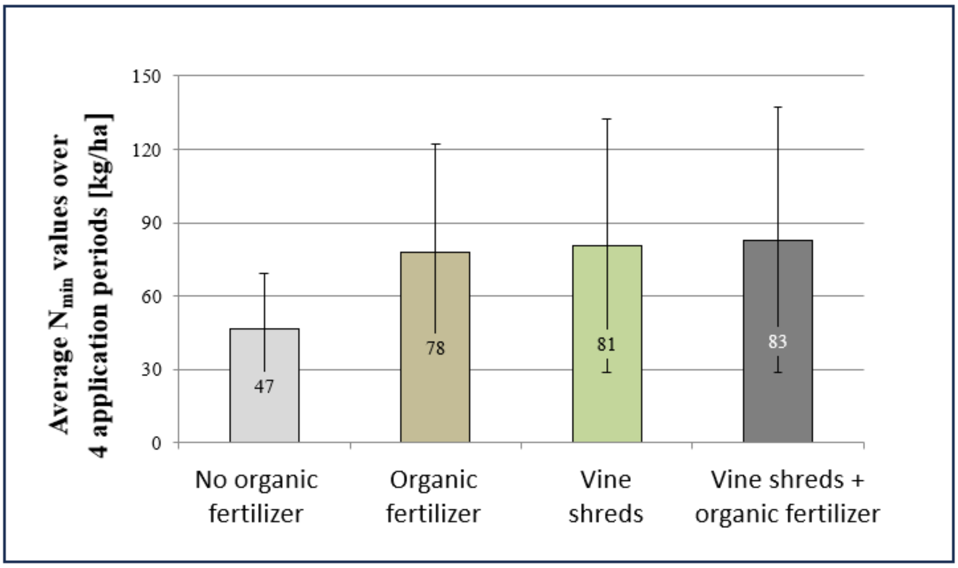


Figure 15: Average spring N_{min} contents over 4 samples depending on the type of organic fertilizers in use on the farm (2018-2021)

During the 4 years of sampling, the data revealed no significant differences in the average N_{min} content that could be attributed to soil types (Figure 16).

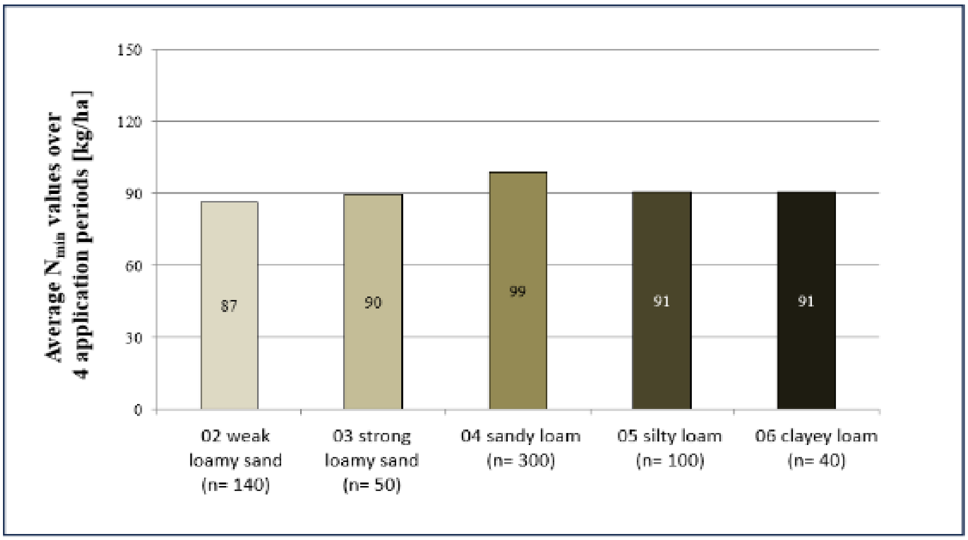


Figure 16: N_{min} contents related to soil types, averaged over all sampling dates (2018-2021)

The N_{min} contents tended to be lowest in areas with very light soils (02). The highest average N_{min} content was found in medium soil types with sandy loam (04).

4.3 Extraction and suitability testing of hop plant fibers for the production of non-wovens (ID 6907)

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)* AG Hopfenbau, Produktionstechnik *(Working Group Hop Cultivation and Production Technology)*
Financing:	Bayerisches Staats-ministerium für Ernährung, Landwirtschaft und Forsten (StMELF) *(The Bavarian State Ministry for Food, Agriculture and Forestry)*
Project Management:	J. Portner
Collaboration:	Hopfenpower GmbH, Wolnzach Leibnitz Institut für Agrartechnik und Bioökonomie (ATB), Potsdam *Leibnitz Institute for Agricultural Engineering and Bioeconomy, Potsdam* HempFlax Group B.V., Oude Pekela (Netherlands) HempFlax Building Solutions GmbH, Nördlingen
Duration	December 1, 2022 to November 30, 2023

Initial situation and objective

Hops are grown on some 20,000 hectares in Germany, of which about 17,000 hectares are in the Hallertau. The plants are grown as a permanent crop, and only the cones are harvested to make beer. The remaining plant materials — mostly the bines, side shoots, and leaves — are usually chopped up and returned to the fields, mostly untreated or sometimes composted, as organic fertilizer. Some of this matter is also used for energy in biogas plants, with the fermentation residues also returned to the fields. Every year, more than 200,000 MT of shredded bines are produced in the Hallertau, which have to be returned to the nutrient cycle.

Since hops belong to the hemp family, the woody stem naturally contains stable bast fibers that are potentially suitable, for instance, for making insulation material.

The aim of a short project funded by StMELF was to show that hop bines cou;d be processed into a fiber raw material that is suitable for the production of insulation, using processing steps already known from other bast fiber plants in the manufacture of marketable insulation mats. The quality of such insulation mats was to be checked in laboratory tests to determine their product properties and quality as required by the market.

To round off the project, the nutrient contents and quantification of the nutrient loads of the hop bines used for fiber production were also examined.

Method and Results

The short project was divided into various work steps that were completed one after the other. Because of the different and complex process steps, the work packages were carried out by different service providers at different locations.

Raw material sourcing and removal of the metal wires

The starting material for obtaining hop fibers were dried hop bines or bine sections from different harvests obtained from Hopfenpower GmbH. The bine sections were separated from the wires, shortened to approximately 50 cm, packed in boxes, and transported to the fiber production plant for further processing.

Figure 17: Hop bines provided and ready for shipping by Hopfenpower GmbH

The length of the bine sections was based on the raw material lengths used in hemp processing. Fiber extraction was carried out at HempFlax Group B.V. in Oude Pekela (Netherlands), using that company's existing equipment. Since there are currently no machines that can remove the wires from bine sections of this size, this work had to be done laboriously by hand.

Mechanical separation of the fibers from the woody part of the hop bine (shives)

The extraction of the hop fibers and the mechanical separation of the plant fibers from the shives took place in the Nawaro pulping plant of HempFlax. The goal was to produce the greatest possible yield of hop fibers for laying fleece intended for insulation production. The company was founded some 30 years ago and has technology systems for processing hemp and flax straw. The processing is divided into several steps, involving the separation of wood from the stem material, cleaning the resulting mixtures of fibers and shives, and refining the fiber fraction.

To obtain fiber and remove wood, the stem material is first processed using hammer mills.

Figure 18: The wood separation unit of the fiber pulping plant of HempFlax Group B.V. in Oude Pekela (NL). Photo by the company

Compared to the crusher principle, hammer mills allow for higher energy input into the fiber plant straw and thus for a greater variability in the types and properties of raw materials it can process. This could be advantageous because hop bines are not roasted before they get there. Field or dew retting (formerly also water retting) marks the starts of the separation of the plant fibers in the stem network by breaking down the biological bond between the bark and the woody stem core, as well as the bark and the fibers. This step is currently not possible during hop processing for beer making.

Figure 19 Moisture dosing of the test material into the wood separation process of HempFlax Group B.V. in Oude Pekela (NL)

The primary digestion usually results in a mixture of fibers with shives partly still attached and partly already loosened. Next comes a further cleaning process until the raw fiber portion is largely free of shives remains.

Figure 20: Fiber cleaning and fiber opening line at HempFlax; (left, middle and right step cleaner, fiber opener in between)

As part of the tests, all relevant data on the processing quantity and resulting material flows were recorded. A total of 605 kg of hop stems were available from the raw materials provided by Hopfenpower. The yield of raw fibers (or fiber bast including adhering shives) after wood separation was 195 kg and thus 32.2% of the input material.

Figure 21: Experimental samples of hop stems (top of each), as well as fractions selected from them (at the bottom left, pure fiber bast; in the middle, fiber bast with firmly adhering shives; and on the right, pure shives)

Two samples of this material were subjected to detailed compositional analysis.

After the first wood separation step there the proportion of pure material, i.e., shive-free fiber bast (fiber bundles), was only 11.8%. This is significantly below the values usually expected from hemp or flax straw processing. The yield of fiber-free shives is also significantly lower, at approximately 11%, and there remains a remarkably high proportion of fiber bast with an average of 74% still with shives that did not get separated.

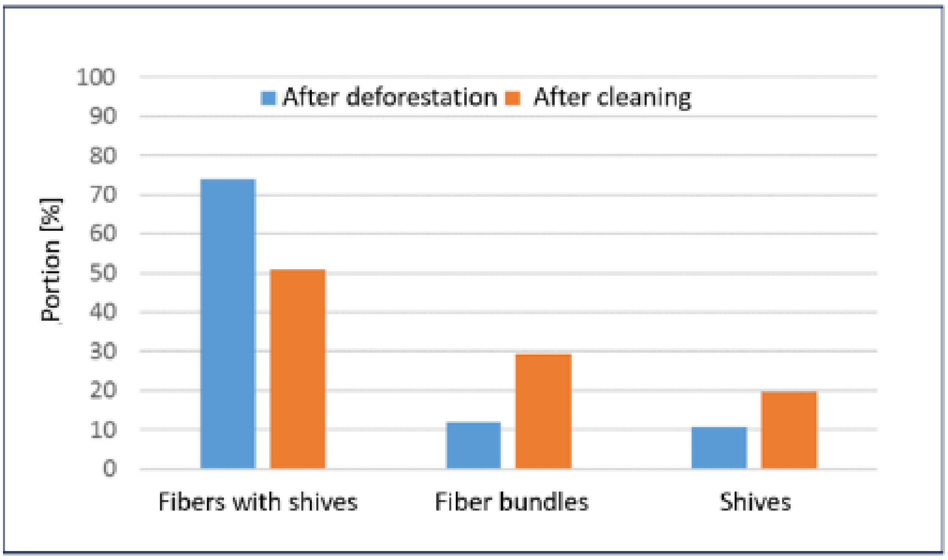


Figure 22: Fractions from hop stem digestion before and after mechanical cleaning

After a further cleaning and fiber-opening step, however, there was a significant improvement, with an increase in the yield of shive-free fiber bundles in the sample to just under 30%. Noneteless, the proportion of non-cleaned fiber bundles was still a high 51%. The portion of shives was at 19.7%. This compared unfavorably to hemp and flax straw processing. The results show that the lack of roasting of the stem material makes wood separation, as well as the separation of the fibrous tissue from the woody inner core of the hop stems, less than optimal.

Only 32% of the original mass (195 kg) remained after wood separation, and only 16% (97 kg), after cleaning. It was not possible to draw detailed conclusions about the remaining mass flows. We can assume that a large mass of shives was separated in the individual processing stages, but large losses of non-digested material cannot be ruled out.

<u>Scientific support of the test run by the Leibnitz Institute for Agricultural Engineering and Bioeconomy Potsdam</u>

Dr. Gusovius from the Leibnitz Institute for Agricultural Engineering and Bioeconomy (ATB) in Potsdam already has plenty of experience with fiber production from hop bines. He has been involved in various preliminary projects (such as the FNR Hop Fiber poject). As part of his work at the institute, he is very familiar with the production and processing of bast fiber plants.

That is why he was engaged as an advisor during the test run of this project. This gave us the benefit of an independent assessment of the processing results and to achieve the best possible quality and quantity.

Incorporation of the hop fibers into the ongoing insulation production and laboratory testing of the finished insulation mats.

In a Bavarian factory that specializes in the processing of NAWARO fibers (such as hemp and jute) into insulation materials, we attempted to produce hop fibers obtained in combination or in exchange with other natural fibers using a fleece laying process with subsequent thermal solidification. The insulation factory of HempFlax Building Solutions GmbH in Nördlingen, which has many years of experience in the use of natural fibers in insulation production, was commissioned to further process the hop fibers.

The raw material batches delivered are first broken down or cleaned and then mixed with a supporting fiber and other components such as a fire protection compound.

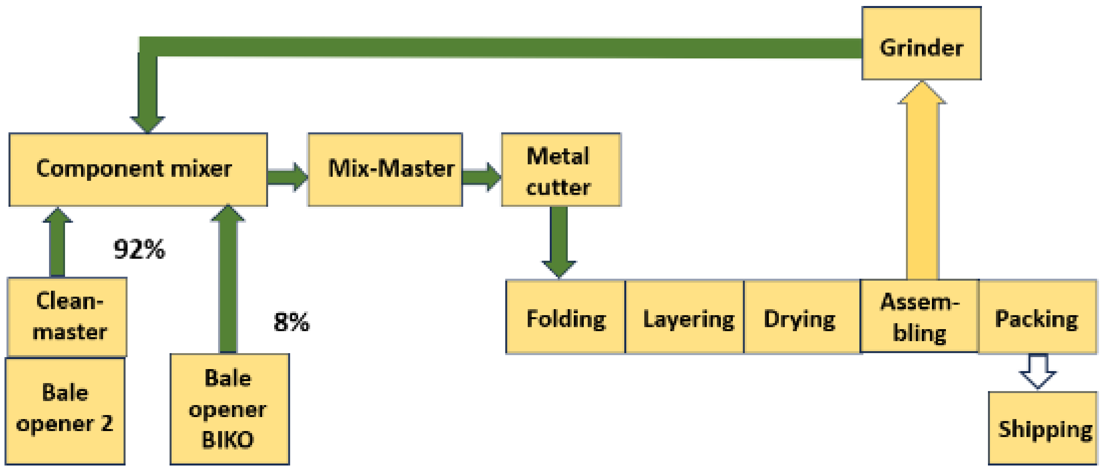


Figure 23: Process sequence of insulation material production at HempFlax Building Solution GmbH in Nördlingen. Representation by the company

A single-layer fleece is made from the fiber mixture and then placed in layers on top of each other to form a three-dimensional fiber structure. By introducing thermal energy, the supporting fiber partially melts and gives the insulation material the properties that are typical for building applications. These include dimensional stability and density.

According to this process, hop fibers, remaining shives, and incompletely digested mixed material (30%), together with hemp fibers (60%) and bonding fibers (10%), were mxed, fed into the bale opener, and sent to a fleece layer. Based on our observations and the assessment of the specialist staff on site, these steps did not cause any significant problems. There were hardly any losses or blockages in spite of the presence of shives and the partially incomplete fiber digestion.

Figure 24: Mixture of hemp, hops and bonding fibers (left) as well as fleece after carding

At the end of the process, a multi-layered, stable matt was the result. This was thermally treated in the dryer without a problem.

Figure 25: Multi-layer pile before thermal solidification

The result was convincing in every respect, and the resulting insulation mat could be assembled (cut to size) without any further difficulties.

Figure 26: Thermally compressed insulation mat (left) and width calibration (assembly) of the product (right)

The overall mass balance of the experiment looks positive. An input of 210 kg hemp fibers, 90 kg hop material, and 25 kg supporting fiber (total = 325 kg) yielded an output of approximately 205 kg of insulation material (63%). During raw material processing at the beginning of production, the metal separator often tripped, whereupon a total of 16 kg of raw material was separated from the rest because of metal parts (18% of the hop material fed in, 5% based on the total input mass). Further mass losses relative to the amount of raw materials fed into the process are attributable to moisture, dust, shives, edge cutting, and waste at the beginning and the end of the mat production.

Figure 27: Finished insulation mat made from 30% hops, 60% hemp, and 10% bonding fiber material, compared to the starting fiber material (right)

In order to meet fire protection requirements, the hop fibers, as well as the hemp and jute raw materials, needed to be treated with soda before the fleece laying step. Because of the limited quantity used in the experiment, treatment with soda as fire protection was omitted.

The project partner/service provider's laboratory then carried out detailed analyses of the relevant properties of the insulation material, including a test for flammability under direct flame exposure in accordance with DIN EN ISO 11925-2, even though no inhibitor was used in the sample production. It was no surprise that the material did not meet the fire protection class E requirements. However, because the structure and chemical composition of the hop biomass is comparable to that of hemp and jute, it can be assumed that with the application of a retardant, the insulation material could come up to the specifications.

Finally, the thermal conductivity of the material was determined using a standardized procedure, repeated twice on different days.

The measured lambda value (10 °C) of 0.0404 - 0.0407 W/(m*K) was in line with the comparative values shown on the company website for a range of products that are based on pure hemp fiber (0.038 - 0.043 W/(m *K)) or wood fiber insulation (0.036 – 0.045 W/(m*K)). This result shows that the thermal insulation properties are the same with the incorporation of the new raw material; and that direct marketing might therefore be possible without an additional approval process.

<u>Investigation of the nutrient contents and quantification of the nutrient loads in the bine shredded portion used for fiber production</u>

Since the hop harvest takes place on a farm, the harvested hop bines are usually chopped together with the leaves and other waste, including the wire. After a short storage period, they are taken back to the fields as organic fertilizer. Thus, significant amounts of nutrients remain in the internal cycle on the farm and must be taken into account when determining fertilizer requirements (fertilizer regulation) and nutrient balancing (material flow balance regulation).

Since there are no guideline values or basic data for the nutrients removed with the partial material recycling of hop bine shreds (hop bine sections for fiber production), these were collected for two important varieties (Hercules and Perle) as part of the project.

To calculate the nutrient content and the nutrient loads of the bine portion of the harvest waste in hop production, exact experimental harvesting of two plots was carried out at the hop research center of the State Agricultural Institute in Hüll. In addition to the pure nutrient loads in the bine component, it can also be estimated how much raw material is produced per hectare for possible fiber use. For the Perle variety, the harvested lots produced an average dry matter of 1,450 kg/ha, while for the Herkules variety, it was 2,821 kg/ha.

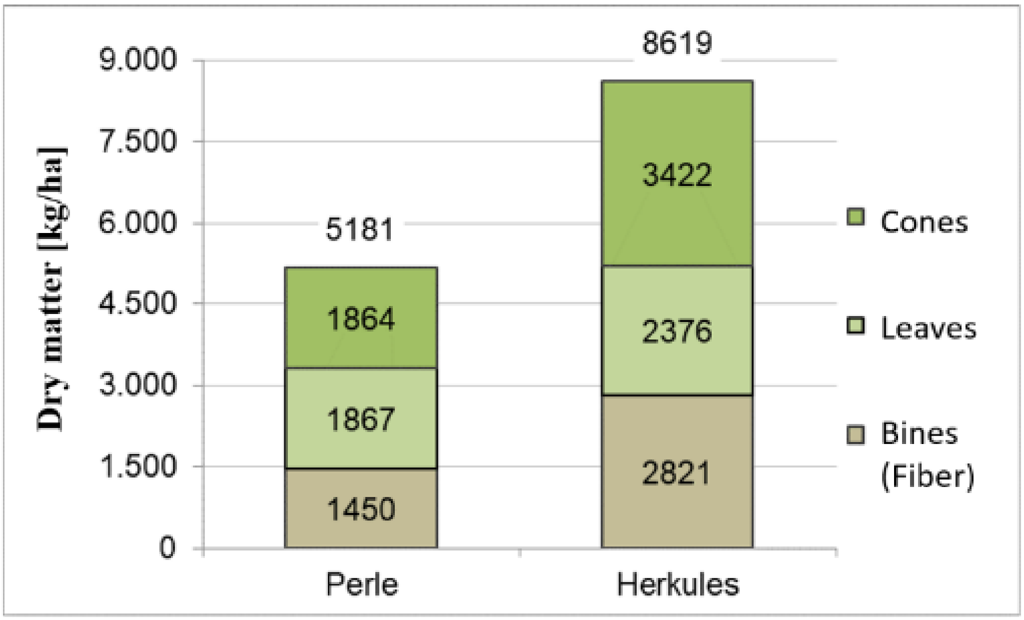


Figure 28: Dry matter yield in kg/ha divided into 3 fractions for Perle and Herkules, 2023

For the nutrient nitrogen (N), which is most relevant from a fertilizer perspective, an average N load of 20 kg N/ha was found in the bine component of Perle that are usable as fibers; and 41 kg N/ha, in Herkules. This corresponds to a share of 15.5% for Perle and 19% for Hercules of the total N load. If the bine components are used to produce fiber, they would no longer be a factor in the fertilizer balancing required by law, because these nutrients leave the enterprise altogether.

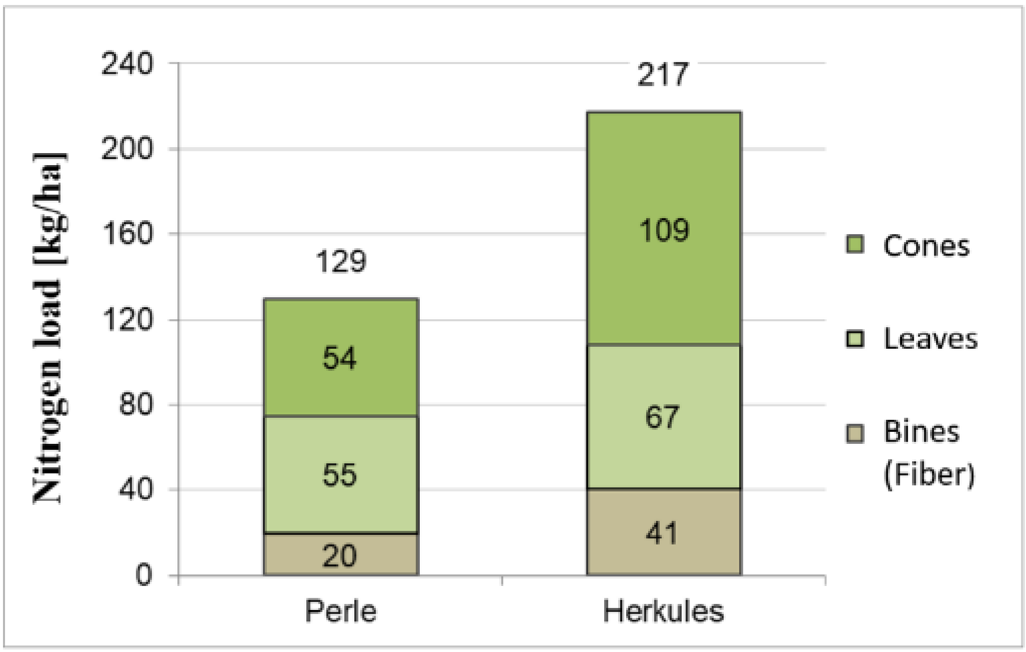


Figure 29: Nitrogen load of Perle and Herkules (2023) at harvest time, divided into 3 fractions

Outlook

The first test run for the material recycling of hop fibers into insulation materials was very promising in terms of both suitability and quality. As the market for natural building and insulation materials grows, so will future markets for NAWARO fibers. These markets are mostly in the automotive industry and its suppliers, and in the area of geotextiles.

If the extraction of fiber from hop bines and the further processing into marketable products is economically and qualitatively competitive, Bavarian hop production offers a potential of several 10,000 MT of renewable raw materials in the form of hop fibers, without the need for additional cultivation areas and without any competition with food production. However, the greatest challenges lie in the logistics of economically providing materials for fiber production (economic collection, wire removal, and storage of hop bines).

There is also a direct benefit for hop growers: specialized hop growing operations with a difficult nutrient situation (Fertilizer Regulation and Material Flow Balance Regulation) can be relieved of the burden of dealing with excess nutrients in their hop bines. Hop growers with phytosanitary problems (*Verticillium*, CBCVd) can interrupt the cycle of infection by removing hop bines and thus reduce the risk of spreading hazards within their operations. Another sustainable aspect is the improvement of the CO_2 balance of hop growing operations by permanently storing CO_2 in hop fibers. And finally, the disposal of the hop bines means an improvement in the image of hop growers as polluters of the environment.

4.4 Studies to measure soil moisture and resource-saving hop irrigation control (ID 6911)

Background

The necessity and technical implementation of hop irrigation has been tested and proven many times in previous research projects. The state of science and technology in hop irrigation was summarized in the LfL information brochure “Drip Irrigation and Fertigation for Hops.” Despite the numerous test results, questions continue to arise in practice as to which drip distances or which irrigation times and quantities are optimal or economically sensible depending on the type of soil. Due to the limited availability of water for hop irrigation, these questions are of crucial importance for the economic success especially of companies with limited water resources.

The aim of the project is to carry out studies to measure soil moisture in cooperation with Mr. Parssa Razavi from Irriport GmbH, one of the leading companies in Germany in the planning, construction and operation of communal irrigation systems in fruit, vegetable, and wine growing. Specifically, it involves controlling irrigation in a resource-saving and location-adapted manner, that is, by reducing the amount of irrigation that has hitherto been the norm, based on soil moisture in and an optimization of the drip distances and dripper outputs.

Experimental Set-up and Method

In a hop garden with Hercules in a light, sandy soil, TDR soil moisture sensors were installed in 4 test plots at 2 different depths in order to determine the soil moisture depending on irrigation and to control on and off times. The operational irrigation control and a non-irrigated control variant served as comparisons. The experiment was combined with the use of different drip hoses in the furrows with different drip distances and output quantities.

Important components of optimized irrigation control are intelligent control and settings options. For this purpose, electrically controllable valves and digital water meters were installed for the individual variants. All data from the soil moisture sensors and a weather station could be viewed online through data transmission. The valves could also be controlled remotely. By digitally combining sensor data and the valve settings, an automated valve control system could be set up after soil moisture thresholds were reached. The test involved three furrows. For the test, three almost identical harvest samples per variant were taken from the middle row in Hüll. These were examined for yield (with DM determination) and quality parameters (alpha acid and oil content). In addition, the dry matter and N removal parameters were determined separately for cones and plant remains.

The following variants were irrigated and experimentally harvested in different doses and cycles depending on the type of drip hose and depending on the soil moisture:

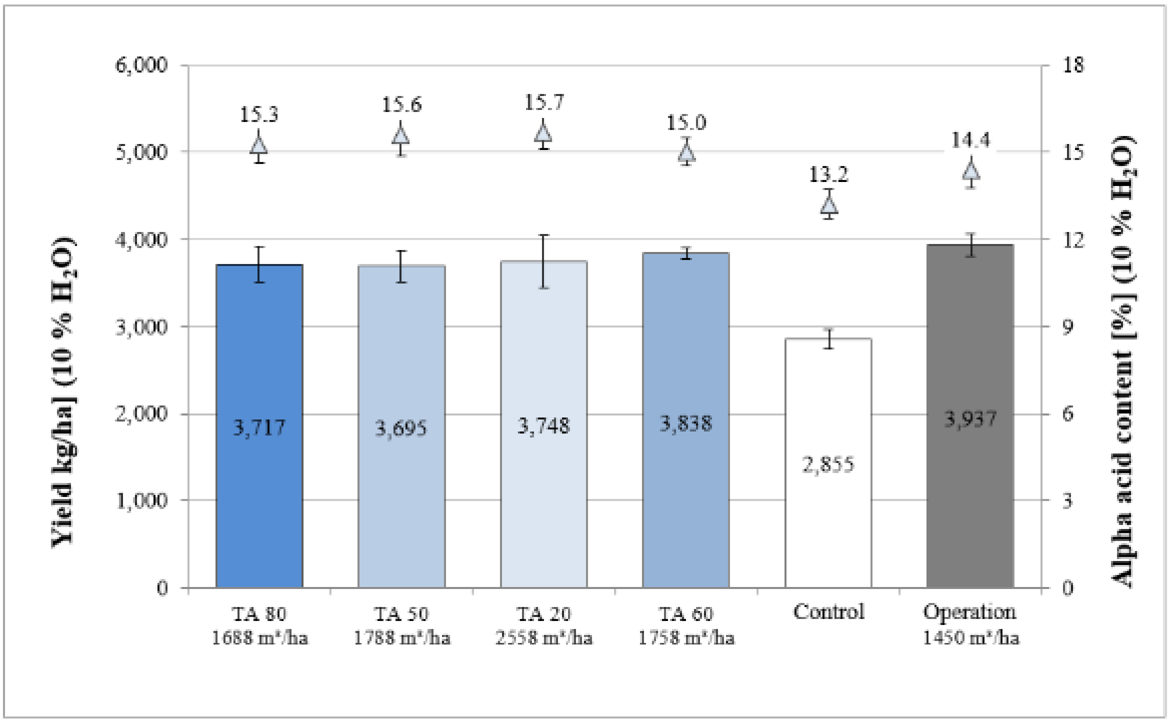
Table 9: Overview of test variants/drip hoses

Variant	Dropper distance (cm)	Output per dropper (Liter)	Output per meter Drip hose (l/m)
A - TA 80	80	1.75	2.2
B - TA 50	50	1.6	3.2
C - TA 20	20	1.0	5.0
D - TA 60	60	2.4	4.0
E - Control	No irrigation		
F - Customary	50	1.0	2.0

Results

In 2023 there was a pronounced dry phase in June and July, followed by a rainy period in August. The weather station at Stadelhof, approximately 8 km south of the test site, recorded a total of 131 mm of precipitation for June and July combined, whereas it recorded 167 mm in August. The experimental setup was completed in mid-June, which allowed different types of irrigation to start for the individual test variants. At the beginning of August, a visual assessment of the plants already revealed differences. Variants A, C, and especially F appeared to be more vigorous. But this difference became less apparent as the harvest approached. The harvest results in Figure 1 also show hardly any difference in cone yield between the irrigated variants, even though the amounts of water applied differed significantly.

These yields can possibly be explained by the wet August and the great yield compensation ability of Hercules. Despite a small dropper distance of only 20 cm in the “TA 20” variant (output 1 l/h) and the resulting high water application rate of 2558 m³/ha, no additional yield increase was possible. The highest yield in the experiment was measured in the standard variant with a distance of 50 cm (output 1 l/h) and a water quantity of 1450 m³/ha.



The control variant without irrigation had a significant 32% lower cone yield compared to the mean of the irrigated variants. The unirrigated control was also slightly lower in alpha acid content. Although the standard variant has the highest cone yield compared to the irrigated variants, the alpha acid content was also lower.

Figure 30: Cone yield and alpha acid content of the experimental Herkules variants, 2023

Outlook

In subsequent experiments we will only focus on two drip hose types: one with a dripper distance of 80 cm and one with 50 cm. There is a future research plan to consider various methods and tools (e.g., ALB irrigation app) for measuring the timing and amount of irrigation in addition to the operational control.

4.5 Thermal imaging technology as a further aid in optimizing belt drying

Initial situation:

There are belt dryers with different configurations in use today. These include belts equipped with one or two warm air generators and with different air and heating outputs. Numerous evaluations and documentation show different drying behaviors and different drying results, depending on operating methods.

Optimal drying processes are those that ensure a constant removal of water from the hops as they move through the dryer while on the three drying belts.

Method:

Several belt dryers installed today have data loggers above the drying belts at the beginning and end, as well as in the middle of the upper belt. This makes it possible to document the temperature of the air flowing through the hops at the selected measuring points. A thermal imaging camera was also installed at the end of the upper belt.

Result

With the help of data logger evaluations, the drying behavior could be assessed. Figures 31 and 32 show the temperatures of the drying air flowing through the dryers above the hop layers.

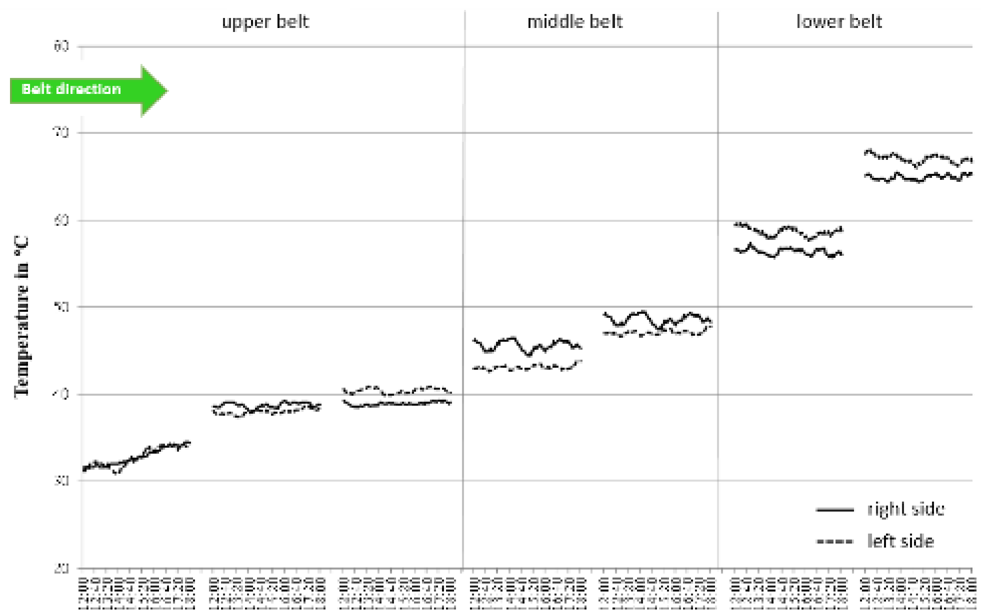


Figure 31: Uniform temperature rise of the drying air flowing through all drying belts

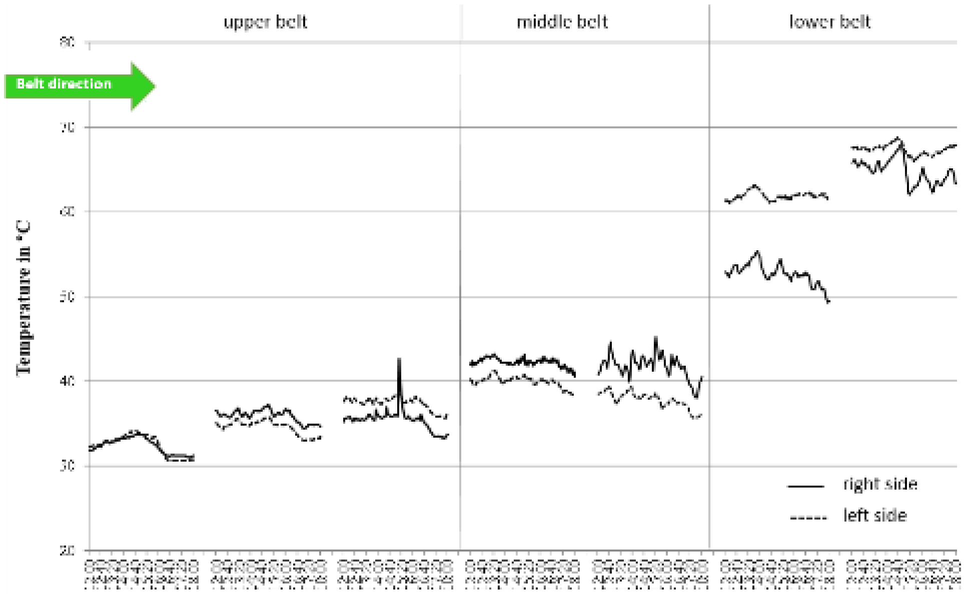


Figure 32: Stagnant temperature curve of the drying air flowing over the middle drying belt

The continuous increase in temperature over the 3 drying belts in Figure 2 suggests a uniform drying process. In contrast, the temperature curve in Figure 3 levels off above the middle belt. This indicates that little or no drying occurs there. Slow or static water removal requires a longer drying time and reduces efficiency.

By installing a thermal imaging camera at the end of the top belt, the hop cone surface temperatures were recorded across the entire belt. This meant that the drying of the hops on the upper drying belt could be observed during the entire drying time and checked for uniformity in real time.

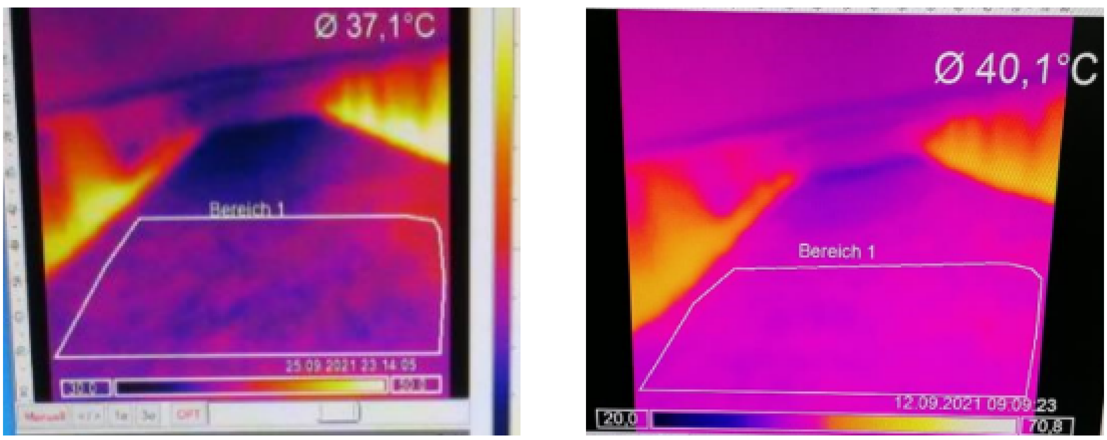


Figure 33: Displays from a thermal imaging camera installed at the end of the upper drying belt looking towards the entire installation

The right thermal image in Figure 4 shows almost uniform drying over the entire drying surface of the upper belt. The cone surface temperature has risen to an average of 40° C. In contrast, the left thermal image (dark blue areas) clearly shows that the hops are drying too slowly, especially at the front of the drying area. In addition, drying is more uneven. In this case, reducing the height from which the hops are dumped might be a first remedy.

Conclusion:

Instead of or in addition to the data loggers, the drying process or the degree of dryness of the hops on the respective drying belts can be checked using mobile thermal imaging cameras that measure the cone surface temperatures. In addition, the installation of a thermal imaging camera at the end of the top belt makes it possible to check the uniformity of the drying process over the entire belt width and belt length.

4.6 Testing various biodegradable materials as a replacement for the plastic cord on the "string wire"

Background

In the Hallertau, almost half the hop-growing area relies on wires that have plastic cords at the ends. These are made of polypropylene (PP) and are used to tie the wires to the trellises. The wires are strung anew every year. Compared to wires alone, the flexible cords does not rub against the trellises. They do not create potential breaking points. They makes the entire configuration more stable; and minimize the number of bines falling during high winds and severe storms. Unfortunately, the cords usually do not break during the harvest but remain on the trellises for years. However, the sun's UV radiation eventually makes them porous and they can fall and become plastic residue in the soil. Because polypropylene does not decompose well, these residues can accumulate and turn into visible soil contamination. Even mechanical shredding cannot make the plastic disappear and particles smaller than 5 mm, called microplastics, increasingly accumulate in the environment, where they can be transported by wind or runoff water and end up in previously uncontaminated fields or in our streams and rivers.

To counteract this increasing amount of environmental plastic string waste, wire suppliers have been experimenting for years with alternative materials that not only meet tear strength and handling requirements but are also be completely biodegradable to solve the environmental problem.

The Bavarian State Institute for Agriculture is now conducting for the second year in a row comparative "string wire" tests at two locations (described below) to investigate and evaluate marketable solutions objectively.

Method

The test locations in both years were in the northern part of the Hallertau, near Ilmendorf and Forchheim. To create the right challenges, both hop areas are open to the prevailing westerly winds. The test variety was Herkules. As is customary, the wires were strung in early spring. The two barbed wires per furrow were also hung for each variant.

Biodegradable materials of natural origin, which were provided by various manufacturers, were used. Because of the limited availability of the test materials, not all variants could be hung over the entire length of the hop garden. In some variants, only 100 cord wires were available. Since individual materials were available in spools only and had to be fastened to the wires by hand before they could be attached to the barbed wire.

The following alternatives to the plastic cord were tested in 2023:

- Cords made of polylactide (PLA) or polylactic acids
- Cellulose cord from Joro Verde
- Yarn based on sisal and other natural fibers

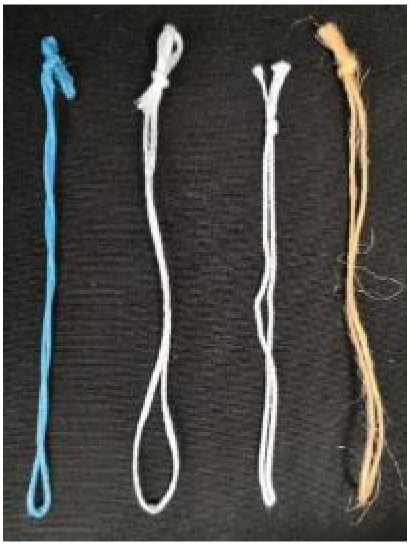


Figure 34: Tested materials: plastic, PLA, cellulose, and sisal cord (from left)

The following common materials were used as a reference in the experiment:

12-mm plastic cord wire and 13-mm iron wire.

During the attachment of the wires, the handling of the respective materials was assessed and the test area was checked for fallen bines throughout the growing season until harvest time.

Results and discussion

The table below summarizes the initial assessment of the materials in both test locations, with regard to handling, tensile strength (number of fallen bines), and environmental compatibility (biological degradation behavior),

Table 10: Evaluation of the cord wire materials compared to iron wire only

Material	Handling (when hanging)	Tensile strength (downed bines)	Environmental sustainability (Biological degradation)
Iron wire	+ + +	+ +	+ + +
Plastic cord	+ +	+ + +	-
PLA-cord	+ +	+ + +	(+)
Cellulose	+	+ + +	+ + +
Natural fibers (sisal)	+ +	(+)	+ + +

+ = good, positive - = bad, negative

The **iron wire** as a climbing aid for bines has been standard in hop cultivation for decades. However, it has slowly been replaced by string wire in wind-prone locations during the past three decades, mostly to reduce the number of downed bines. After the harvest, chopped iron wires can largely be separated from the bine shreds using magnetic separators. The iron is then sent as scrap for recycling. Wire segments returned to the fields oxidize and the iron enters the soil's natural iron reserves.

The **plastic cord** has advantages in wind-susceptible locations and for varieties with high bine weights. Fewer downed bines mean fewer bines have to be restrung laboriously. Recently, however, plastic cords have come under criticism for environmental reasons (see above).

Cord wire made of polylactide (PLA) is being marketed as an environmentally friendly alternative. It is similar to conventional plastic cords in terms of handling and tear resistance. It is a bioplastic made from renewable and natural raw materials, such as corn starch. However, there are limitations to its environmental compatibility becauts its biodegradation works only in industrial composting plants at temperatures above 55 °C, wihle rotting in the soil under natural conditions occurs only very slowly or not at all.

In order to offer sustainable alternatives to plastic cords, the focus has been on materials that also rot in the ground and are completely biodegradable. A **cellulose cord** was tested and found promisingly last year. It shows very good tear resistance (no downed bines!). It breaks down in the soil within a few months without leaving any residue. The raw material for the cord is cellulose from beech wood, which is industrially processed into a solid fiber. The only disadvantage is the somewhat poorer handling during wire hanging, as the cellulose cord is less stiff than the plastic cord. Trials with dipping the cord in a starch solution and then drying it, which causes the stiffness to improve significantly, show promising results.

Figure 35: Hop bine on cellulose twine shortly before harvest

A **cord made of sisal** and other natural fibers was tested as another natural material that has the desired stiffness and is also 100% biodegradable. However, the material did not have the required tensile strength, leading to an unacceptable number of downed bines. As an improvement, the diameter of the cord could be increased, or the twist could be optimized. However, naturally obtained, processed materials always run the risk of fluctuating quality.

To achieve further improvements and ultimately offer a sustainable and environmentally friendly product as a real alternative to plastic cords, the Bavarian State Institute for Agriculture intends to test additional biodegradable cord wire alternatives in 2024.

4.7 LfL projects as part of the production and quality initiative

From 2019 to 2023, the Bavarian State Institute for Agriculture collected, recorded, and evaluated representative yield and quality data for selected agricultural crops as part of a production and quality offensive for agriculture in Bavaria. The network partner Hopfenring e.V. carried out these activities for the IPZ hop working group. The objectives of the hop projects are described below and the results for 2023 are summarized.

4.7.1 DM (dry matter) and alpha acid monitoring

From August 16 to September 26, 2023, one line of hops was harvested on several dates at weekly intervals and dried separately from each of 10 commercial hop gardens distributed across the Hallertau. The samples were harvested for each of the following varieties: Hallertauer Mfr., Hallertauer Tradition, Perle, Hersbrucker Spät, and Tango (all aroma varieties), as well as Hallertauer Magnum, Herkules, and Titan (all high alpha varieties). An accredited laboratory then determined the water removal and analyzed the DM and alpha acid content of these 5 aroma and 7 bitter varieties. The dry matter content of the green hops and the alpha acid content of the hops at 10% water were determined the day after and sent to the LfL hop advisory service for evaluation. The results were averaged, prepared in tables and graphics, and posted online with a comment. Based on the results and presentations, farmers could glean information about the optimal harvest maturity of the most important hop varieties.

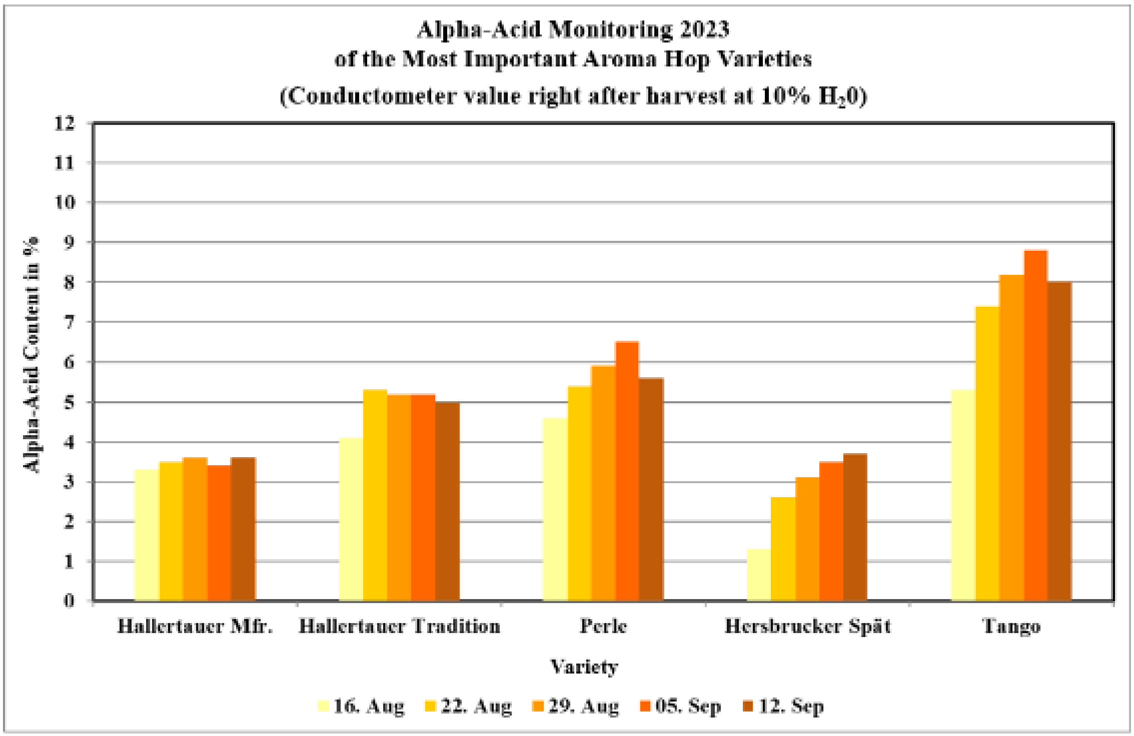


Figure 36: Monitoring of the development of alpha acid levels in 2023 in the most important aroma varieties

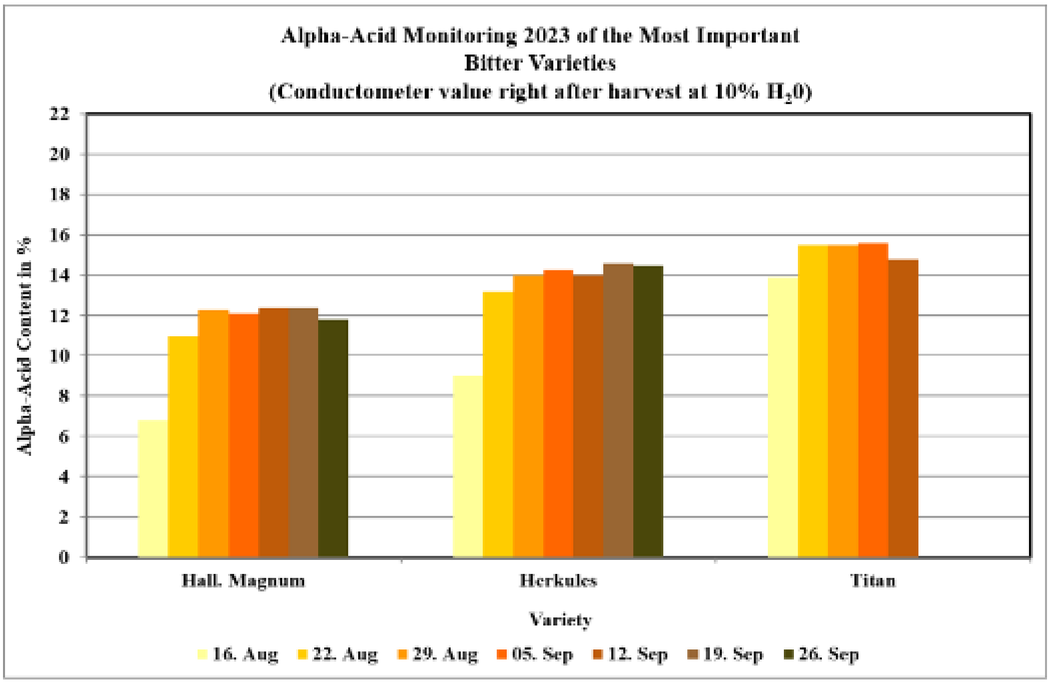


Figure 37: Monitoring of the development of alpha acid levels in 2023 in the high alpha varieties

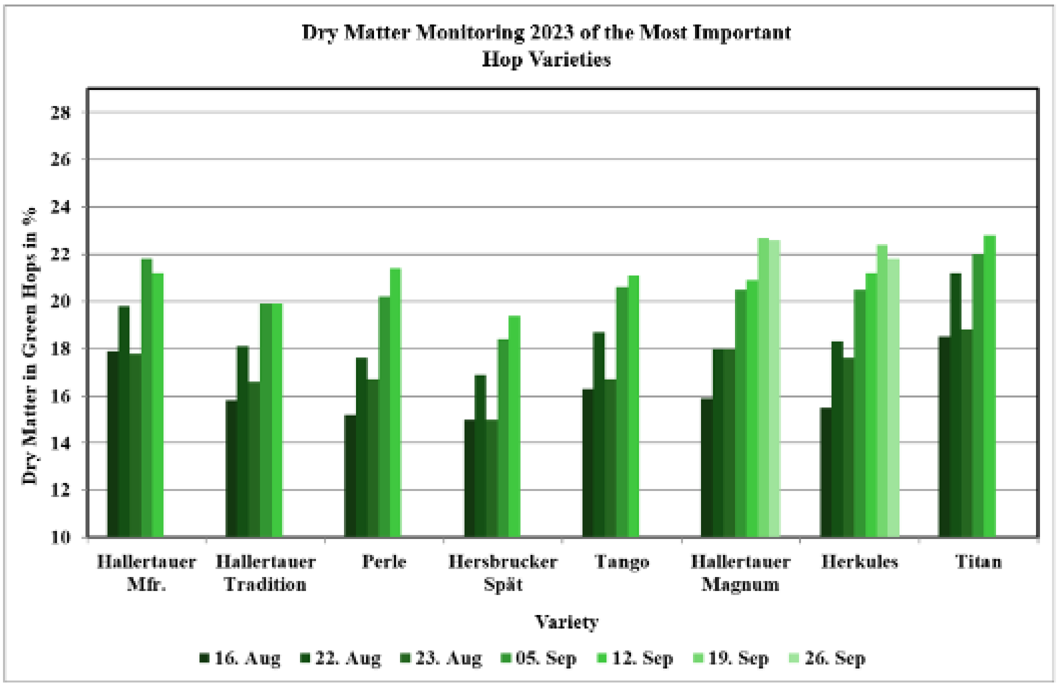


Figure 38: Monitoring of the development of dry matter content in 2023 of the most important hop varieties

The following graphics give a comparative overview of 2022 and 2023 data for Perle and Herkules relative to the average of the past 6 years and staggered by harvest times. They show that 2023 alpha acid values for Perle and Herkules were disappointing and below the long-term average.

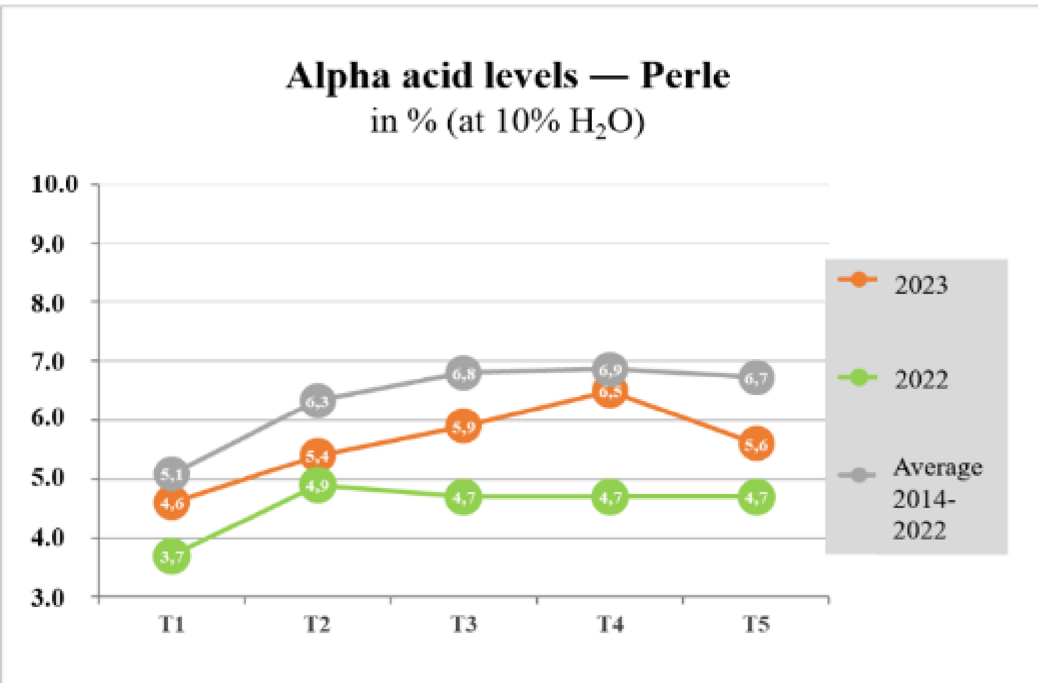


Figure 39: Development of alpha acid levels for Perle compared to previous years

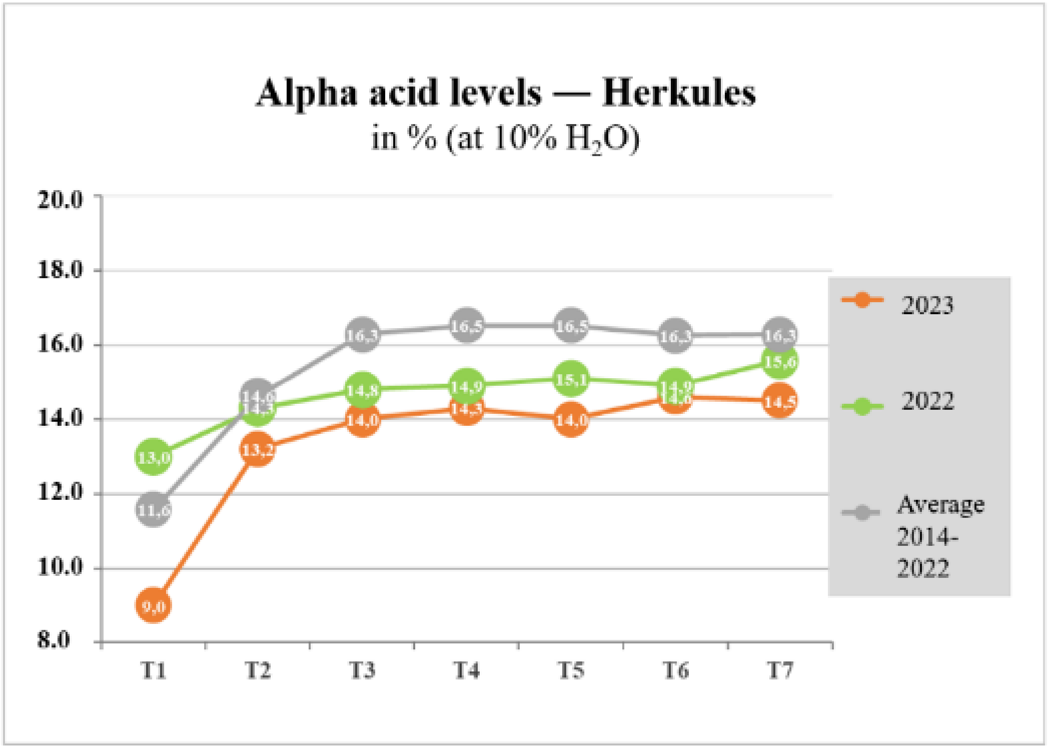


Figure 40: Development of alpha acid levels for Herkules compared to previous years

4.7.2 Annual survey and investigation of pest infestation in representative hop gardens in Bavaria

To assess aphid and spider mite infestations for the prupose of developing advisory and control strategies, 33 representative commercial hop gardens (including 3 organic hop gardens), each cultivating different varieties in the Hallertau (23), Spalt (7) and Hersbruck (3) were surveyed weekly on 12 dates between May 22 and August 7, 2023. The results were published in advisory statements and used to formulate control strategies.

An overview of the progression of the spider mite infestation index is shown in the following figure. Because of the cool and wet spring in 2023, the first spider mites appeared on the hop leaves 2 to 4 weeks later than usual. The infestation developed significantly more slowly than in previous years. There was also no sudden increase in the infestation index. This meant that any control measures could be implemented in a premeditated and limited fashion.

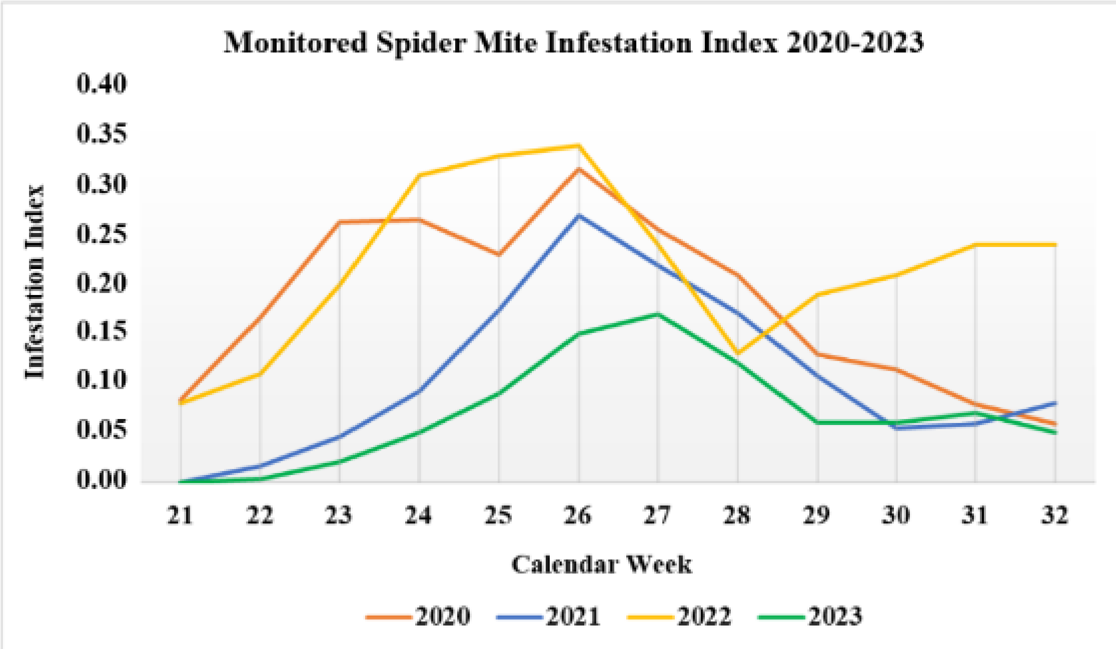


Figure 41: Course of the spider mite infestation index as an average across all 33 monitoring locations

4.7.3 Chlorophyll measurements on hop leaves to assess nitrogen supply and fertilizer requirements

Objective:

The requirements and restrictions of the new German fertilizer regulations pose major challenges for hop growers. On the one hand, it is important to maintain the hop yield level and achieve optimal quality. On the other hand, water protection measures must be followed consistently. With regard to nitrogen fertilization, this means that the nitrogen must be administered evenly and carefully, in a targeted and nutrient-efficient manner. Because the main nitrogen uptake by hops occurs in June and July, if the weather is too dry during that peirpd, nitrogen fertilizer may no dissolve into the soil. Ifm on the other hand, conditions are too moist, organically bound nitrogen in the soil can mineralize. In either case, the nitrogen supply in the soil and the necessary amounts of fertilizer are difficult to assess. Therefore, regular leaf examinations at different locations and on different varieties are intended to generate information about the nutritional status of the hop plants, which in turn provides need-based advice on fertilizer quantities.

Method:

From 2019 to 2023, chlorophyll measurements were carried out between the end of May and mid-August on hop leaves using the SPAD meter ("soil plant analysis development" SPAD-502 plus). The tests were conducted in a weekly rhythm on 10 dates in various plots. For representative statements, 20 individual measurements were taken on leaves at a height of approximately 1.6 m per date and plot. To obtain an idea of the actual N supply status, each of the 20 measured leaves were separated from the bines, collected, and dried for the overall N content determination in their total dry matter (according to the Dumas method). The 20 leaves were always taken from each of the two wires, of each of 10 hop bines in a row. This avoid including false measurements as a result of the possibly variable exposure of some leaves to sun or shade. SPAD values were determined from several repetitions for each variety, location, and variant. This allowed for the detection of differences among the varieties, as well as in the supply of nitrogen. In addition, we could use linear regression analysis to uncover the relationship between the measured chlorophyll values and the actual N contents.

From 2019 to 2021 and in 2023, the measurements were carried out in nitrogen fertilization trials to identify whether the chlorophyll measurements can capture the differences in nitrogen supply. In 2022, these measurements were carried out in parallel in two breeding research gardens. The purpose was to detect possible variety-related and location-related differences with the same nitrogen supply.

Results:

Chlorophyll measurements:

From 2019 to 2021 and in 2023, a differentiated N supply range was identified using the SPAD meter measurements in the fertilizer trials with 3 different levels of N fertilizer each. In each of the experiments, the variants that received more fertilizer also had higher N values and vice versa, including plants that received no fertilizer at all. Significant differences in nitrogen supply were usually measurable earlier in the season (beginning of June), while small differences in supply often became measurable only very late (beginning of July); or they were barely measurable at that point. In 2019 and 2020, the differentiated N supply was detectable using chlorophyll measurements at the beginning of July (see annual reports 2019 and 2020), while in 2021, significant differences in N supply were already detectable at the beginning of June (see annual report 2021).

In 2022, a closer look at various hop varieties at two locations and with comparable or identical N supplies revealed clear differences in SPAD meter values taken simultaneously and averaged across all dates. For Hallertauer Magnum and Pearle, for instance, the SPAD value was 5.4. It can be assumed that variety-related differences in leaf color (Hallertauer Magnum significantly darker than Pearle) influence SPAD meter measurements unrelated to the nitrogen supply (Annual Report 2022). As past studies have shown, a difference in the SPAD value of 5.4 points for the same variety can be due to a significant N deficiency. This confirms that the SPAD meter value can vary greatly depending on the variety, regardless of the N supply status. In the trial year 2023, the measurements were again carried out in a fertilization trial with organic fertilizers and different N supplies. In this test year, the difference in N supply between 90 kg N and 180 kg N was again visible across all measurement dates. However, relative to the 90 kg N variant, there was no improved N supply as a result of multi-year fertilization with bine shreds or digestate, even though these types of fertilizers had a measurable effect in experimental harvests, where they translated into creased yields and higher nitrogen removal values. (Figure 42).

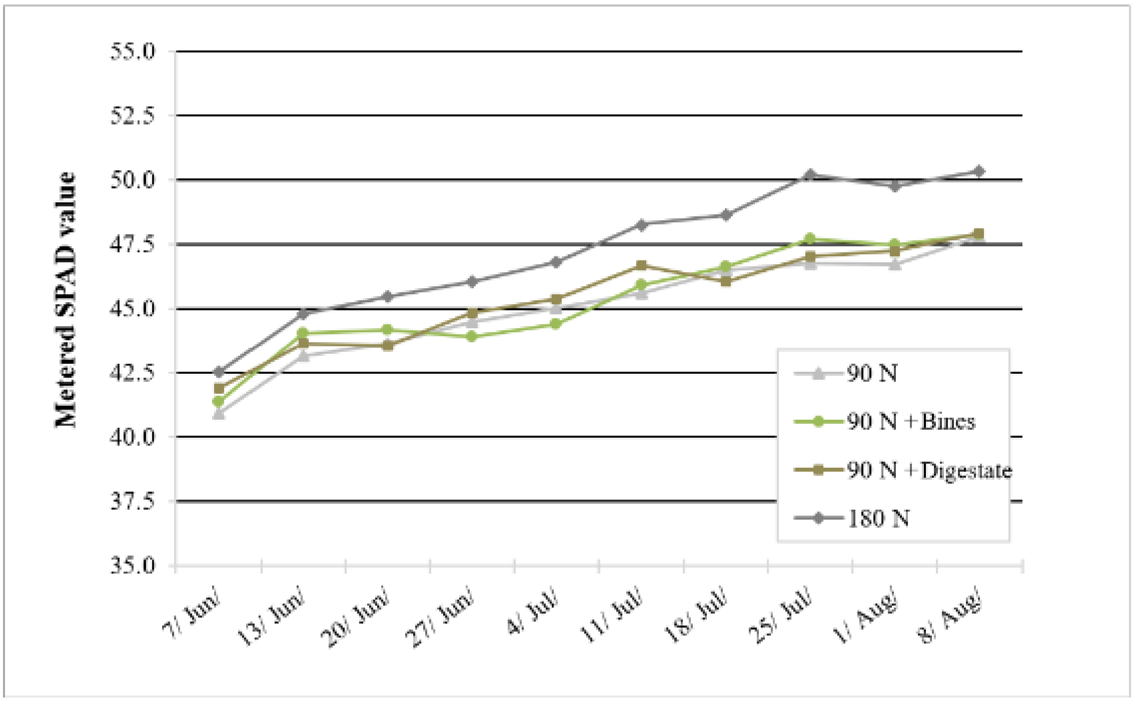


Figure 42: SPAD meter values over the course of 2023 across 10 dates in the fertilization trial with organic fertilizers; medium soils; variety Herkules. (The variants are: 90 N = 90 N mineral in 2 doses; 90 N + bine shreds = 90 N mineral in 2 doses + 90 N via bine shred in the fall; 90 N + digestate = 90 N mineral in 2 doses + 90 N over digestate in June; 180 N = 180 N mineral in 4 doses)

<u>Relationship between chlorophyll measurements and N content in the leaves</u>

In all 5 years of the experiment, the leaves measured with the SPAD meter were collected and then examined for their N content in dry matter (Dumas combustion method). Parallel to the curves of the SPAD meter values, the curves of the actual N content in the plant biomass could be displayed and compared. As can be seen in Figure 43, the test values show similar differences in the variants. The N level curve, however, declines steadily, while the SPAD meter values increased until mid-August. The decrease of N content in the green parts of plants during the vegetation period is known as the dilution effect. The increase in biomass is disproportionate compared to the uptake of nitrogen, which is the reason why the relative N content declines.

Figure 43: Nitrogen content as % of DM in the leaf blade over 10 dates in the fertilization trial with organic fertilizers in 2023 (with the variants: 90 N = 90 N mineral in 2 doses; 90 N + bine shreds = 90 N mineral in 2 doses + 90 N via bine shreds in the fall; 90 N + digestate = 90 N mineral in 2 doses + 90 N over digestate in June; 180 N = 180 N mineral in 4 doses), easy location, variety Herkules

Figure 44 shows the connection between the chlorophyll measurements and the actual N contents in the leaves at 2 dates. This result illustrates what was noticeable in almost all years of testing: at the beginning of the series of measurements, it was not yet possible to determine a very close connection between SPAD value and N content. At the later dates, coefficients of determination of $R^2 > 0.60$ could be calculated in the linear regression models, which allowed for a relatively precise conclusion from the chlorophyll measurements to the actual N contents in the measured leaf blades and thus to the N supply of the plants. In this experiment, higher coefficients of determination (R^2) of over 0.60 could only be achieved from T6 onwards. The results of recent years indicate that the connection between the measured chlorophyll values and the actual nitrogen supply cannot be established as precisely at earlier as opposed to later dates in the vegetation cycle.

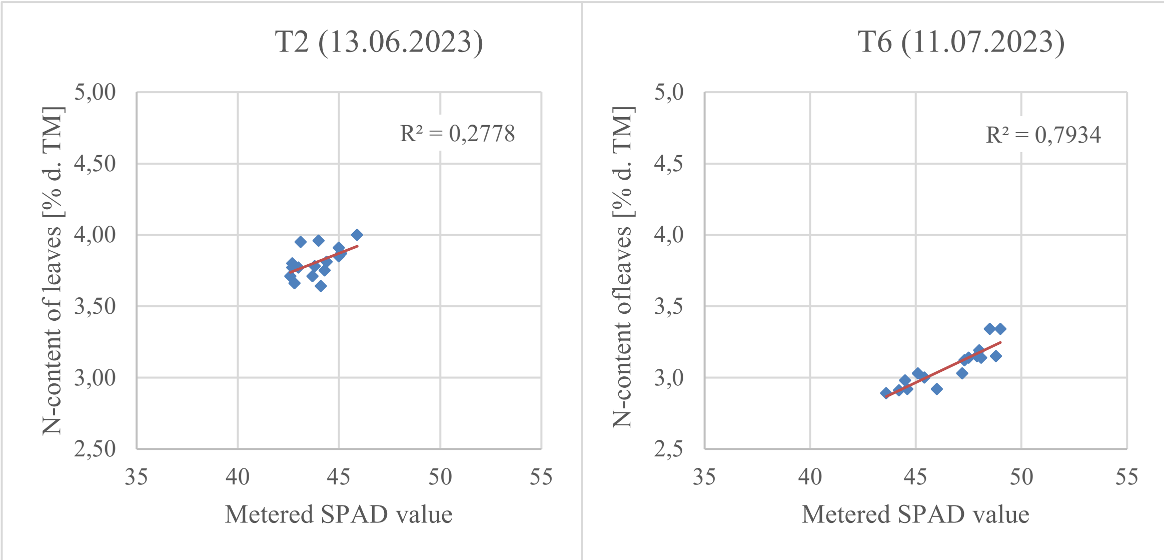


Figure 44: Linear regression between chlorophyll value and leaf N content on 2 dates in 2023, light location, variety Herkules

Conclusion:

The experimental results from several years demonstrate that chlorophyll measurements are a useful tool, especially from the second half of June onward, for determining differences in nitrogen uptake by hops. An N supply variation in terms of time and quantity could be clearly depicted using the curves. If one wants to transfer the measurement system from experiments into commercial practice, it is obvious that a system with variety-specific threshold values would have to be established, in which certain minimum values would have to be precisely defined for individual development stages. While the data is currently not sufficient, the experiments showed that different maximum values were actually detectable using SPAD meter measurements for the same varieties at different locations with sufficient nitrogen supplies. In addition, differences in nitrogen supplies were often only measurable late in the fertilization season. This confirms that even a system with threshold values for location-related growth differences is not sufficiently precise to be able to make clear and timely fertilization recommendations during the vegetation period. The findings from this project have strong overlap with those obtained from a large-scale research project conducted from 2017-2019 on fertilization systems using fertigation. These results are explained, among other studies, in a dissertation “Need-based nitrogen nutrition of hops through fertilizer systems with fertigation.” The measuring system using chlorophyll contents as described here, however, is considered unsuitable to guide fertilization during the vegetation period, if that fertilization involves an irrigation system with fertigation.

4.7.4 Chain analyses for quality assurance in the determination of alpha acids requirements in hop supply contracts

For years, hop suppliers have used supplementary contractual agreements that take into account the alpha acid content of the delivered hops when determining payments. The alpha acid content is determined in state laboratories, corporate laboratories, and separate private laboratories depending on the available testing capacity. The procedure (sample division, storage) is precisely defined in the specifications of the “Working Group for Hop Analysis.” The tolerance ranges permitted for the analysis results are clearly defined, as are the laboratories that are approved to carry out follow-up tests. To ensure the quality of alpha acid analyses in the interests of hop growers, there analyses are organized as a chain; and thewy are executed and evaluated by the Bavarian State Agricultural Institute as a neutral body.

As part of the project, the task of the Hopfenring (Hop Circle) is to carry out the sampling of a total of 60 randomly selected hop batches on 9 or 10 dates in the Hallertau and to provide the samples to the LfL laboratory in Hüll.

4.8 Consulting and training activities

In addition to conducting applied field research in hop cultivation production technologies, the working group Hop Cultivation, Production Technology (IPZ 5a) is tasked with the preparation of test results, along with advice and practical recommendations. It also has to make these available directly to hop growers. The tasks may include special consultations, lectures, organizing working groups, training courses, seminars, publishsing print media, and internet content. Specific examples are the organization and implementation of a downy mildew warning service; updating instructions for this warning service; cooperating with various hop organizations; and providing training and technical support to such partners as the Hopfenring.

The training and consulting activities of the past year are compiled below.

4.8.1 Information in written form

- The “Green Booklet” Hops 2023 - Cultivation, Varieties, Fertilization, Plant Protection, Harvesting was updated together with the Plant Protection Working Group in coordination with the advisory centers of the federal states of Baden-Württemberg and Thuringia and sent to the LfL. The press print run was 2,100 copies, distributed by the LfL to the ÄELF and research institutions and by the Hopfenring Hallertau to hop growers.
- The LfL used an established Hopfenring fax network to distribute time-sensitive cultivation instructions and warnings in 31 faxes via the Hopfenring ring fax (2023: 69 transmissions in Hallertau, Spalt and Hersbruck; 956 subscribers).
- Advice and specialist articles for hop growers and the brewing industry were published in 6 monthly issues of the Hopfen-Rundschau and 1 article in the Hopfen-Rundschau International.

4.8.2 Internet and Intranet

Warning service and advisory information, specialist articles and lectures were made available to hop growers via the Internet.

4.8.3 Telephone advice, announcement services

- The *Peronospora* warning service of the Working Group on Hop Cultivation and Production Technology, located in Wolnzach, was active from May 9 to September 4, 2023. The service was available to iussue warnings and instructions, and to answer inquiries via an answering machine (Tel. 08161 8640 2460) or the internet. The service was updated 79 times.

- Technical advisers of the same working group also provided information during roughly 1,100 telephone inquiries, as well as one-on-one consultations in meetings or on site.

4.8.4 Training and further education

- Examination of 2 projects written by master students as part of their examination
- 14 lessons about hop cultivation at the Pfaffenhofen Agricultural School
- 1 study day during the summer semester at the Agricultural School in Pfaffenhofen
- 3 meetings of the “Hops Management” working group

5 Plant Protection in Hops

Simon Euringer, M.Sc. Agricultural Management

5.1 Pests and Diseases of Hops

5.1.1 Downy mildew warning service 2023

The downy mildew (*Pseudoperonospora humuli*) warning service is used to determine the risk of downy mildew secondary infections. This year, the downy mildew warning service started on May 9, 2023. The number of spores was at a low level for a long time because of the dry weather. However, primary downy mildew infections could still be detected until mid-June. A strong primary *Peronospora* infestation, in some cases on an enormous scale, was observed at many locations in 2023.

Historically, the first call for spraying was made very late in the season on July 27, 2023. The background to this call for spraying was the number of spores in combination with the high prevailing risk of infection as a result of heavy rains and changeable conditions during the previous days. The risk of infection at this time was confirmed in weather-based models by the damage thresholds being exceeded by susceptible and tolerant varieties.

A total of four calls for spraying against downy mildew infection were necessary in the 2023 growing year. Two of the four calls for spraying were for all growing regions and all varieties without restrictions. However, the call for spraying on August 22, 2023 and September 4, 2023 — though made for all growing regions and varieties — was adjusted for the anticipated time of harvest.

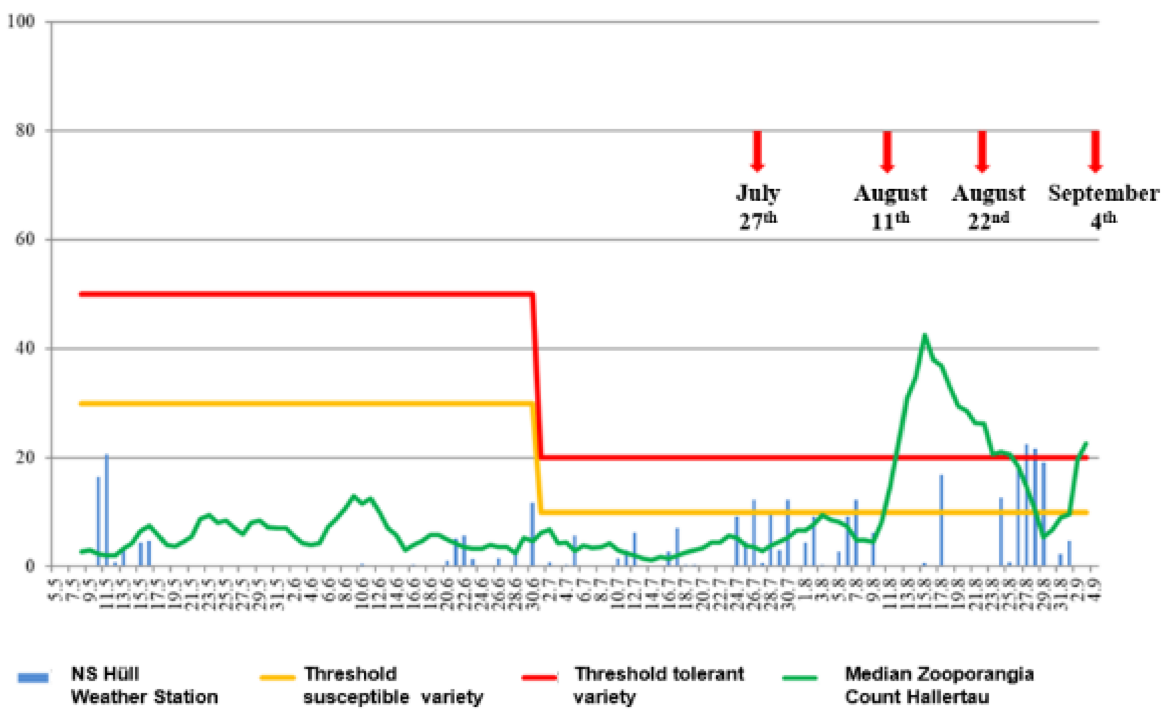


Figure 45: Presentation of the downy mildew warning service 2023 (average number of zoosporangia*, Hallertau, 4-day total, 5 locations, and calls for control). Source IPZ 5a*

5.2 Official Effectiveness Tests

Management: S. Euringer

Team: A. Baumgartner, M. Felsl, K. Kaindl, K. Lutz, R. Stampfl, J. Weiher, F. Weiß

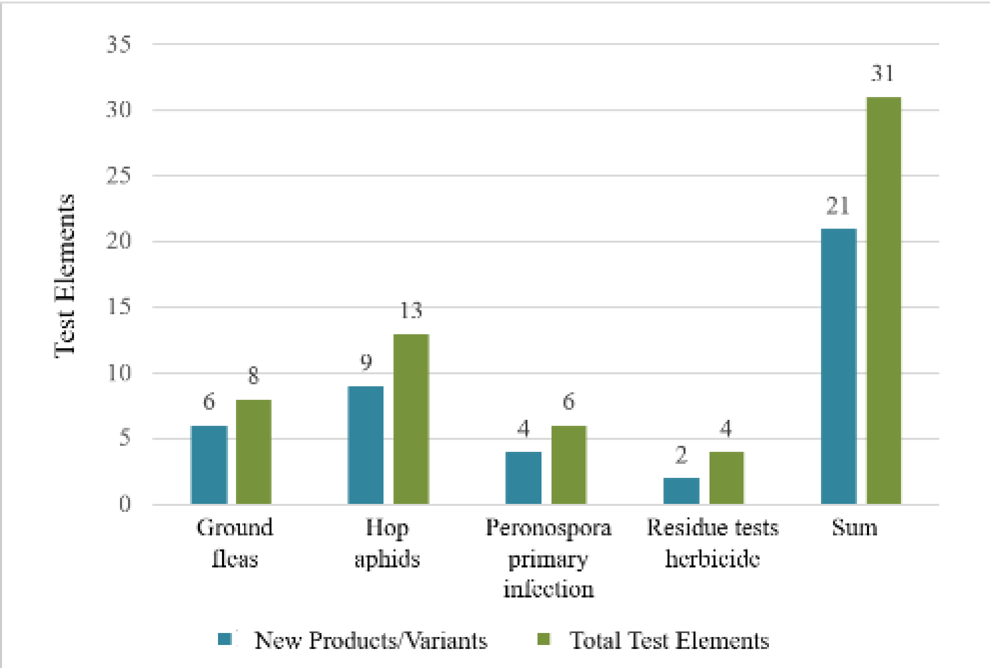


Figure 46: Official GEP (Good Engineering Practice) tests in 2023

In the experimental year 2023, seven tests were carried out according to the Good Engineering Practice (GEP) standard in the official means test. Furthermore, some greenhouse experiments were carried out on powdery mildew and phytotoxicity (toxicity to plants). Four indications were covered in the GEP trials. In total, 21 new products or combinations were tested in 31 test sections on approximately 4.5 hectares.

5.2.1 Creation of a test garden for testing the effectiveness of crop protection products

A test hop garden was created in 2021 for official effectiveness tests of the new agrochemicals to provide early support in the development of crop protection products and thus ensure that new products are quickly available for practical use. The fresh hop area was planted with certified Herkules seedlings in October 2021 and maintained as a young hop area in 2022. It has an area of roughly 1 ha, which is sufficient space for nine experimental units. The first trial on the hop aphid indication took place on this area in 2023.

Figure 47: Test hop garden on June 19, 2023

5.2.2 New experimental sprayer for representative testing

Plant protection in hop cultivation is hardly comparable to that in regular farming. It poses a number of unique challenges, especially for experimentation, in part because applications require special technologies that must work up to a trellis height of 7 m. Also, it must cover much larger plots than in regular farming to prevent drift into adjacent plots.

Experimental systems rely on randomized blocks, which means there is a problem with regard to soil compaction because of the random distribution of plots in the blocks. This requires plenty of vehicle traffic on the paths into the plots. Conventional vehicles are equipped with just one spray tank. Therefore, selected test sections in plots receive applications one trip at a time, with all spray rows/lanes used several times to treat the selected test sections sequentially.

Figure 48: Multi-tank test sprayer for representative testing

In unfavorable weather, this can lead to increased ground pressure and structural damage. To remedy this problem, a group of several companies have developed a test sprayer with several spray tanks designed specifically for hop cultivation. This allows for the treatment of several plots with only one pass per spray row/lane. Starting in 2024, this new spray technology, funded by HVG, will revolutionize experimental work at the Hop Research Center. In addition to being more soil-friendly, it also makes test results more precise because the different test sections can be treated in a single run, almost simultaneously. This significantly reduces extraneous, time-related influences on test results and makes them more representative.

5.3 Resistance and effectiveness tests against hop aphids in the spray tower

Management: S. Euringer

Team: A. Baumgartner, M. Felsl, R. Stampfl

Hop aphids (*Phorodon humuli*) attack all hop varieties every year. However, the current efforts to phase out of several important insecticides makes it much more difficult to alternate between active ingredients and to avoid building up resistances. The repeated use of the one and the same active ingredient or ingredients relying on the same containment strategy, unfortunately, leads to a one-sided selection of harmful organisms that have developed resistances to the measures; and eventually, successful pest control becomes impossible. Therefore, currently available as well as new-to-market active ingredients against hop aphids need to be validated in spray tower experiments. Laboratory tests producing consistent repeat results can detect resistances at an early stage. Such laboratory results for different substances, however, can deviate greatly from field applications and are, therefore, not made public. In 2023, five active ingredients were tested in seven concentrations each.

5.4 Resistance and effectiveness tests against the hop flea beetle in a spray tower

Management: S. Euringer

Team: A. Baumgartner, R. Stampfl

The hop flea beetle (*Psylliodes attenuatus Koch*) is generally considered to need controlling in the spring if, at that time, the infestation is rather severe during hop budding phase up to a plant height of 1 m. Furthermore, a massive occurrence in the summer can also damage flowers and cones, also making control necessary.

In the spray tower, plant protection products approved for other indications, as well as possible future candidates, were tested for possible side effects or effects on the hop flea beetle. To do this, hop leaves were first sprayed with a defined concentration of the respective product (Potter spray tower). A cage was then placed on each leaf. After the spray coating had dried, up to 10 flea beetles were placed in the cages, which were then sealed.

After just one day, the damage to the leaves was already apparent. Further tests are needed to determine the extent to which the tested agents influence the feeding activity or death of the pest.

Figure 49: Treated variant

Figure 50: Untreated variant

5.5 Enzyme-linked immunosorbent assay (ELISA) for the identification of hop mosaic virus (HpMV) and apple mosaic virus (ApMV) infection on hops

Management: S. Euringer

Team: A. Baumgartner, M. Felsl, S. Huber, K. Lutz

Viral diseases are widespread in all hop-growing areas. In order to identify and detect plants infected with viruses, the ELISA test was re-established at the Hop Research Center Hüll.

Table 11: Results of the ELISA-Tests in 2023

	Total number of plants	ApMV		HpMV		Total plants	
		n.n.	positive	n.n.	positive	n.n.	positive
Mother plants for hop propagation	116	116	0	115	1	115	1
Breeding material IPZ 5c	702	697	5	668	34	663	39

* n.n. = undetectable

Samples that result in values close to the detection threshold are considered positive to minimize the risk of introducing potentially infected material into propagation.

Of 818 plants tested, 40 were discarded. The healthy plants were provided as breeding material and as mother plants for the GfH contract propagator.

5.6 Research Project on *Citrus bark cracking viroid* (CBCVd)

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)*
Financing:	Erzeugerorganisation Hopfen HVG e. G. *(HVG Hop Processing Group)*
Project Management:	S. Euringer
Team:	Dr. C. Krönauer, F. Weiß
Duration:	April 1, 2023 to March 31, 2026
Collaboration:	Molekulare Diagnostik: Virologie *(Molecular Diagnostics: Virology)* IPS 2c Züchtungsforschung Hopfen *(Hop Breeding Research)*: IPZ 5c, B. Forster, P. Hager, B. Haugg Hopfenbau und Produktionstechnik *(Hop Cultivation and Production Technology)*: IPZ 5a Slovenian Institute of Hop Research and Brewing: Dr. S. Radišek

The Citrus Bark Cracking Viroid (CBCVd) was detected for the first time in the Hallertau in 2019 and is therefore a comparatively new pathogen in German hop cultivation. Research into the effects of CBCVd on hop varieties grown in Germany and possible plant resistance is still in the early stages. The aim of the CBCVd research project is to use the knowledge gained to create an evidence-based foundation for the future handling of CBCVd in agricultural practice.

The CBCVd research project is divided into five areas: field hygiene, rehabilitation, establishment of a test variety garden, yield assessment, and the biology of the pathogen. To carry out the field studies, a 1.9 hectare hop garden was selected that had already been heavily infested with CBCVd in the past and is therefore suitable as a test area.

Planting of the test garden started at the beginning of the 2023 season. As a basis for later breeding experiments, the susceptibility to CBCVd of more than 20 hop varieties and breeding lines currently under cultivation worldwide will be observed in the following years.

On a sub-plot of approximately one hectare, tests are being carried out to determine whether it is possible to cultivate a healthy population once again on an area that had previously been affected by CBCVd. To this end, the first of four rehabilitation sections was cleared in the spring of 2023. On a further 0.5 ha, three field sections will be compared to check whether there are differences in the spread rate of the CBCVd infestation after three years, with standard cultivation procedures employed in one section; with the best possible disinfection strategies in another; and finally with minimal cultivation interventions in the last one.

Furthermore, the project aims to assess the specific damage caused by a CBCVd infection. A decrease in yield of plants affected by CBCVd is to be expected due to reduced growth and reduced cone formation. For the project, test harvests after an infestation with CBCVd allowed for the quantification of the decline in yield and for the detection of possible differences in the relevant hop compounds of the most common varieties in the Hallertau.

The project aims to further advance research into the molecular mechanisms of a CBCVd infection. To this end, the LfL works closely with numerous international partners. Information about the CBCVd is available on the LfL website and is passed on to the public through publications and lectures. Based on our previous results, hop growers will be advised on how to avoid CBCVd infections. They will also receive support relating to containment measures. The current plan is to publish detailed test results at the end of the project in 2026.

5.7 CBCVd Monitoring 2023

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)*
Financing:	Erzeugerorganisation Hopfen HVG e. G. *(HVG Hop Processing Group)*
Project Management:	S. Euringer
Team:	Dr. C. Krönauer, F. Weiß
Sample Analysis	AG Züchtungsforschung Hopfen *(Hop Breeding Research)* IPZ 5c: B. Forster, P. Hager, B. Haugg
Duration:	July 15, 2023 to October 15, 2023
Sampling Period	July 2023 to August 2023

Planning and Execution

During the 2023 CBCVd monitoring, 226 plots from 64 farms were examined. In addition to hop growing enterprises that registered proactively for monitoring because they had suspicious-looking plants, 50 suppliers to the Hallertau biogas plant were randomly selected to participate in the monitoring. In total, an area of 520 ha was specifically monitored for plants that showed the characteristic symptoms of a CBCVd infection. These symptoms include torn bines, compressed growth, smaller leaves, and misshapen cones. In addition, aerial photos were taken with a camera drone. Ten suspicious plants per area were combined into a mixed sample and tested for CBCVd infection using qPCR. In contrast to 2022, a mixed sample was no longer taken in every field. Areas that have been infected with CBCVd in recent years and in which no effective clearing measures have taken place, are still classified as CBCVd-positive and were not sampled. In areas with a very uniform population of strong, normal plants, an infestation or the chance discovery of a latent infestation is very unlikely. These areas were not sampled either and were classified as CBCVd negative. The sample locations and area findings were digitally recorded in a geographic information system application and evaluated using qPCR.

Findings

Since the previous year, 3 hectares of affected area have been cleared. CBCVd infestation had been confirmed in 107 ha. In addition, CBCVd was detected for the first time in 40 ha. Currently therefore, 52 plots with an area of approximately 147 hectares are proven to be infested with CBCVd. In total, active CBCVd infestations were detected in fields of 12 hop growing operations in the Hallertau in 2023. CBCVd was detected for the first time in one company. A farm with the first CBCVd detection last year has no findings this year because it has since cleared the area (Table 12). Due to the wet weather in July, symptoms caused by CBCVd were less pronounced than last year. In order to continue to record the spread of CBCVd and to offer appropriate advice, voluntary CBCVd monitoring is planned again in 2024.

Table 12: Figures and results of CBCVd monitoring 2019 – 2023

Number of samples taken and spread of CBCVd in farms and areas.

1) After the initial infestation was discovered, comprehensive monitoring was no longer possible in 2019. Therefore, the spread of CBCVd is expected to be under-reported in 2019.

2) Only the fields and companies with known FID or company numbers selected for assessment were counted. nd = not determined (data was not yet available at the time of this evaluation)

Year	**2019[1)]**	**2020**	**2021**	**2022**	**2023**
Number of samples tested	320	2312	416	513	249
- of which CBCVd-positive	67	157	77	56	43
Number of companies assessed [2)]	17	431	162	194	64
- Companies with initial CBCVd proof	3	4	3	3	1
- Companies with CBCVd proof in the respective year	3	7	9	12	12
Number of fields examined [2)]	54	650	310	407	226
- of which CBCVd-positive	12	28	39	41	52
Total area surveyed [ha]	106	1868	726	1204	520
- of which CBCVd-positive [ha]	44	83	109	110	147
- - cleared, formerly CBCVd-positive area [ha]	2	6	9	3	---

5.8 GfH Project on *Verticillium* Research

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)*
Financing:	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)* Erzeugerorganisation Hopfen HVG e. G. *(HVG Hop Processing Group)*
Project Management:	S. Euringer
Team:	K. Lutz, F. Weiß, Team IPZ 5b
Cooperation:	AG Züchtungsforschung Hopfen *(Hop Breeding Research)* IPZ 5c: R. Enders, B. Forster, Hager, B. Haugg, J. Kneidl, A. Lutz AG Produktionstechnik Hopfen *(Hop Production Technology)* IPZ 5a: S. Fuß, A. Schlagenhaufer Slovenian Institute of Hop Research and Brewing (IHPS): Dr. S. Radišek
Duration:	June 1, 2017 to October 29, 2023

Objective

Since the first appearance of lethal *Verticillium nonalfalfae* strains, the causative agent of the aggressive form of hop wilt, a continuous spread of the infested area in the Hallertau growing region has been observed. *Verticillium* is a soil-dwelling fungus that has a wide host range and can survive in the soil as a permanent mycelium without host plants for up to five years. *Verticillium* cannot yet be controlled with pesticides. To manage disease infestation, an integrated approach consisting of sanatory measures, breeding efforts, adapted cultivation techniques, and remediation concepts should be implemented. A rapid transfer of knowledge will provide affected hop growers with assistance in implementing management measures on infested plots and contribute to the fastest possible restoration success.

Alternative remediation concepts: biological soil decontamination

During the course of the project, various renovation concepts were examined. In addition to the classic remediation through crop rotation with grain, which leads to the absence of host plants, the alternative concept of biological soil decontamination was tested (see Annual Report 2022). Because of the lower work and cost requirements, multi-year remediation with grain as an intermediate crop is still recommended. Care must be taken to remove sporadic hop plants and weeds.

Selection gardens

In three test gardens that were proven to be infested with lethal wilt, 102 test sections were tested for *Verticillium* tolerance in three replicates with seven plants each. At each location, so-called reference varieties (HTR = susceptible; HKS = tolerant) were rated over five years in addition to the breeding lines to be tested. The susceptibility of the breeding lines and varieties is stated in relation to the Hercules variety. It is covered in the Green Booklet.

Remote sensing

The evaluation of the remote sensing data from BayernAtlas began in 2018 in order to detect hop gardens affected by wilt. Furthermore, drones flew over selected areas. Their true-color RGB (red-green-blue) images contribute to a better understanding of the spread of wilt within the crop. Since 2021, hyperspectral sensors have also been used to distinguish *Verticillium*-infected plants from healthy plants. In order to validate the visual impressions, samples were taken for qPCR analysis at all locations. These analyses are carried out by the AG Breeding Research.

Thermal sanitation of bine shreds

Crop residues contaminated with *Verticillium* have a high potential for infection and should not be returned to the fields immediately after harvest. Correct storage can significantly reduce the infection pressure from the bine shreds. Storing in heaps for four weeks with one turn will ensure sufficient oxygen supply and thus keep the temperature high. This hot form of rot leads to a significant degradation of the *Verticillium* fungus. The sanitizing effect on the bine shreds increases with extended storage times and higher temperatures resulting from regular turning.

Eggplant indicator plant

When hops are artificially infected with *Verticillium nonalfalfae* in pots, the infection rate is often low and the plants only show symptoms after a few months. The eggplant (*Solanum melongena L.*) has proven to be a good indicator plant for hop wilt. Both the thermal sanitizing effect on bine shreds and the effectiveness of experimental agents could be assessed on eggplants. The following promising test materials were selected for outdoor testing: Polyversum, Prestop, Albosite, quicklime, ash-lime, Akra Kombi, Infinito, and Zorvec Enicade Nzeb. The outdoor experiment had to be stopped after three years because too many plants had died.

Practical tests

Since 2020, various cultivation measures have been tested in 27 hop gardens: increased potash fertilization, liming, clearing of individual stocks, partial area rehabilitation, and planting of a tolerant variety. Single-rhizome clearing proved to be most effective when there was only a slight wilt infestation, as the number of newly infected plants was reduced over the trial years. Clearing partial areas provides a head start on rehabilitation and prevents the entire hop garden from being shut down. The long-term effect of increased potash fertilization and increased liming should be clarified in further experiments. For this purpose, the test areas are assessed three times a year on an individual plant basis. IPZ 5c uses optical ratings and verifies these randomly using qPCR analyses. The team also supported IPZ 5c in all microbiological tasks during the project.

There will be a joint final report on this project and the follow-up project "Combating *Verticillium* wilt in hops" (see 5.9). This is scheduled to be published in 2026.

5.9 Innovative strategies for combating *Verticillium* wilt in hops

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)*
Financing:	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (StMELF) *(The Bavarian State Ministry for Food, Agriculture and Forestry)* Erzeugerorganisation HVG e. G. *(HVG Hop Processing Group)*
Project Management:	S. Euringer
Team:	K. Lutz, Team IPZ 5b
Cooperation:	AG Züchtungsforschung Hopfen *(Hop Breeding Research)* IPZ 5c: B. Forster, P. Hager, B. Haugg, J. Kneidl AG Mikro- und Molekularbiologie *(Micro-and Molecular Biology)* (AL 1c): V. Flad, B. Munk KU Eichstätt (Catholic University Eichstätt): Dr. M. Stark Slovenian Institute of Hop Research and Brewing (IHPS): Dr. S. Radišek
Duration:	October 30, 2023 to October 31, 2026

Objective

The pathogen that causes hop wilt (*Verticillium nonalfalfae*) spreads through the soil, planting material, and crop residues. Currently, infected plants cannot be cured.

The aim of the project is to work with farmers to develop practical strategies for reducing *Verticillium* infestations using an on-farm-based approach through field trials. Already known measures are evaluated and combined with new approaches to form a uniform concept. The focus is on better understanding the pathogen using new technical possibilities. This should be supplemented by knowledge gained about the interactions between the rhizobiome (bacteria, fungi, protista) and *Verticillium*.

Because there is currently no way to effectively combat the fungus, financial losses on thefarm from *Verticillium* can be significant. In this innovative research project, practical strategies for optimized disease management are being developed.

Method

Because of the close cooperation with commercial growers, test areas are available at several locations. The sub-projects described below are carried out in different areas. The extent of *Verticillium* infestation is determined by visually assessing the plants.

The effectiveness of the “classic” remediation measures against new *Verticillium* strains is assessed through tests in several commercial hop gardens.

The use of drones for visual assessment is becoming established in hop cultivation. This allows the workload reduction of inspections. It also makes it possible to detect *Verticillium* infestation arlier. Farmers can quickly and easily check the success of control measures without having to enter the field, thus minimizing the risk of them spreading the pathogen.

By planting a garden with several varieties, cultivars that show tolerance to new aggressive *Verticillium* strains can be identified. Variety testing forms the basis for breeding tolerant varieties, which in turn can ensure a successful future in hop cultivation in all German growing regions.

All currently existing *Verticillium* strains are cataloged and become part of a collection of single-spore isolates. IPZ 5c employes the molecular biological qPCR method for detecting *Verticillium* and distinguishing between the different variants. This method will be adapted to new variants if necessary.

In a newly planted hop garden with *Verticillium nonalfalfae*-contaminated soil, the rhizobiomes of healthy hop plants and of plant suffering from wilt for the first time are analyzed on a molecular level using DNA and RNA sequencing at the DNA and RNA. The worlk was done by AL 1c (see nder “Cooperation” above). The results will be used to develop strategies for the microbiological control of hop wilt.

6 Hop Breeding Research

District Administrator A. Lutz (LRA), Dr. S. Gresset (LOR) & the Hop Research Team

A big thank you goes to the staff of IPZ 5c: J. Kneidl, D. Ismann, B. Brummer, A. Hartung, K. Merkl, S. Ostermeier, U. Pflügl, J. Redl, A. Roßmeier, M. Schleibinger, M. Siglhofer, and A. Zimmermann, as well as our colleagues in Hüll, Wolnzach, and Freising who also supported us actively in 2023. Plant breeding, especially for perennial, vegetatively propagated crops such as hops, is a laborious but exciting task that is only successful as a team effort.

6.1 Crossings in 2023 and further development of promising breeding lines

In 2023, 82 crossings were successfully carried out in Hüll. Of these, 48 were hybridizations of aroma varieties; 34, of bitter varieties.

After harvesting these, 12 promising breeding lines from two locations each were presented to the advisory committee of the Society for Hop Research (GfH), which is composed of representatives from the entire hop and brewing industry value chain (researchers, brewers, hop processors, and experimental farmers). This joint group created a detailed aroma profile and discussed the next steps. Trial beers with two of these breeding lines were also tasted and evaluated. After presentation to the advisory committee, additional developments continued in close coordination with the GfH and the entire hop and brewing industry.

6.2 Research and work on the *Verticillium* problem in hops - Molecular detection of *Verticillium* directly on the bine via real-time-PCR

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)*
Financing:	Erzeugerorganisation HVG e. G. *(HVG Hop Processing Group)*
Team:	R. Enders, B. Forster, P. Hager, B. Haugg, J. Kneidl, A. Lutz
Cooperation:	AG Pflanzenschutz im Hopfenbau (Plant Protection in Hop Cultivation) (IPZ 5b): S. Euringer, K. Lutz Slovenian Institute of Hop Research and Brewing (IHPS): Dr. S. Radišek
Duration:	March 1, 2008 to October 31, 2023

Objective

In addition to phytosanitary and crop cultivation measures, checks for *Verticillium nonalfalfae* are also crucial to produce healthy seedlings. Laboratory tests are often necessary, for example, because young hop plants do not show any visible symptoms. Since 2013, it is mandatory for any planting material to be examined for the presence of

Verticillium, using a highly sensitive real-time PCR-based detection method. This ensures that only *Verticillium*-free hops are used in the field.

Method

Based on research by Maurer et al. (2013) a very reliable and sensitive molecular detection technique for *Verticillium* is now in place for hop bines. Work is continuing to optimize this test system. The aim is not only to test for *V. nonalfalfae* in general in one PCR run, but also to differentiate between mild and lethal strains of the fungus simultaneously. This knowledge is of crucial importance for breeding and commercial cultivation. The identification of different *Verticillium* strains has since become possible using a multiplex PCR analysis.

Investigations conducted on *Verticillium*

This year, 441 plants were tested for *Verticillium*. This corresponds to around 1050 PCR reactions. Since one cannot assume a homogeneous distribution of *Verticillium* fungus in the test material, 2 to 3 samples are taken per plant. The DNA is then extracted from each sample and analyzed both undiluted and diluted to 1:10, in real-time PCR. If the results are inconclusive, the PCR test is repeated. This year, the investigation covered the following:

- Planting material for the LfL-owned breeding garden in Stadelhof and for commercial cultivation trials (row and large-plot trial cultivations in the Hallertau, Tettnang, Spalt and Elbe-Saale). Testing to verify the absence of V*erticillium*.
- Various plant materials from Hallertau commercial gardens for studies of the spread of *Verticillium* infections (lethal strains).
- Mother plants given to propagation partners of the Society for Hop Research (GfH) to ensure the delivery of *Verticillium*-free rhizomes.
- Mother plants at these propagation partners to ensure the delivery of *Verticillium*-free seedlings rhizomes to hop growers.
- Samples from test areas to verify visual evaluations, in cooperation with IPZ 5b. These studies are also important in connection with effectiveness tests to reduce *Verticillium* infestations in plants. The studies also help with our understanding of the rhizobiome of healthy and infected young hops.

Results

None of the planting material required for breeding (62 samples) nor any of the 114 mother plants of the GfH contract partners showed *Verticillium* infestations.

The results of the qPCR analyses confirm that the spread of aggressive (lethal) *Verticillium* strains is increasing across the Hallertau. The lethal form of the fungus was detected in 26 of 57 hop bines in commercial gardens. None of the samples that had *Verticillium* infections carried only mild strains.

Outlook

In order to continue to keep track of all *Verticillium* strains that occurr in the Hallertau, the reaction conditions and primers/probes used must be checked and adjusted continuously. The collection of starting and control materials for (q)PCR and inoculation tests remain important microbiological tasks. In addition, the reference collection with pure cultures of *Verticillium* strains from Germany will be maintained and expanded further. The aim is to add to the collection of single-spore isolates in order to carry out such future tasks as sequencing of the pathogen population. This work will be continued in the project “Innovative Strategies to Combat *Verticillium* Wilt in Hops” (see 5.9).

Literature

Maurer, K.A., Radišek, S., Berg, G., Seefelder, S. (2013): Real-time PCR assay to detect *Verticillium albo-atrum* and *V. dahliae* in hops: development and comparison with a standard PCR method. Journal of Plant Diseases and Protection, 120 (3), 105–114.

6.3 Development and validation of gender-specific DNA markers for hop breeding

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)*
Financing:	Wissenschaftliche Station für Brauerei in Münchner e.V. *(Scientific Station for Brewery in Munich e.V.)*
Team:	Dr. T. Albrecht, Dr. B. Büttner, R. Enders, B. Forster, P. Hager, B. Haugg, J. Kneidl, A. Lutz, Dr. S. Gresset
Cooperation:	IPZ 1c
Duration:	January 1, 2023 to December 12, 2023

Introduction

Hops are dioecious, meaning female and male flowers are on different plants. In common hops (*Humulus lupulus L.*), gender is determined analogously to humans using an XY chromosome system, whereby plants with XX chromosomes are female and those with XY chromosomes are male. Only the female plants produce cones and are thus used commercially, while male plants are required only for breeding purposes.

To date, there is no known genetic marker that can reliably distinguish between male and female hop plants. Therefore, the selection of female lines for breeding has to wait until the sex can be determined visually. This costs time and money. Male hop plants are removed from hop gardens to prevent pollination, subsequent seed production, and an associated reduction in hop quality. In addition, some of the breeding strains show delayed flower development or some even male and female flowers occurring on the same plant (hermaphrodites). These individuals cannot be weeded out before planting. Our goal is therefore to find a cost-effective detection method for a high-throughput marker that can be used to reliably distinguish between males, females, and hermaphrodites already at the early stages of the hop breeding process.

Execution

Genotyping by sequencing was used to create DNA profiles based on SNP (single nucleotide polymorphism) markers for the hop diversity panel reservoir (DP). The DP consists of male and female breeding lines from both the Hüll and international breeding programs. They are used for the identification of gender-specific SNP markers by linking information about gender to SNP markers. This allows for the identification of markers on the X or Y chromosome that reflect gender assignments.

The detected SNPs were converted into CASP markers (competitive allele-specific PCR) and tested on a set of male and female hops.

Results

Six markers were tested on a set of 25 hops of known gender. Of these, two predicted genders with 100% certainty. These two markers were tested on an expanded set of 86 hops including hermaphrodites; and, indeed, they were also able to reliably identify the gender. One of the two markers is shown in Figure 51.

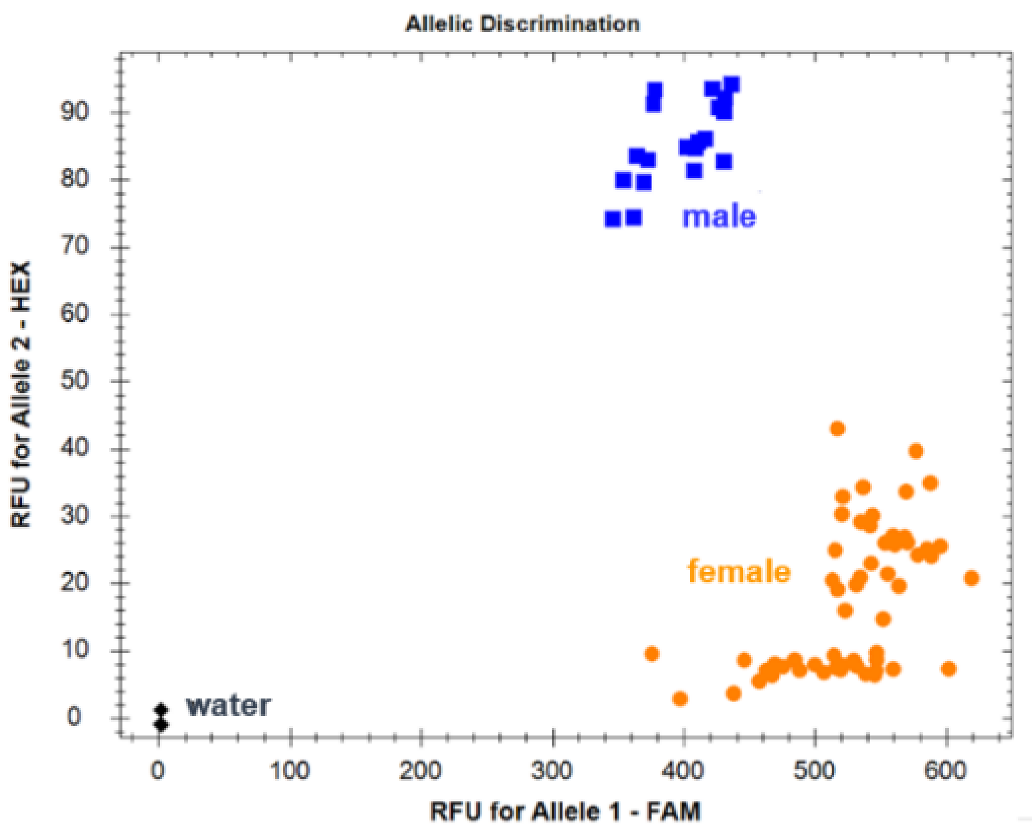


Figure 51: Scatterplot of DNA assay with water controls, males and females

Outlook

To ensure these markers can be used in the breeding program, they will be coupled with rapid and cost-effective DNA extraction. This is the next step. Once the tests are completed, these markers will be used in the breeding program to determine the sex directly already on the seedlings. This optimizes the selection process and generates greater breeding successes.

6.4 Improvement in the hop breeding process through the introduction of genome-wide predictions

Sponsors: Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung
(*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)*

Financing: Wissenschaftliche Station für Brauerei in Münchner e.V.
(Scientific Station for Brewery in Munich e.V.)

Team: Dr. T. Albrecht, Dr. B. Büttner, D. Ismann, J. Kneidl, A. Lutz, Dr. S. Gresset

Cooperation: IPZ 1c

Duration: January 1, 2023 to December 31, 2023

Developing a new hop variety is a lengthy process. It starts with crossing a male and a female hop strain, then putting the resulting roughly 1,000 offspring through a lengthy selection process. Initially, seedlings that prove to be particularly susceptible to powdery and downy mildew are sorted out in the greenhouse. The surviving offspring are then evaluated for gender and juvenile growth potential. At this stage, most of the male plants can already be eliminated. The following year, the female hop offspring that are free of growth defects are put out into the field for additional tests. These may take more than 10 years, whereby their yield potential and yield stability are among the key selection criteria. By that time, fewer than 10 plants may still be in contention and enter the final selection step, which involves extensive quality tests of the cones to determine such relevant values as the alpha acid and oil amounts. They are also put through brewhouse tests with sensory and analytical evaluations of the finished beers. Based on all the information gathered thus far, it is now time to decide if the offspring has the potential for becoming a new, commercial variety for which it is probable to generate demand in the brewing industry. Thus, it can take as much as 15 to 20 years from the original crossing to the commercial release of a new variety.

The climatic conditions for hop cultivation in the Hallertau have already changed significantly; and this process will likely continue. Specifically, hop plants will have to adapt to more hot days (defined as days with temperatures above 30 °C), as well as an insufficient water supply. Given the rapid change of the climate, hop breeding needs to be accelerated. In Hüll, we are pursuing several approaches. Importantly, these include the development of genome-based selection techniques (GS).

To speed up the selection process for crossings, a wide range of German and international hop varieties and breeding lines has been assembled. It helps that we can draw on field observations from the last decade. All hop varieties and strains in this diversity range (DP) were genotyped using sequencing, i.e. the differences between the genotypes were recorded at the DNA level throughout the entire genome in order to correlate the genetic differences with the different, already-known field performance, in terms of, for instance, total yield per hectare and α and β acid content.

The genetic variation of our DP is shown in Figure 1 using principal component analyses. It clearly shows that European landraces differ genetically from US and Asian varieties. The most recent Hüll breeding material used in this study ranks in many parameters somewhere between the old European landraces, on the one hand, and the American and Asian materials, on the other. This reflects the successes of the Hüll breeding program in recent years, which involved adding American breeding material to the hybridizations. It is also clear that, along many parameters, the Hüll breeding material is very separate from international varieties. This is probably because only portions of genetic potential of these varieties has thus far been transferred into the Hüll breeding program. Alternatively, some properties of the international varieties are unsuitable for growing conditions in the Hallertau.

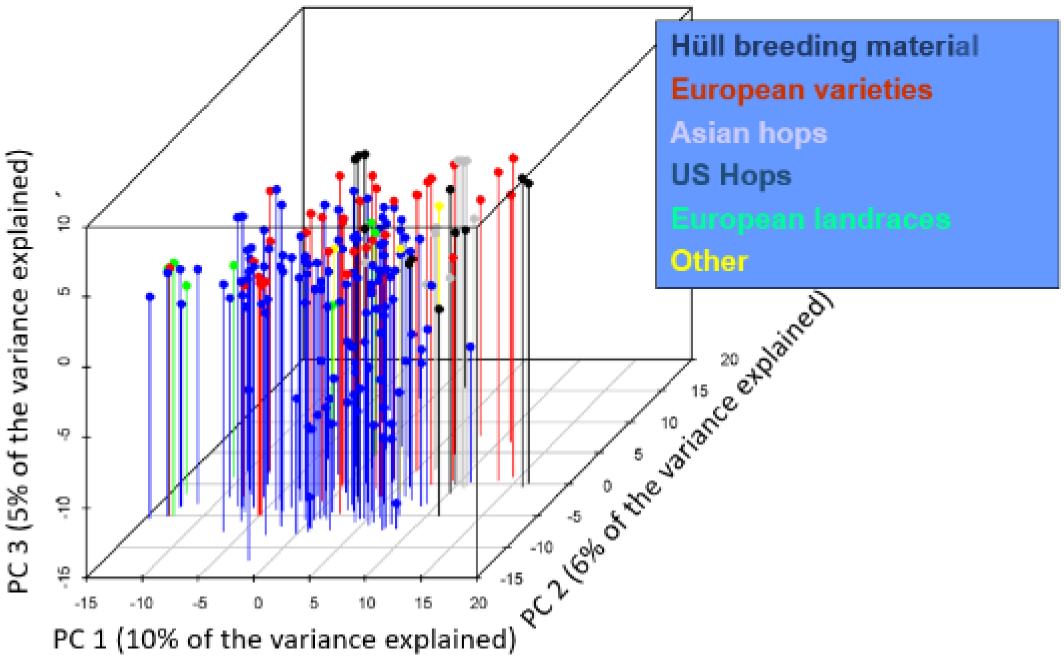


Figure 52: Genetic variation of the hop diversity range based on 1800 SNP

Genotyping the DP using sequencing yielded 1800 genetic markers (single nucleotide polymorphism, SNP) of very high quality across all genotypes. Statistical models for prediction were developed based on these SNPs in combination with the multi-year field data. When using GS in hop breeding, one crucial question is how many SNPs are needed for a good prediction. Figure 3 shows the prediction accuracy within the 10x5-fold cross-validation for the characteristics of total yield and of α and β acid content of the hop cones with an increasing number of markers. Even with a low marker density of 1800 SNPs, sufficient prediction accuracy could be achieved for the total yield and for the α- and β-acid content of the hop cones in the DP. In other crops, individual missing values in SNPs can be statistically supplemented depending on closely adjacent SNPs. The position of the SNPs in our analysis is based on the position of these SNPs along the well-sequenced genome of the American hop variety Cascade. Our analysis has shown that the position information based on Cascade cannot be directly transferred to European materials. Therefore, the estimates of the missing SNP values are very error-prone, which may explain the stagnating prediction accuracy as the number of SNPs increases.

These initial results show the potential of GS in hops. However, the genetic composition of the DP does not correspond to the conditions of our conventional breeding range. In the breeding process, the plants produced by our crossing are mostly siblings, which means their genetic differences are much smaller than those between the international varieties and strains of the DP. Therefore, in 2023, we carried out targeted crossings to develop populations that allowed us to check the prediction accuracy of the statistical models in a realistic breeding process and to develop correct positions for the SNPs in the European materials. These will be genotyped in 2024 and tested in the field during subsequent years. The resulting genetic maps and the selection results from the use of GS will allow us to firmly establish this method in our hop breeding and thereby accelerate the entire breeding process.

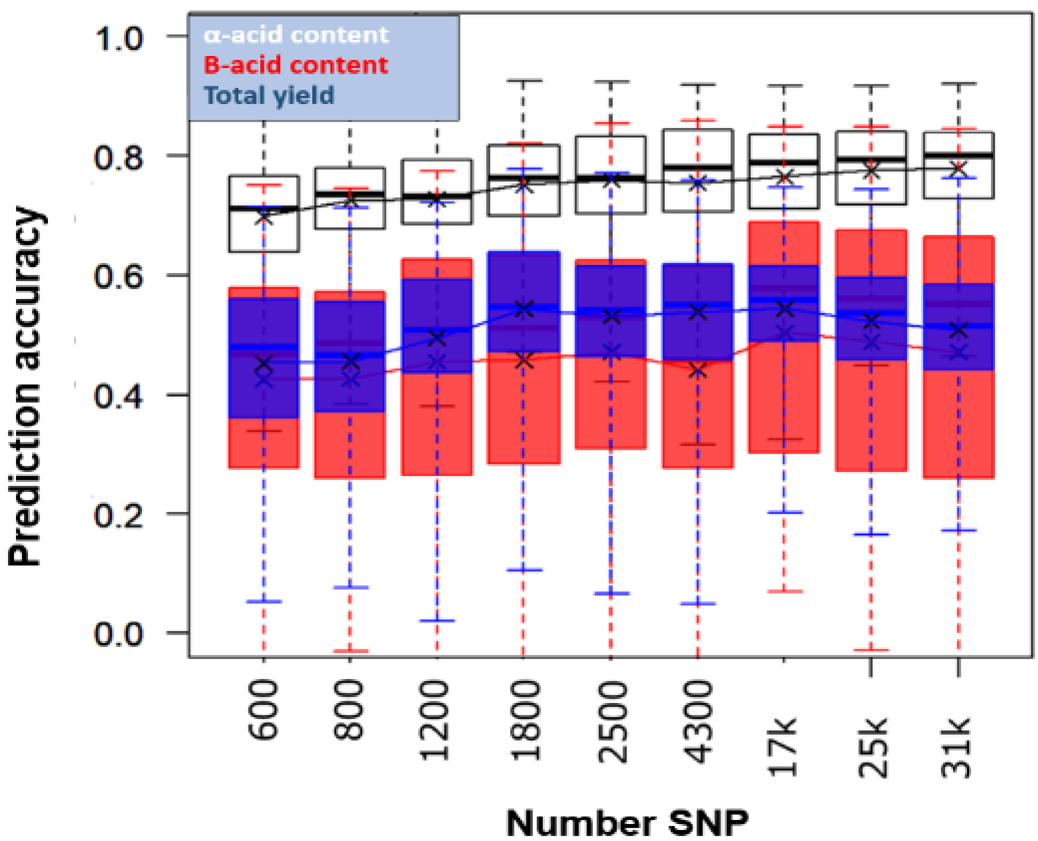


Figure 53: Prediction accuracy within the 10x5-fold cross-validation based on a GBLUP (genomic best linear unbiased prediction) model with different SNP densities for the characteristics of hop yield, alpha acids, and beta acids of the hop cones

7 Hop Quality and Analysis

Bureau Director (RD) Dr. Klaus Kammhuber, Dipl.-Chemist

7.1 General

The Working Group IPZ 5d conducts all analytical investigations within Section IPZ 5 Hops. This work is used to support tests requested by other working groups, especially in the area of hop breeding. Hops are mainly cultivated for their valuable compounds. Therefore, hop cultivation and research is not possible without hop analytics.

Hops have three groups of valuable compounds. In order of importance, these are bitter substances, essential oils, and polyphenols (Figure 54).

Figure 54: Valuable compounds in hops

Alpha acids are considered the primary quality feature of hops since they are a measure of the bitter potential. In addition, the amounts of hops added to beer are based on their alpha acid content. Currently, the international average amount of alpha acids added to beer is about 4.5 to 5 g per 100 l. Alpha acids are also increasingly important in setting hop prices. Hop growers are either paid directly by the weight of alpha acids (in kilograms), or there are additional clauses in hop contracts for surcharges and discounts if shipments are outside an agreed-upon "neutral" alpha acid range.

Hops were discovered as raw materials for brewing in the Middle Ages. Because of their antimicrobial properties, they also increased a beer's shelf life. Today, the main function of hops is to give beers their characteristic fine bitterness and pleasant, fine aroma. In addition, hops have many other positive properties (Figure 7.2).

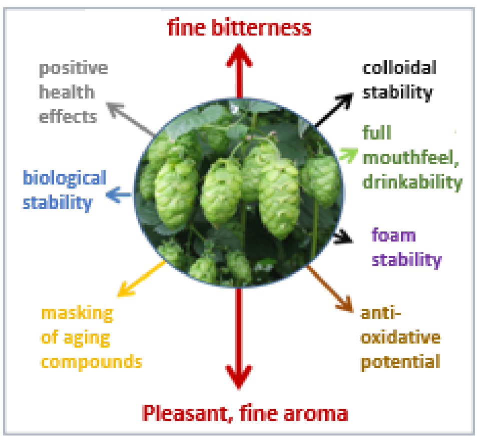


Figure 55: The many functions of hops in beer

7.2 Which requirements should hops meet in the future?

Hops are grown almost exclusively for brewing beer. Some 95% is used in breweries and only 5% in other applications. There are now efforts underway to find additional uses for the plant.

Figure 56: Uses for hops

7.2.1 Requirements for the brewing industry

With regard to the use of hops in the brewing industry, there are many different philosophies. Some breweries are interested only in cheap alpha acids, while others select hops deliberately according to variety and cultivation terroir (Figure 57). Yet other breweries rank somewhere in between these two views.

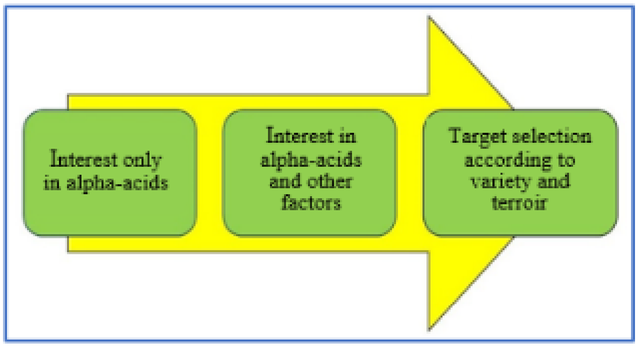


Figure 57: Different philosophies regarding the use of hops

However, there is agreement that the development of varieties with the highest possible amounts of alpha acids and the most stable alpha acid yields from year to year are important breeding objectives. Climate change will also be the biggest future problem for hop cultivation. A low cohumulone value relative to the overall alpha acid content is no longer considered important, even though in beer, a low proportion of cohumulone is beneficial for foam stability. For so-called downstream products and applications outside of beer making, high-alpha varieties with large portions of cohumulone are even desirable.

Hop oils produce classic aroma profiles in beer. Polyphenols, on the other hand, have not been considered of great importance in the brewing industry, even though they also contribute to the sensory profile of beer by affecting its mouthfeel, for instance. In addition, polyphenols have many health benefits (see 7.2.2).

7.2.1.1 Special requirements of craft brewers

In the US, the craft brewing movement has been a huge success. The share of craft breweries in total beer sales is around 14%. Globally, craft breweries make up only 2.5% of the total number of breweries but they consume 20% of the global hop crop. In Germany, on the other hand, where traditional beer styles are still the overwhelming preference, craft brewing is much less prominent.

In general, craft brewers prefer hops with fruity and floral aromas that do not correspond to classic hop aromas.

7.2.1.2 Dry hopping is experiencing a Renaissance

Craft brewers rediscovered the classic technique of dry-hopping, that is, of adding hops to cold beer. This process was already well known in the 19^{th} century and is now being revived. It is a form of cold extraction, whereby hops are added to the finished beer in the bright, lagering, or conditioning tank; and the dosages are calculated based on the hop oil content, not on the amount of alpha acids. Beer is a polar solvent; and the average beer contains roughly 92% water and 5% ethanol. This means that the compounds released by the hops in the cold area are primarily polar (Figure 58).

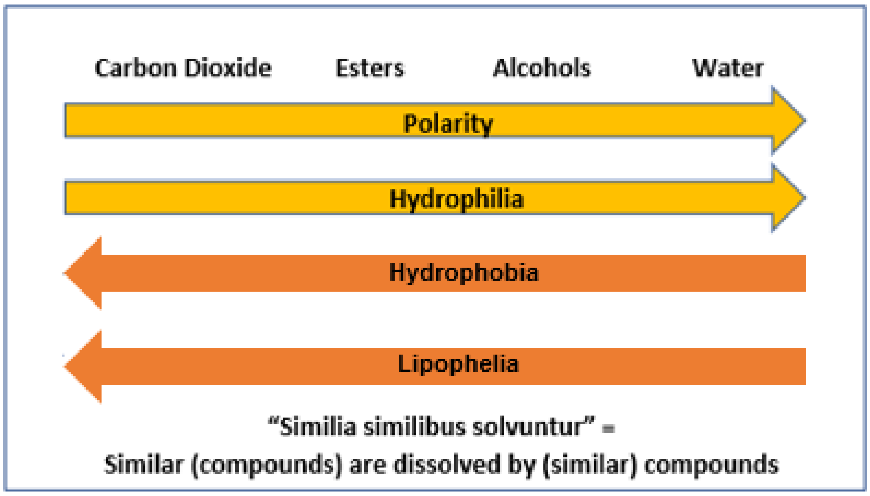


Figure 58: The solubility behavior of hop compounds is based on polarity

Alpha acids dissolve only minimally in wort or beer unless they are isomerized. On the other hand, especially low molecular esters and terpene alcohols are easily transferred. This is why dry-hopped beers have fruity and floral aromas. Traces of non-polar substances such as myrcene are dissolved, too.

The group of polyphenols is also easily soluble because of their polarity. Unfortunately, undesirable substances such as nitrate also transfer entirely into cold beer. The average nitrate content of hops is around 0.7%. However, the nitrate threshold of 50 mg/l for drinking water does not apply to beer.

Pesticides tend to be non-polar and thus not very soluble in water. In cold-hopped beers, therefore, there is no measurable increase in concentrations of pesticide residues compared to conventional beers.

7.2.2 Alternative uses of hops

In alternative applications, the entire hop plant, not just the cones, can be used. The inner, wooden parts of the hop bine, for instance, are known as shives or shoves. They have excellent insulation properties and mechanical strength, which makes them well suited as a material for insulation. They can also be turned into molded parts for such applications as automotive door panels. To date, however, no such applications exist on a large scale.

As for cones, the antimicrobial properties of their bitter acids are of special interest for alternative uses. Even in catalytic quantities (0.001 to 0.1% by weight), they reveal their antimicrobial and preservative effectiveness, in ascending strength from iso-alpha acids, to alpha acids, to beta acids (Figure 59).

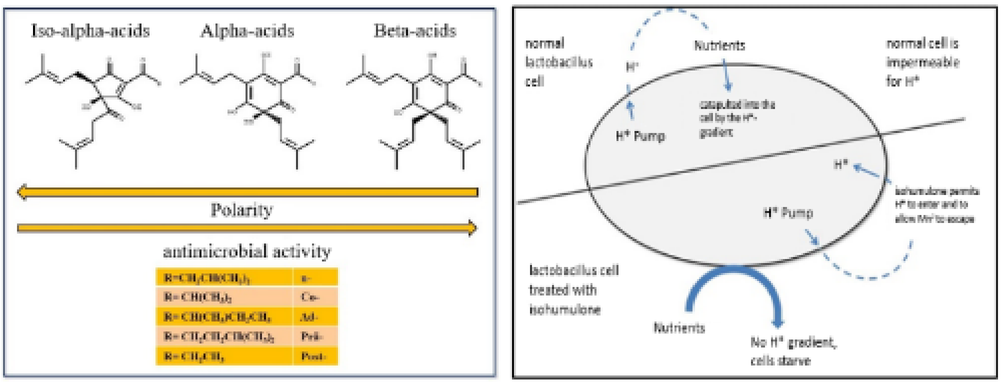


Figure 59: Sequence of antimicrobial activity of iso-alpha acids, alpha acids, and beta acids, as well as their effectiveness

The more non-polar a molecule is, the greater is its antimicrobial effectiveness. Hop bitter substances destroy the pH gradient on the cell membranes of gram-positive bacteria, which prevents the bacteria from absorbing nutrients. This causes them to die.

Iso-alpha acids inhibit inflammatory processes and have positive effects on fat and sugar metabolisms. In beer, they even protect against *Helicobacter pylori*, a type of bacterium that can trigger stomach cancer. Beta acids are effective against the growth of gram-positive bacteria such as listeria and clostridia; and they can inhibit the tuberculosis-causing pathogen *Mycobacterium tuberculosis*. Because of these properties, hop bitter substances can be used as natural biocides wherever bacteria must be kept in check. In the sugar and ethanol industries, beta acids have already become a successful substitute for formalin. Some applications based on the antimicrobial activity of hops are listed below.

Table 13: Antimicrobial uses of hops

●	Beta acids control gram-positive bacteria (clostridia, listeria, the tuberculosis pathogen mycobacterium tuberculosis)

●	Use as a preservative in the food industry (fish, meat products, dairy products)
●	Sanitation of biogenic waste (sewage sludge, compost)
●	Elimination of mold infestations
●	Smell and hygiene improvement of litter
●	Control of allergens
●	Use as an antibiotic in animal nutrition
●	Biological control of bacteria in the sugar and ethanol industry (formalin replacement)

A greater demand for hops in these applications is certainly conceivable in the future. Therefore, it is also a breeding goal in Hüll to increase the beta acid content in certain varieties. Currently the beta acid "record" is a content of roughly 20%. There is even a breeding line that produces only beta and no alpha acids. This variety (Relax) is used in the production of tea.

Hops are also interesting for the areas of health, wellness, dietary supplements, and functional food because they contain a variety of polyphenolic substances. Polyphenols are secondary plant substances that are synthesized by the plant as defense substances against diseases and pests, as growth regulators, and as dyes. Because of their antioxidant properties and their ability to capture free radicals, they have many positive health effects.

Diseases that are based on oxidative processes include cancer, atherosclerosis, Alzheimer's and Parkinson's. The polyphenols are easily absorbed into the beer because of their polarity. Their importance for the sensory system is currently still underestimated but could become more important in the future. In beer, they contribute, for instance, to the body and mouthfeel. Higher molecular weight polyphenols combine with proteins via hydrogen bonds and can cause turbidity. Therefore, higher molecular weight polyphenols are more problematic and are removed with filter aids such as PVPP (polyvinylpolypyrrolidone).

The literature on polyphenols and health is almost inexhaustible. Table 14 presents a summary of the key properties.

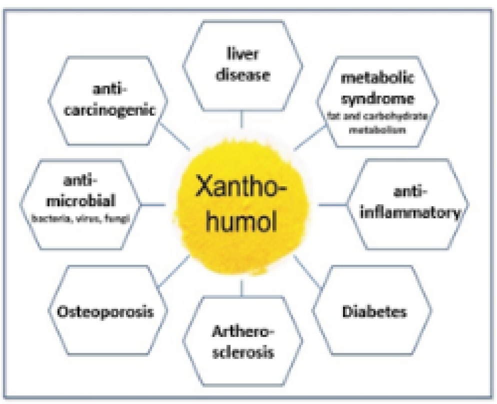
Table 14: Health properties of polyphenols

Polyphenols act as antioxidants in the body
Polyphenols protect against heart attacks and cancer
Certain polyphenols such as catechins prevent dental caries
Flavonoids prevent cell oxidation
Polyphenols ensure good intestinal flora
Polyphenols are anti-inflammatory

There is a clear consensus that one should eat a diet very rich in polyphenols. This means you should eat lots of fruit and vegetables. Hops are very rich in polyphenols compared to other fruits.

Of all the hop polyphenols, however, xanthohumol has received the most public attention in recent years; and scientific work on it has exploded. The health-promoting effects of xanthohumol have now been scientifically proven. In 2016, the US Food & Drug Administration (FDA) approved the “Health Claim” status for the “DNA protection” of the XAN extract from T.A. XAN Development S.A.M. Extensive information about the history of xanthohumol and its effects can be found on this company's homepage https://www.xan.com/. The company has also applied for — but not yet been granted — a “Health Claim” status at the European Food Safety Authority (EFSA). Xanthohumol has many benefits (Figure 60), but the most important one is its anti-carcinogenic effect.

During the brewing process, prenylated flavonoids (Figure 60) are constantly being converted. During wort boiling, xanthohumol is isomerized to iso-xanthohumol, as is demethylxanthohumol to 8- and 6-prenylnaringenin. This is why desmethylxanthohumol is not found in beer and the concentrations of prenylated naringenins are significantly higher in beer than in hops.



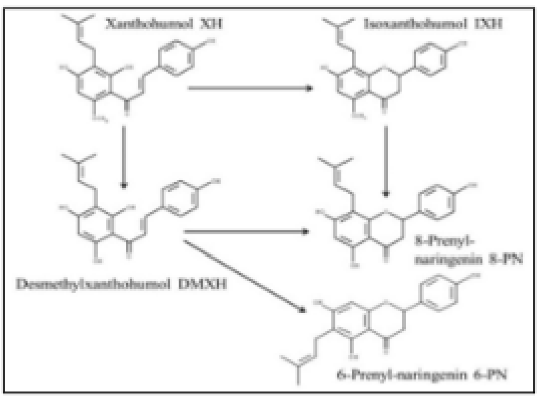


Figure 60: Effects of xanthohumol and transformations in the brewing process

8-Prenylnaringenin is one of the strongest phytoestrogens that exists in the plant kingdom. The estrogenic effect is due to the fact that 8-prenylnaringenin has a similar structure as the female sex hormone 17-ß-estradiol.

Another group of substances that occurs in hops at up to 0.2% are multifidols (Figure 61). These connections have already been extensively described in the 2021 and 2022 Annual Reports. Because of their polarity, multifidolglucosides are completely transferred into the beer.

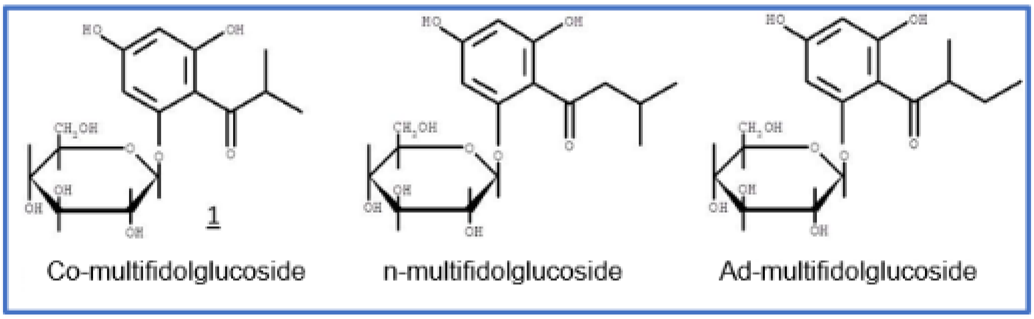


Figure 61: Chemical structures of multifidols

The main compound in hops is co-multifidolglucoside. Multifidolglucosides have anti-inflammatory properties because they can inhibit the enzyme cyclooxygenase. This enzyme is key in the development of inflammation. Well-known painkillers such as Aspirin (acetylsalicylic acid), Ibuprofen, Naproxen, Voltaren (Diclofenac) work on the same principle.

7.3 The essential oils of hops

The primary task of hops in beer brewing is to give the beverage its typical pleasant, harmonious bitterness. The second task is to ensure a delicate aroma. Hop aroma is assessed sensorily by smelling. Common descriptors are floral, spicy/herbaceous, woody/aromatic, green, citrus, sweet fruits, green fruits, red berries, creamy caramel, vegetal, tea, and menthol. Physiologically, aroma impressions can be differentiated into only five categories. However, the sensory evaluation of hops must be viewed more subjectively, as everyone has different preferences depending on cultural background or current mood. No other sense influences our subconscious as strongly as smell. This is known as the Madeleine effect. In Marcel Proust's novel “In Search of Lost Time,” the narrator relives very specific memories of childhood through the taste of pastries dipped in tea (Madeleines).

Otto Wallach (1847-1931, Nobel Prize 1910) was the first to discover that the essential oils of plants are always made up of 5 carbon units (C5, C10, C15). Leopold Ružička (1887-1976, Nobel Prize 1939) identified these C5 building blocks as isoprene (isoprene rule). That is why these compounds are also called isoprenoids. Feodor Lynen (1911-1976, Nobel Prize 1964) clarified the biosynthetic pathway. There are two different ways, one via mevalonic acid and another via deoxy-xylulose-5-phosphate. Both biosynthetic pathways are carried out in parallel by plants. Figure 62 shows the mevalonic acid pathway and Figure 63 shows the deoxyxylulose-5-phosphate one. The mevalonic acid pathway occurs in the cytoplasm and the deoxyxylulose-5-phosphate, in the plastids.

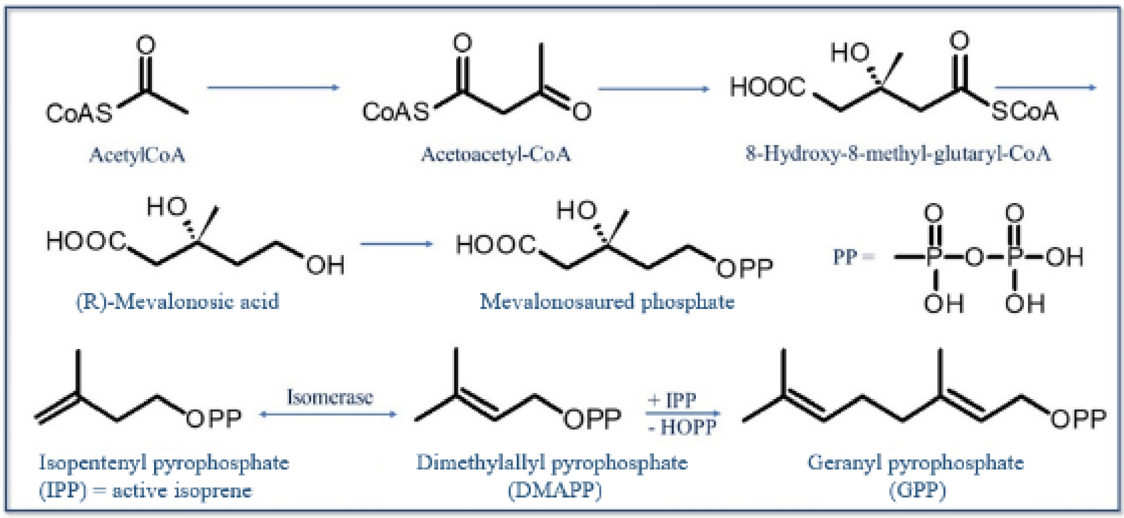


Figure 62 Biosynthesis pathway of terpenoids via the mevalonic acid pathway

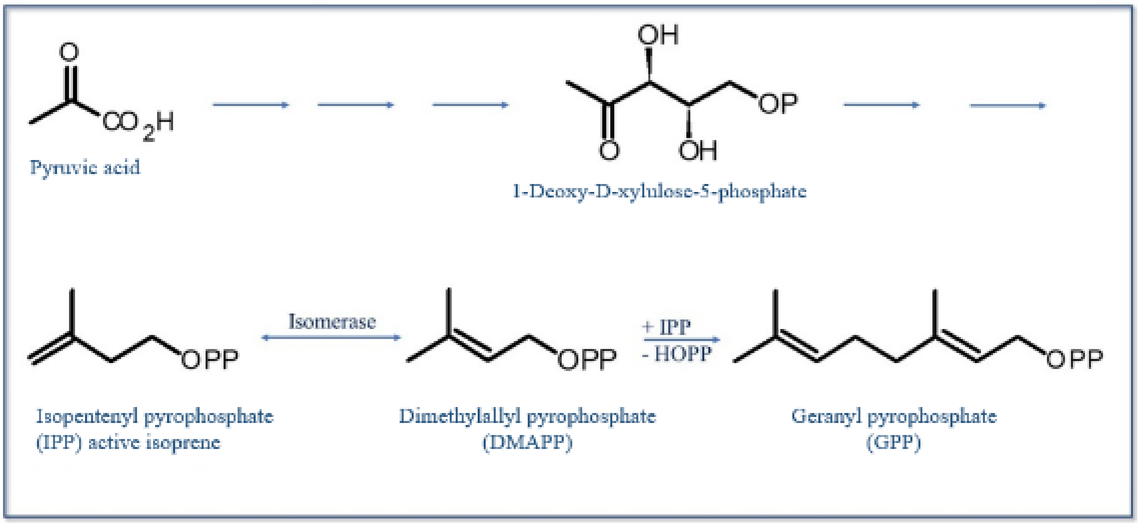


Figure 63: Biosynthetic pathway of terpenoids via the 1-deoxy-D-xylulose-5-phosphate pathway

The key compounds are isopentyl pyrophosphate (IPP) and dimethylallyl pyrophosphate (DMAPP). These compounds are in balance with each other and the structurally very different terpenoids are built up through different connections (head-head, tail-tail, head-tail, tail-head), but all of them have one characteristic in common: they consist of (C5)n-units (Figure 64).

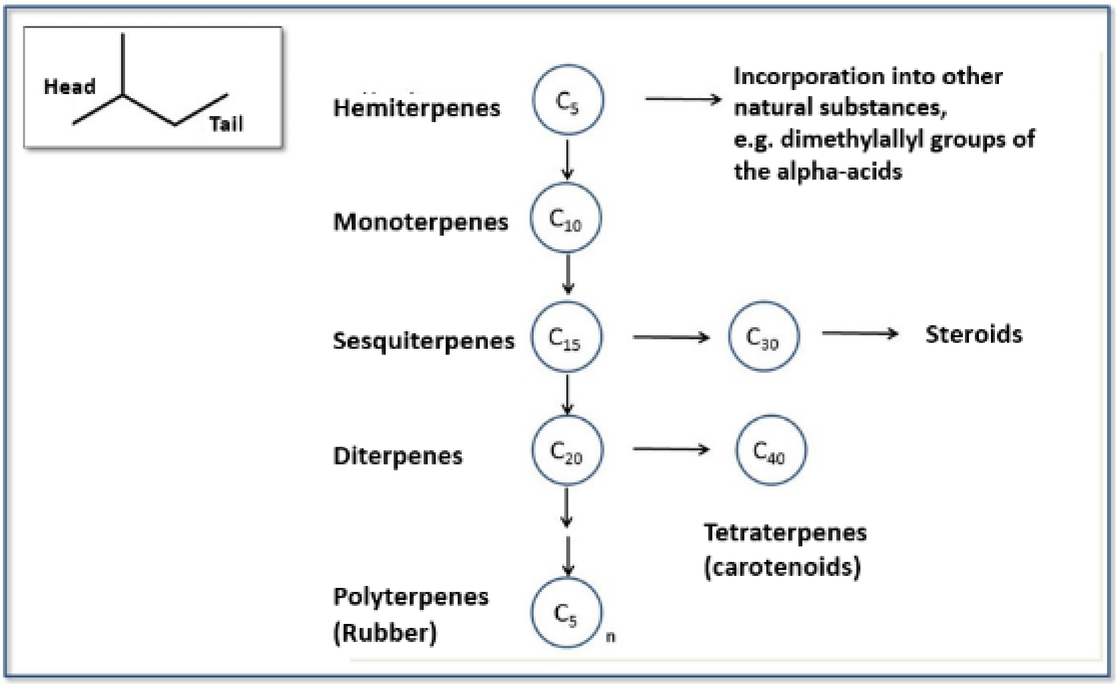


Figure 64: *Structure of terpenoid compounds*

Figure 65 shows the biosynthesis of some important hop monoterpenes and Figure 66 shows the systematics of hop oils.

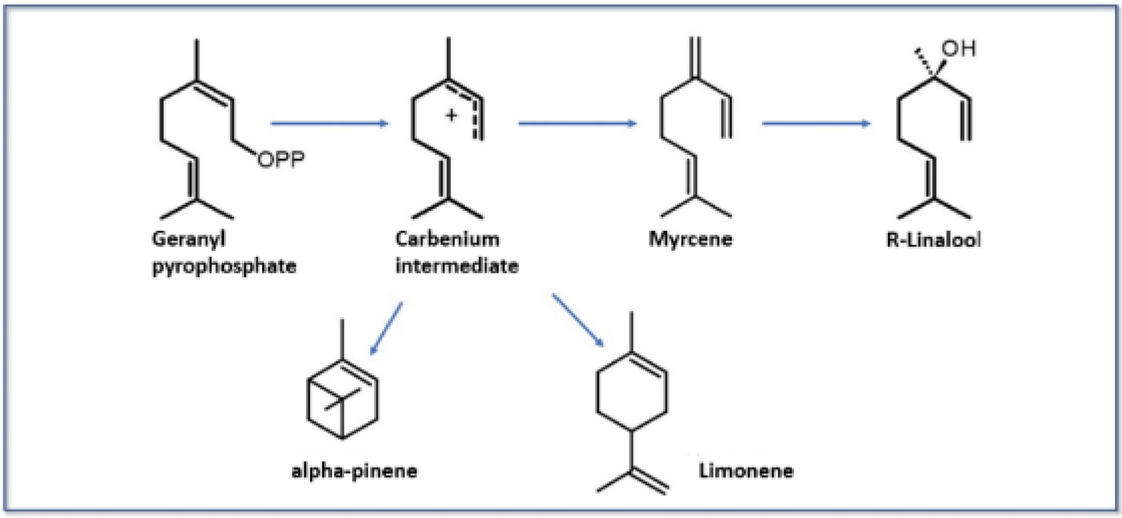


Figure 65: *Biosynthesis of some important hop monoterpenes*

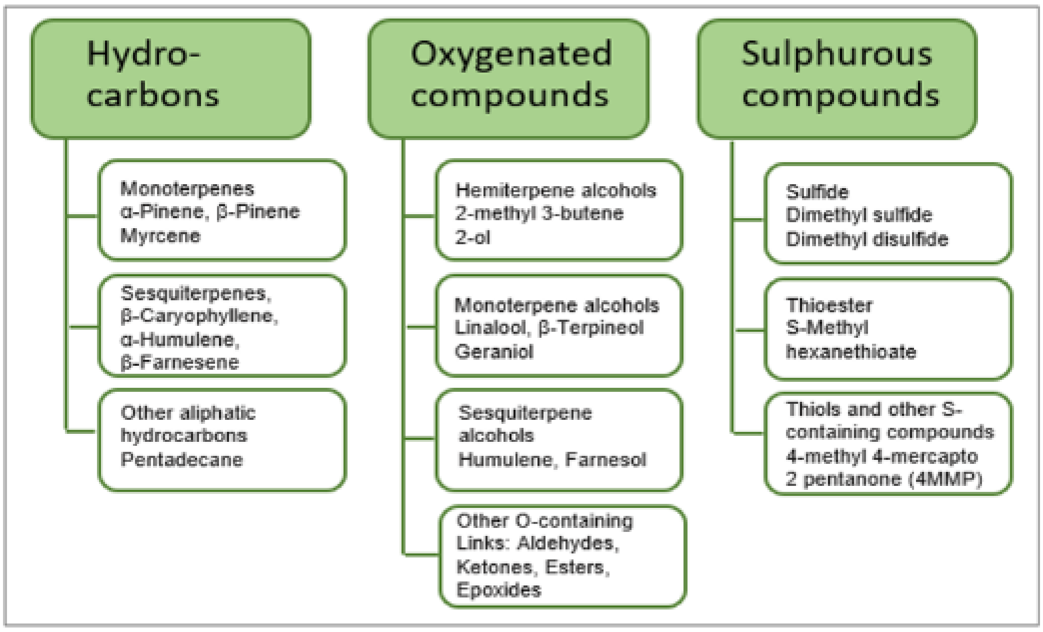


Figure 66: Systematic classification of essential hop oils

Around 300 – 400 oil components are described in the literature. In the Hüll laboratory we can qualitatively determine 143 substances. The Hüll laboratory is interested in the following three questions regarding essential oils:

- Which oil components are important for differentiating between varieties?
- Which substances determine the aroma of hops?
- Which substances enter the beer?

Sesquiterpenes such as ß-ocimene, ß-caryophyllene, aroma dendrons, humulene, ß-farnesene, α-selinene, ß-selinene, ß/γ-cadinene and 3,7-selinadiene are particularly valuable for differentiating between varieties, although these substances have nothing to do with contributing aroma and, as non-polar substances, do not pass into the beer. The hop aroma is primarily determined by myrcene, linalool and polyfunctional thiols such as 4-mercapto-4-methyl-2-pentanone (4-MMP). Polar substances are transferred into the beer, as shown in 7.2.1.2. These are terpene alcohols, low molecular weight esters, and polyfunctional thiols. The smell impression is created by the interaction of many individual substances. Some substances neutralize each other, while others increase their effect. During fermentation, yeast can also change flavors. Esters are transesterified to ethyl ester, geraniol can be reduced to citronellol, and glycosidically-bound flavoring substances such as linalool or geraniol can be released.

7.4 World Hop Portfolio (2022 Crop)

Every year, essential oils from the world hop portfolio are analyzed using gas chromatography. Likewise, bitter substances are analyzed using HPLC. Table 7.3 shows the results for the 2021 crop year. It can serve as an aid to assigning unknown hop varieties to a specific variety type.

Hop ingredients can be identified by their DNA, which varies with variety. However, many external, so-called exogenous factors can also play a role in the development of the morphological appearance of hop ingredients (metabolome).

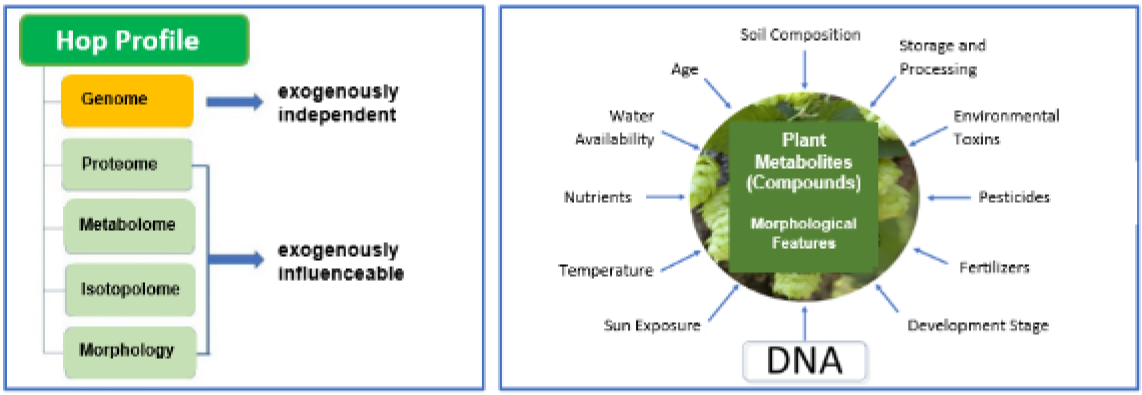


Figure 67: Hop morphology and metabolome are characterized by many exogenous factors

Table 15: World Hop Portfolio (Harvest 2022)

Variety	Myrcene	2-Metyl-butyl-isobutyrat	Methyl-isohep-tanoat	ß-Oci-mene	Lina-lool	Aroma-dend-ren	Unde-canone	Hu mulene	ß-Far-nesene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß/γ-Ca-dinene	3,7-Seli-nadiene	Gera-niol	α-acids	ß- acids	ß/α	Co-humolone	Co-lupulone
Admiral	5516	2407	0	203	101	0	21	702	0	24	3	6	50	1	1	11,7	5,1	0,44	47,6	68,5
Agnus	920	176	3	5	23	0	8	232	0	28	5	10	51	0	12	10,1	5,2	0,51	29,9	53,1
Ahil	3715	1126	76	12	49	0	26	476	41	24	6	12	45	0	27	6,1	3,0	0,49	33,3	56,0
Alliance	1571	274	0	5	42	0	16	464	0	24	2	4	51	0	1	2,9	1,7	0,61	29,2	52,5
Ariana	1681	650	284	81	37	0	49	534	61	30	20	42	63	0	4	9,7	5,2	0,54	40,9	58,1
Atlas	4012	1539	54	16	42	0	6	488	57	24	9	20	47	0	20	4,8	2,8	0,58	39,8	61,9
Backa	4766	1862	0	139	57	0	25	628	25	23	1	3	45	0	1	5,2	3,3	0,63	44,2	65,6
Blisk	2140	702	73	2	55	0	7	525	21	26	9	19	52	0	20	5,9	2,8	0,48	33,5	59,1
Bor	3152	435	4	230	28	0	24	592	0	18	2	4	45	0	8	6,1	3,5	0,57	23,2	45,8
Bramling Cross	3722	451	2	5	71	0	32	632	0	22	7	13	39	0	1	2,1	2,8	1,35	37,9	61,2
Braustern	1550	317	1	113	21	0	15	388	0	24	2	4	49	0	1	4,3	4,0	0,91	29,7	48,9
Brewers Gold	3157	884	53	47	39	0	2	420	0	29	6	12	52	1	31	6,4	4,3	0,68	38,1	62,7
Callista	6850	1049	193	10	171	0	32	733	0	42	41	87	70	0	2	4,0	7,5	1,89	26,4	38,2
Cascade	3450	832	126	12	51	0	18	640	4	34	11	25	58	0	9	6,4	6,3	0,97	32,8	48,9
Challenger	2954	751	1	92	47	0	33	575	2	20	35	81	45	0	1	3,1	3,6	1,16	29,6	45,9
Chang bei 1	2976	340	4	1	71	0	40	557	4	39	23	49	63	46	3	1,4	2,6	1,85	29,9	43,4
Chang bei 2	2603	2157	0	0	60	1	50	641	0	102	60	123	157	1	14	4,0	4,1	1,03	44,1	66,4
Chinook	1755	904	17	4	19	0	7	458	0	92	11	22	149	36	8	9,7	3,2	0,33	31,7	55,1
Columbus	2004	647	82	3	27	0	3	395	0	66	10	20	117	34	9	10,6	3,6	0,33	34,3	56,3
Comet	1169	243	22	47	25	0	8	14	0	7	39	86	12	25	7	7,3	3,2	0,43	39,6	59,7
Crystal	1888	104	17	7	65	47	13	522	0	44	37	74	52	105	2	1,3	4,2	3,12	18,1	33,2
Density	4949	669	28	45	87	0	30	597	0	23	34	68	43	0	3	3,1	3,6	1,16	32,9	57,3
Early Choice	2178	264	0	38	13	0	13	503	0	17	29	71	40	0	1	1,6	1,1	0,69	32,2	49,5
Emerald	1260	232	11	39	14	0	23	492	0	23	2	5	46	0	1	3,1	4,3	1,39	31,1	46,4
Ging Dao Do Hua	3502	2712	0	0	69	1	52	625	0	106	67	137	163	0	15	3,9	3,8	0,97	46,2	69,5

Variety	Myrcene	2-Metyl-butyl-isobutyrat	Methyl-isoheptanoat	ß-Ocimene	Linalool	Aroma-dendren	Undecanone	Hu mulene	ß-Farnesene	γ-Muurolene	ß-Selinene	α-Selinene	ß/γ-Cadinene	3,7-Selinadiene	Geraniol	α-acids	ß- acids	ß/α	Co-humolone	Co-lupulone
Golden Star	3373	2197	0	2	60	1	45	628	0	95	56	119	154	0	13	3,6	3,7	1,01	45,9	69,2
Granit	2590	512	31	48	27	0	68	541	0	20	6	12	37	0	6	5,2	3,6	0,69	22,8	45,5
Hallertau Blanc	12635	2126	625	25	155	1	34	130	0	33	420	1010	68	6	23	9,6	6,4	0,67	21,1	37,4
Hall. Magnum	2388	432	86	45	17	0	14	545	0	22	3	7	52	0	1	10,5	5,9	0,56	24,9	40,5
Hallertauer Merkur	2454	498	99	25	51	0	17	537	0	26	2	4	56	0	3	12,4	6,0	0,49	15,2	37,3
Hallertauer Mfr.	1038	278	1	2	65	0	33	443	0	39	2	5	69	0	2	3,5	4,0	1,12	20,7	37,2
Hall. Taurus	3359	248	46	46	87	0	31	523	0	23	43	100	51	0	3	13,7	4,3	0,31	20,1	41,3
Hall. Tradition	2595	462	33	8	92	0	29	622	0	27	2	4	59	0	1	5,3	3,8	0,72	25,9	47,1
Herkules	4349	739	254	240	27	0	29	656	0	22	2	4	52	1	14	16,6	4,7	0,28	30,7	50,5
Hersbrucker Pure	3091	504	23	21	91	0	27	607	0	23	2	4	52	0	2	4,8	3,5	0,73	27,6	48,8
Hersbrucker Spät	2667	173	21	10	76	36	4	519	0	44	36	77	57	88	2	2,8	4,3	1,56	18,5	33,9
Huell Melon	10109	5125	4	77	82	2	76	137	35	78	283	629	129	235	38	6,4	8,1	1,27	30,0	47,9
Hüller Anfang	1303	311	27	2	48	0	26	487	0	35	3	5	60	0	0	2,1	2,7	1,33	24,2	40,4
Hüller Aroma	1511	275	2	2	58	0	36	546	0	34	3	5	62	0	0	2,0	2,9	1,42	27,8	45,9
Hüller Fortschritt	2076	190	17	3	61	0	30	638	0	30	2	5	55	0	0	1,3	2,9	2,14	29,3	44,4
Hüller Start	1336	98	3	8	25	0	32	509	0	34	3	5	57	0	1	1,6	2,4	1,5	24,1	41,8
Kirin 1	2659	1974	0	1	57	0	55	592	0	97	54	112	159	0	12	3,7	3,8	1,01	44,0	67,6
Kirin 2	3533	1867	0	2	51	0	43	581	0	83	53	112	130	0	10	3,6	3,6	1	46,9	69,9
Kitamidori	1688	58	16	59	14	0	11	551	0	30	2	4	58	0	4	5,0	3,6	0,72	24,1	42,5
Kumir	2395	342	6	146	67	0	25	486	0	24	2	4	51	0	4	7,2	4,3	0,59	17,7	40,3
Lubelski	2477	172	21	9	36	0	41	677	17	26	7	13	51	0	2	2,9	3,8	1,31	23,5	40,6
Mandarina Bavaria	5603	1554	96	28	52	0	42	713	1	45	81	82	76	0	36	10,5	6,9	0,66	32,5	52,6
Neoplanta	1608	357	0	115	13	0	11	343	9	24	1	3	49	0	1	4,8	3,2	0,66	36,0	64,8
Neptun	1468	318	175	10	44	0	9	351	0	27	2	4	57	1	1	11,8	4,9	0,42	20,3	40,9
Northern Brewer	2053	333	1	124	20	0	14	378	0	21	1	3	50	0	3	8,7	4,6	0,53	24,0	46,9
Nugget	2419	430	2	139	40	0	13	416	0	16	6	14	35	0	2	10,3	3,7	0,36	27,5	51,2

Variety	Myr-cene	2-Metyl-butyl-isobutyrat	Methyl-isohep-tanoat	ß-Oci-mene	Lina-lool	Aroma-dend-ren	Unde-canone	Hu mulene	ß-Far-nesene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß/γ-Ca-dinene	3,7-Seli-nadiene	Gera-niol	α-acids	ß- acids	ß/α	Co-humolone	Co-lupulone
Opal	1983	160	75	28	65	0	27	473	0	27	2	0	56	0	6	6,7	4,9	0,74	14,3	30,7
Orion	1314	345	14	31	41	0	26	326	0	26	2	3	50	0	1	5,3	3,6	0,69	27,2	49,8
Perle	1616	316	4	100	26	0	16	379	0	23	1	4	49	0	2	4,3	3,3	0,77	29,9	52,4
Polaris	2475	384	99	203	16	0	17	409	0	23	2	3	50	0	4	18,4	4,6	0,25	22,4	43,3
Record	2316	77	1	4	47	0	31	661	0	25	2	5	51	0	1	1,9	4,7	2,39	24,6	38,7
Relax	2700	442	22	11	25	0	38	696	0	42	3	6	66	0	16	0,9	7,4	8,29	43,7	30,8
Rottenburger	1935	90	4	2	37	0	24	680	0	25	2	4	49	0	2	1,4	4,3	3,16	27,1	40,0
Rubin	3990	758	103	44	36	0	11	523	0	31	60	139	62	1	10	11,9	4,1	0,34	32,3	52,1
Saazer	3951	1	6	14	102	0	74	742	33	32	2	4	63	0	7	3,4	4,1	1,21	23,2	39,9
Saphir	2916	195	19	49	86	2	106	475	0	30	17	38	49	54	5	2,6	4,5	1,73	15,0	40,9
Sladek	2154	300	3	80	58	0	25	508	0	25	2	5	54	0	3	6,0	3,7	0,62	20,0	43,4
Smaragd	2585	107	33	18	83	0	21	608	0	30	10	7	57	0	7	3,7	4,1	1,12	17,3	32,7
Sorachi Ace	1907	345	0	47	30	0	22	540	0	33	2	5	65	0	8	9,1	5,7	0,62	26,0	51,5
Spalter	4063	6	11	10	119	0	86	764	26	33	2	6	61	1	17	3,1	4,8	1,54	23,2	38,8
Spalter Select	3936	311	43	8	166	19	50	535	59	33	26	55	49	76	2	2,4	3,1	1,29	22,1	39,5
Strisselspalter	1965	178	8	6	60	38	11	515	0	47	42	89	58	94	2	2,7	4,5	1,67	19,4	36,2
Tango	8215	424	17	7	194	39	64	248	107	51	108	223	58	173	25	6,5	8,4	1,29	22,3	37,3
Target	3624	985	1	120	82	0	39	403	0	35	4	10	71	14	1	8,8	4,1	0,46	35,8	61,7
Tettnanger	3925	56	7	11	114	0	91	770	28	35	2	5	61	0	15	2,6	3,2	1,23	24,7	41,5
Vojvodina	2653	314	3	86	20	0	26	527	0	21	2	3	44	0	3	4,0	2,6	0,66	29,7	59,1
WFG	4946	33	8	13	80	0	65	777	40	27	3	6	50	0	2	2,2	2,8	1,28	24,8	41,1
Xantia	3733	643	21	416	26	0	14	345	100	18	19	45	41	0	9	9,5	3,3	0,35	26,8	46,5
Yeoman	2274	559	83	71	28	0	17	406	0	16	24	59	40	0	10	10,1	4,0	0,4	23,3	42,6
Zenith	2883	345	1	177	73	0	27	511	0	18	49	120	46	0	5	5,8	2,6	0,44	27,8	50,8
Zeus	2120	475	73	2	21	0	5	416	0	64	11	22	124	38	7	13,7	4,5	0,33	34,2	56,9
Zitic	2156	8	3	41	24	0	32	560	0	23	2	4	48	0	15	2,7	3,6	1,36	21,1	41,4

Essential oils = relative values, ß-caryophyllene = 100, α - and ß-acids in %, analogues in % of α - or ß-acids

7.5 Quality assurance in alpha acid analysis for hop delivery contracts

7.5.1 Chain analyses for the 2022 harvest

Starting in 2000 hop supply contracts have also included an agreement specifying that the α-acid content of a delivery batch should be taken into account, and that the agreed-upon price can be modified, up or down if the α-acid content is outside the stipulated, so-called neutral range. The working group for hop analysis (IPZ 5d) specifies precisely how hop samples are to be processed (sample division, storage), which laboratories can carry out the follow-up tests, and which tolerance ranges are permitted for the analyses. In 2023, once again, the working group had the task of organizing and evaluating chain analyses to ensure the quality of the α-acid analyses. That year, the following laboratories took part in the chain of tests.

- Hallertauer Hopfenveredelungsgesellschaft (HHV), Werk Au/Hallertau
  (Hallertauer Hop Processing Society [Hopsteiner], Au/Hallertau plant)
- Hopfenveredlung St. Johann GmbH & Co. KG, St. Johann
  (Hop processing St. Johann GmbH & Co. KG, St. Johann)
- Hallertauer Hopfenveredelungsgesellschaft (HHV), Werk Mainburg
  (Hallertauer Hop Processing Society [Hopsteiner], Mainburg plant)
- Hallertauer Hopfenverwertungsgenossenschaft (HVG e.G.), Mainburg
  (Hallertauer Hop Processing Cooperative, Mainburg)
- AGROLAB Agrarzentrum GmbH, Leinefelde
  (Hallertauer Agricultural Center, Leinefelde)
- Bayerische Landesanstalt für Landwirtschaft, Arbeitsbereich Hopfen, Hüll
  (Bavarian State Research Center for Agriculture, Hops Section)
- BayWa AG Tettnang

The round robin test started in 2023 on September 12th and ended on November 10th, while the majority of the hop batches were examined in the laboratories during that time. The chain tests were carried out a total of nine times (9 weeks). The sample material was kindly provided by the Hopfenring Hallertau. Each sample was only taken from one bale to ensure the greatest possible homogeneity. Every Monday, the samples in Hüll were ground with a hammer mill, divided using a sample divider (Figure 68), vacuum packed, and taken to the individual laboratories. One sample per day was analyzed on the following weekdays. The results were returned to Hüll a week later and evaluated there. A total of 35 samples were analyzed in 2023.

Figure 68: Sample divider and hammer mill

The evaluations were passed on to the individual laboratories as quickly as possible. Figure 69 shows an evaluation as an example of what a round robin test should ideally look like. The numbering of the laboratories (1-7) does not correspond to the above list.

Nr. 28: SIR (October 31, 2023)

Laboratory	Measured Value		Mean	s	cvr	z-score
1	2.56	2.62	2.59	0.042	1.6	-0.126
2	2.60	2.63	2.62	0.021	0.8	0.314
3	2.60	2.63	2.62	0.021	0.8	0.314
4	2.60	2.55	2.53	0.035	1.4	-1.269
5	2.59	2.61	2.60	0.014	0.5	0.050
6	2.54	2.55	2.55	0.007	0.3	-0.917
7	2.67	2.71	2.69	0.028	1.1	1.634

mean	2.60
sr	0.027
sL	0.050
sR	0.057
Vkr	1.03
vkR	2.19
r	0.07
R	0.16
Min	2.50
Max	2.71

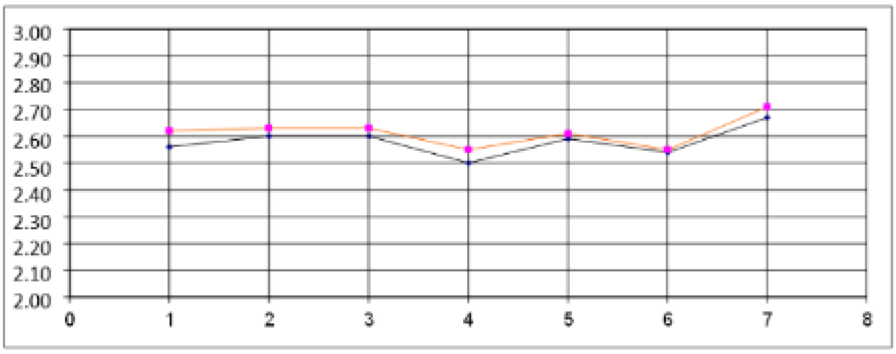


Figure 69: Example of evaluations of a set of chain analyses

In 2023, the z-score was also included in the evaluation. The z-score is calculated using the following formula (Formula 7.1):

$$z - Score = \frac{median - mean}{sR}$$

Formula 7.1

The outlier tests are calculated in accordance with DIN ISO 5725. The Cochran test (formula 7.2) was calculated within the laboratories and the Grubbs test (formula 7.3) was calculated between the laboratories.

$$\text{Cochran:} \quad C = \frac{s_{max}^2}{\sum s_i^2}$$

Formula 7.2

With 8 laboratories and a duplicate determination, at α = 1% C, the value must be less than **0.794** and at α = 5% C, it must be less than **0.680**, otherwise an outlier is detected.

$$\text{Grubbs:} \quad G = \frac{|x_{max} - \bar{x}|}{s}$$

Formula 7.3

With 8 laboratories and a duplicate determination, at $\alpha = 1\%$ G the value must be less than **2.274** and at $\alpha = 5\%$ G, it must be less than **2.126**, otherwise an outlier is detected. But the z-score can also be used to detect laboratory outliers. If the z-score is less than -2 or greater than 2, then these are outliers.

Table 16: Outlier of 2023

	Cochran		Grubbs	
Probe	α = 0.01	α = 0.05	α = 0.01	α = 0.05
14		Lab. 7		
18			Lab. 7	
31				Lab. 6
Total	**0**	**1**	**1**	**1**

The tolerance limit $d_{krit.}$, which indicates the difference within which measurements cannot be distinguished, is calculated according to Formula 7.4, where r is the repeatability and R is the reproducibility (Formula 7.5)

$$d_{krit.} = |x_1 - x_2|_{krit.} = \sqrt{R^2 - \frac{r^2}{2}}$$

.

$$r = s_r * 2.8 \rightarrow R = s_R * 2.8$$

Formula 7.4 *Formula 7.5*

Since 2013 there have been 5 alpha classes and new tolerance limits. Table 17 shows the new classification and the excesses for the year 2023.

Table 17: Updated alpha acid classes and tolerance limits as well as their exceedances in 2023

	< 5.0 %	5.0 % - 8.0 %	8.1 % - 11.0 %	11.1 % - 14 %	> 14.0 %
Critical Range	+/-0.3 0.6	+/-0.4 0.8	+/-0.5 1.0	+/-0.6 1.2	+/- 0.7 1.4
Transgressions in 2023	0	0	0	0	0

In 2023, the permitted tolerance limits were not once exceeded.

In Figure 70, all analysis results for each laboratory are compiled as relative deviations from the mean (= 100%), differentiated according to α acid contents <5%, ≥5% and <10% as well as ≥10%. From this graphic one can clearly determine if a laboratory has a tendency to produce values that are too high or too low.

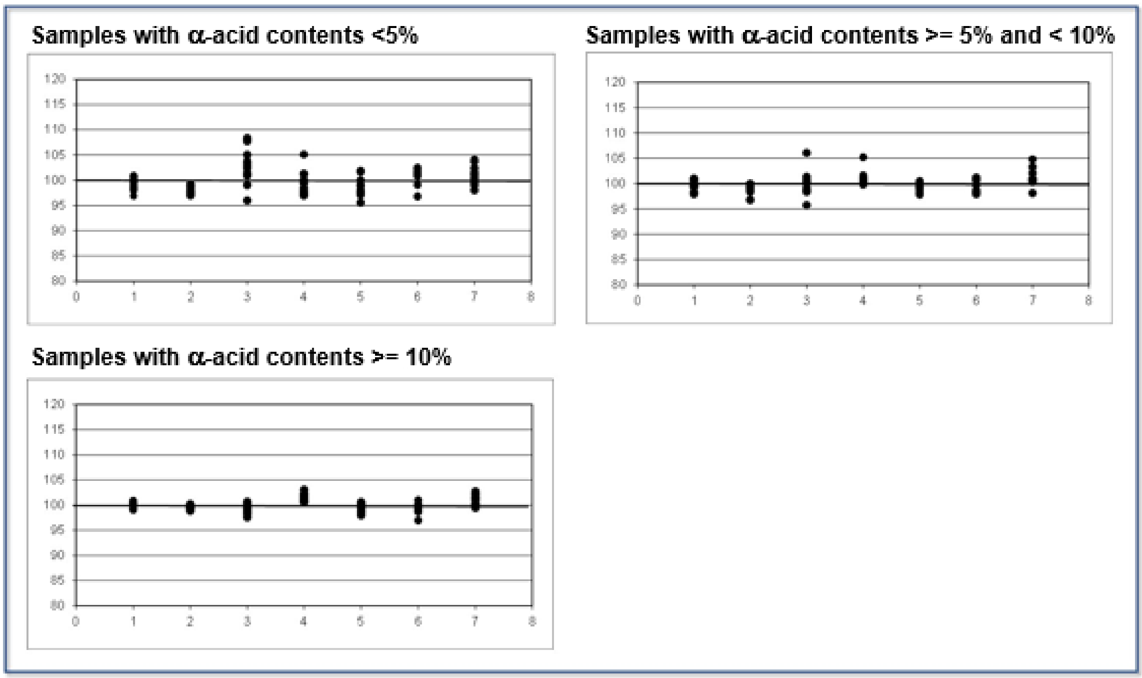


Figure 70: Laboratory analysis results relative to the mean value

The Hüll laboratory is number 5. In 2022, α acid levels were very low, so there were more samples with lower α-acid levels below 5%.

7.5.2 Evaluation of control examinations

In addition to the chain tests, control tests have been carried out since 2005, which the IPZ 5d working group evaluates. It then passes on the results to the laboratories involved and to the hop growers and hop industry associations. An initial testing laboratory selects three samples per week, which are then analyzed by three different laboratories in accordance with the AHA specifications. The initial examination value remains in force if the mean value of the follow-up examination and the initial examination value are within the tolerance limits (Table 17). Table 18 shows the results for 2023. In all cases, the initial test values were confirmed. Since the 2020 harvest, the BayWa Tettnang laboratory has also been an initial testing laboratory.

Table 18: Control evaluation in 2022

Sample name	Initial test laboratory	Initial test value	Follow-up Tests			Average	Results confirmed
			1	2	3		
41983 HTU	Agrolab	11.4	11.2	11.5	11.9	11.53	yes
42055 HAL	Agrolab	4.4	4.3	4.4	4.5	4.41	yes
42072 HTR	Agrolab	4.6	4.3	4.5	4.5	4.45	yes
Batch 15539 TET	BayWA	3.0	3.0	3.1	3.2	3.10	yes
Batch 25621 PER	BayWA	6.4	6.3	6.4	6.4	6.37	yes
Batch 45871 PLA	BayWA	18.3	17.6	17.8	18.0	17.8	yes
HMG, 42390	HVG Mainburg	19.4	19.3	19.7	19.7	19.57	yes
HKS, 41905	HVG Mainburg	12.4	12.0	12.2	12.3	12.17	yes
HMG, 42390	HVG Mainburg	12.6	12.7	12.9	13.1	12.90	yes
KW 40-HTU	HV St. Johann	14.3	14.0	14.1	14.3	14.13	yes
KW 40-HKS	HV St. Johann	11.5	11.5	11.6	11.8	11.64	yes
KW 40-PER	HV St. Johann	6.4	6.3	6.4	6.5	6.41	yes
KW 41 - NUG	HHV Au	11.8	11.7	11.7	11.9	11.77	yes
KW 41 - HMG	HHV Au	11.7	11.6	11.7	12.0	11.77	yes
KW 41 - HKS	HHV Au	13.9	13.6	13.6	14.2	13.80	yes
47016 HKS	Agrolab	11.0	11.3	11.3	11.5	11.35	yes
47353 HKS	Agrolab	12.0	11.8	12.0	12.2	12.00	yes
44862 HKS	Agrolab	11.7	11.4	11.5	11.6	11.5	yes
Batch 362, Variety HTR	BayWA	5.4	5.0	5.3	5.4	5.22	yes
Batch 356, Variety HBC	BayWA	9.1	9.0	9.0	9.2	9.05	yes
Batch 802, Variety HKS	BayWA	14.2	13.8	13.9	14.1	13.95	yes
KW 44 51297, Variety HKS	HVG Mainburg	14.6	14.4	14.6	14.7	14.57	yes
KW 44 47173, Variety HMG	HVG Mainburg	10.4	10.5	10.7	10.9	10.68	yes
KW 44 46527, Variety TTN	HVG Mainburg	14.7	14.4	14.8	15.0	14.74	yes
KW 45 – 46183, Variety PER	HV St. Johann	5.7	5.5	5.6	5.7	5.58	yes
KW 45 – 48105, Variety HMG	HV St. Johann	10.4	10.0	10.1	10.5	10.19	yes
KW 45 – 47902, Variety HKS	HV St. Johann	11.4	11.0	11.2	11.3	11.17	yes
KW 46 - HMG	HHV Au	12.1	12.0	12.0	12.4	12.13	yes
KW 46 - HKS	HHV Au	14.0	13.7	14.0	14.4	14.05	yes
KW 46 - TTN	HHV Au	12.6	12.5	12.7	12.8	12.67	yes

7.5.3 Follow-up examinations for the 2023 harvest

The laboratory in Hüll has been involved as a follow-up laboratory since 2019. It evaluates the results. Starting with the 2020 harvest, the BayWa laboratory in Tettnang was also approved as a testing laboratory (Table 19).

Table 19: Workflow for follow-up laboratories

Initial test laboratory	Follow-up test laboratories		
HHV Au HHV Mainburg	HVG Mainburg	HV St. Johann	LfL Hüll
HV St. Johann	HVG Mainburg	HHV Mainburg	LfL Hüll
HVG Mainburg	HV St. Johann	HHV Mainburg	LfL Hüll
AGROLAB	HV St. Johann	HHV Au	LfL Hüll
BayWa Tettnang	HV St. Johann	HHV Au	LfL Hüll

The evaluation of the follow-up examination is sent to the initial examination laboratory as a LfL follow-up examination report within three working days after receipt of the follow-up examination results, which immediately initiates forwarding to the client of the follow-up examination. In 2023, there were a total of 42 follow-up examinations. In three cases the initial test value was not confirmed (yellow marking). Table 20 shows the follow-up results in ascending chronological order. 17 follow-up examinations were carried out on behalf of Agrolab, 9 by HV St. Johann, and 5 each by HVG e. G. Mainburg and the HHV Au. Of the varieties, the Herkules HKS variety was in first place with 24 follow-up examinations.

Table 20: Follow-up examinations in 2023

Sample Name	Initial test laboratory	Initial test results	Follow-up tests			Mean	Results con-firmed
			1	2	3		
43610 HTR	Agrolab	4.8	5.2	5.3	5.5	5.33	no
Batch 1920125, Variety PER	HHV Au	6.6	6.8	6.9	6.7	6.80	yes
45326 PER	Agrolab	6.7	6.7	6.7	6.8	6.73	yes
45308 PER	Agrolab	6.8	6.6	6.7	6.7	6.67	yes
45376 HKS	Agrolab	11.9	11.8	11.9	12.2	11.97	yes
Agrolab-Analysis No. 48974, Variety HKS	HHV Au	11.4	11.1	11.1	11.5	11.23	yes
Agrolab-Analysis No. 49675, Variety HKS	HHV Au	12.9	12.9	12.9	13.2	13.00	yes

Sample Name	Initial test laboratory	Initial test results	Follow-up tests			Mean	Results con-firmed
			1	2	3		
Variety HHKS, Designation 50486	HV St. Johann	11.7	14.1	14.2	14.4	14.23	no
Batch HHKS, Designation 50330	HV St. Johann	10.7	10.5	10.8	11.1	10.80	yes
Batch DEH HTR, Designation 42495	HV St. Johann	5.4	5.2	5.2	5.2	5.20	yes
Batch PLA, Analysis No. 44472	HVG Mainburg	15.8	16.1	16.3	16.3	16.23	yes
Batch HMG, Agrolab No. 44630	Agrolab	11.0	10.9	11.0	11.0	10.97	yes
Batch HKS, Analysis No. Agrolab 50335	HV St. Johann	14.0	11.6	11.7	12.1	11.80	no
Batch HKS, Analysis No. 50464	HV St. Johann	13.5	13.4	13.5	13.8	13.57	yes
Batch HKS, Agrolab- Analysis No. 48789	HHV Au	11.3	11.3	11.4	11.5	11.40	yes
Batch HKS, Analysis No. 53144	HV St. Johann	13.1	13.0	13.2	13.4	13.20	yes
Batch HKS, Analysis No. Agrolab 51566	HVG Mainburg	14.0	14.0	14.1	14.1	14.07	yes
Batch HKS, Analysis No. Agrolab 52059	HVG Mainburg	14.2	14.0	14.3	14.3	14.20	yes
Batch HKS, Analysis No. Agrolab 50975	HVG Mainburg	14.0	13.9	13.9	14.0	13.93	yes
47016 HKS	Agrolab	11.0	11.3	11.3	11.5	11.35	yes
47353 HKS	Agrolab	12.0	11.6	12.0	12.2	12.00	yes
44862 HKS	Agrolab	11.7	11.4	11.5	11.6	11.50	yes
Batch HHKS, Analysis No. Agrolab 50101	HV St. Johann	12.5	12.1	12.3	12.6	12.33	yes
Batch HHKS, Analysis No. Agrolab 49690	HV St. Johann	11.6	11.5	11.5	11.9	11.63	yes
46461, PER	Agrolab	6.7	6.6	6.7	6.7	6.67	yes
50740, HKS	Agrolab	15.0	14.9	15.2	15.5	15.20	yes
53579, HKS	Agrolab	12.2	12.0	12.2	12.6	12.27	yes
53016, HKS	Agrolab	12.5	12.3	12.3	12.7	12.43	yes
52365, HKS	Agrolab	13.5	13.0	13.1	13.3	13.13	yes

Sample Name	Initial test laboratory	Initial test results	Follow-up tests			Mean	Results con-firmed
			1	2	3		
50784, HKS	Agrolab	14.1	13.8	14.0	14.3	14.03	yes
49497, HKS	Agrolab	13.6	13.0	13.1	13.4	13.17	yes
Batch HMG, Analysis No. Agrolab 53513	HVG Mainburg	11.4	11.6	11.8	12.0	11.81	yes
Probe 52816, Batch HKS	HV St. Johann	13.9	13.8	13.9	14.1	13.93	yes
Probe 54236, Batch PER	Agrolab	6.4	6.1	6.1	6.1	6.10	yes
Probe 54234, Batch HTR	Agrolab	4.9	4.6	4.6	4.6	4.60	yes
Agrolab- Analysis No. 44080, Batch HMG, Designation 40233	HHV AU	10.3	10.0	10.1	10.3	10.13	yes

The results of the control and follow-up examinations are published annually in July or August in the *Hopfenrundschau* magazine.

Table 21: Number of follow-up examinations and complaints from 2019 – 2023

Follow-up exams	Number	Complaints
2019	47	1
2020	42	1
2021	33	0
2022	42	1
2023	36	3

7.6 Studies on the biogenesis of bitter substances and oils of new breeding lines

With newer breeding lines, extensive biogenesis tests are carried out every year on essential oils and bitter substances to obtain information about the optimum harvest timing. Table 22 shows the best harvest dates, although slight shifts in those dates are possible for different years.

Table 22: Harvest times of the biogenesis experiments

T0	T1	T2	T3	T4	T5	T6
16 August	21 August	28 September	4 September	11 September	18 September	25 September

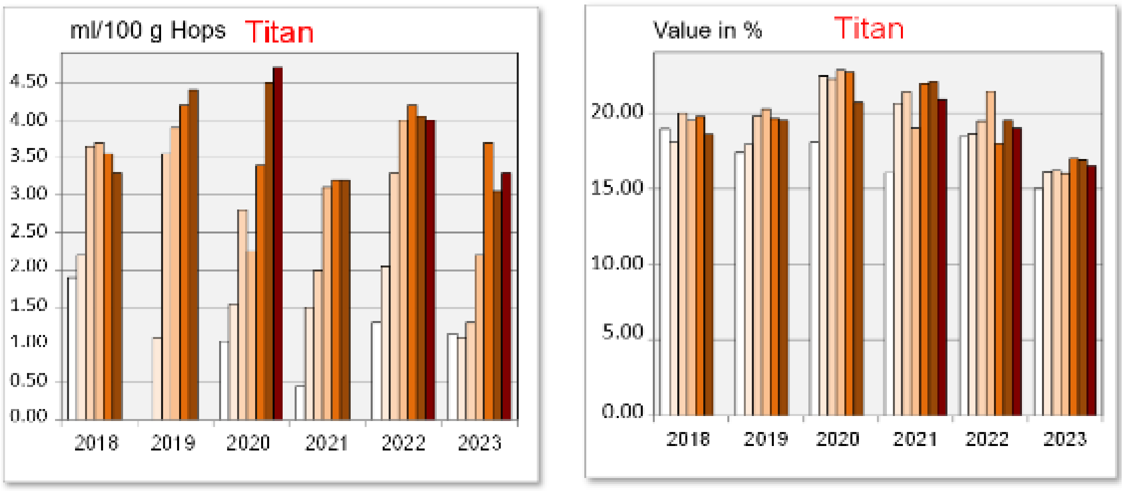


Figure 71: Biogenesis of oils and bitter substances in Titan at the Stadelhof location

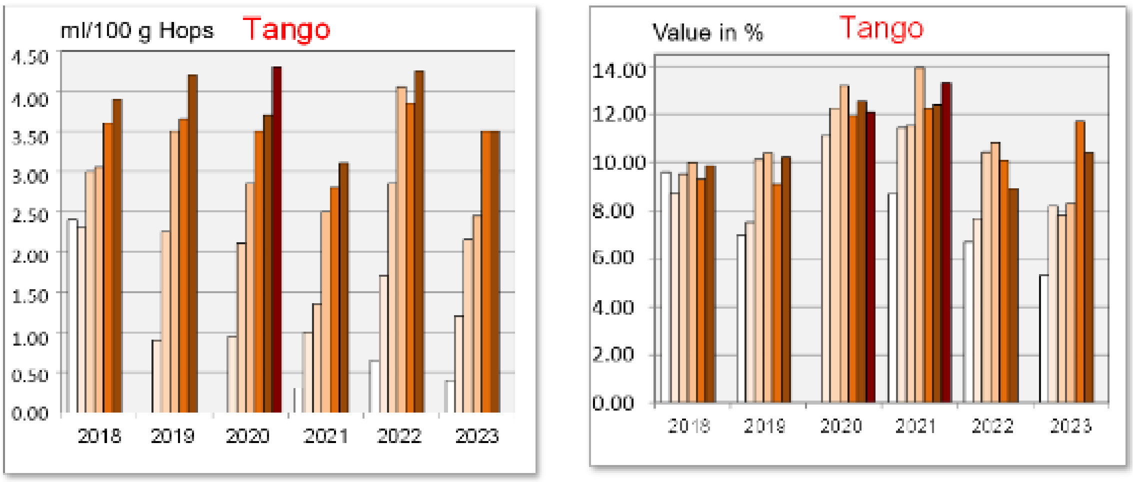


Figure 72: Biogenesis of oils and bitter substances in Tango at the Stadelhof location

The graphics show that the oil content depends much more on the timing of the harvest than on the content of bitter substances. Often, the later the harvest, the more distinctive is the aroma. The new Tango has a very high oil content (2.4 – 4.0 ml/100 g) relative to its alpha acid content (7.5 – 11%). The climatic conditions also seem to have different effects on hop components. In dry and hot years, oil concentration even increases. The year 2021 was ideal for alpha acids. That harvest year produced record alpha acid values, but oil levels were lower. In the dry, hot year 2022, alpha acid levels were very low, but oil levels were relatively high. In 2023, alpha acid levels were close to those in 2022. Alpha acid levels for Titan also dropped slightly in 2023 compared to 2022; and the oil contents were lower for both new varieties than in 2022.

7.7 Development of NIRS calibrations based on conductometer and HPLC data with the new near-infrared reflection spectroscopy device

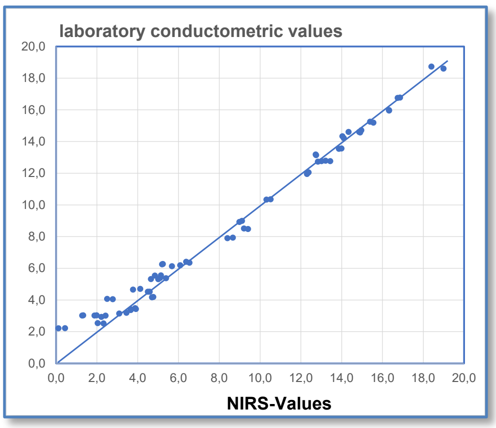
Since the spring of 2017, the laboratory in Hüll has owned a new NIRS (near-infrared spectroscopy) device, which was fully financed by the Society for Hop Research (Figure 73).

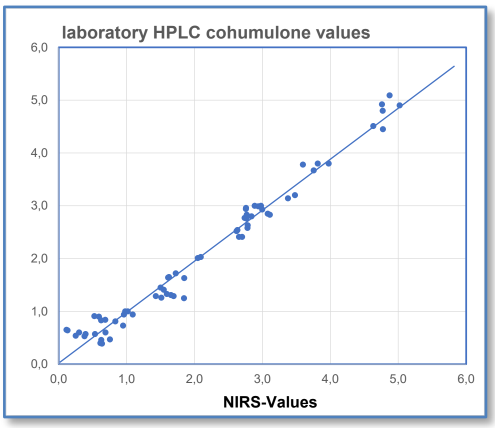
Figure 73: NIRS device from Unity Scientific

The device is compatible with the devices at AQU in Freising. The old calibration of the Foss device could be adapted to the new device using a mathematical transformation formula.

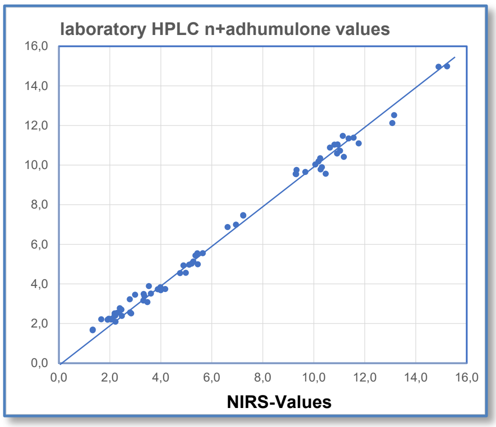
However, we also began to develop our own calibrations of this device based on conductometer and HPLC data. The calibrations are expanded and validated every year with the samples from the interlaboratory test. Figure 74 shows the correlations of individual parameters between laboratory values and NIRS values.

conductometer values in % cohumulone in %

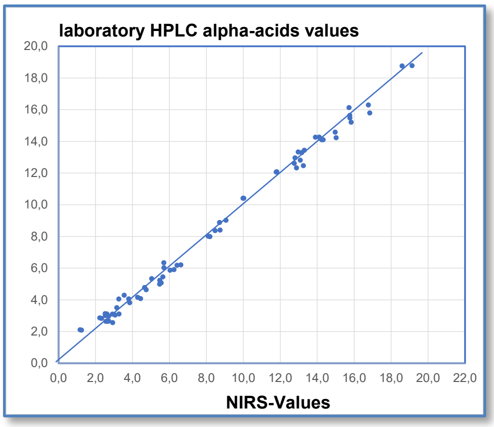




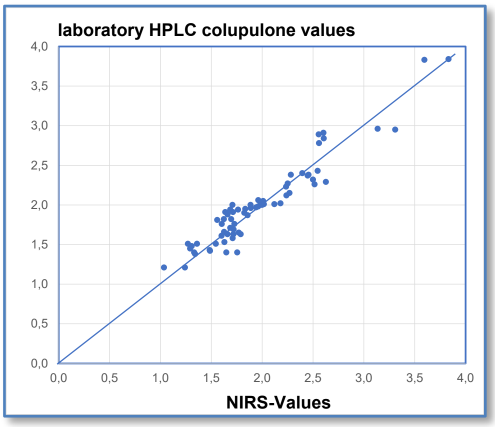
n + adhumulone in %



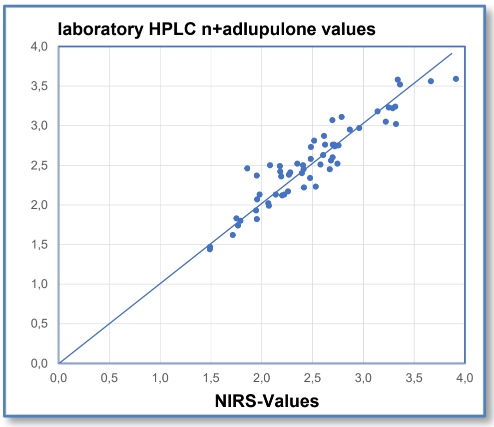
alpha acids in %



colupulone in %



n + adlupulone



beta-acids in %

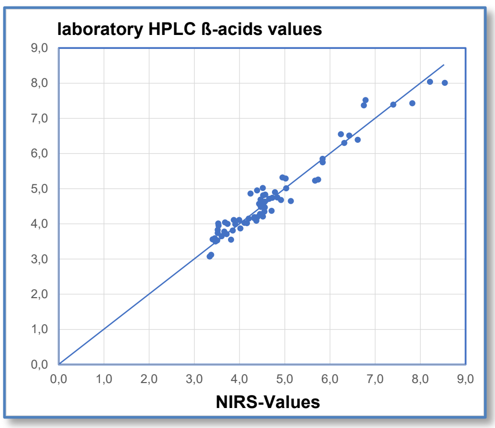


Figure 74: Correlations between laboratory values and NIRS values

Table 13 summarizes the statistical parameters for evaluating the precision of the calibrations. Bias is the systematic deviation between the NIRS values and the laboratory values. SEP stands for Standard Error Prediction, which is the standard error between NIRS values and the values of the validation samples. The SEP is calculated according to Formula 1. The so-called random error SEP(C) is obtained using formula 2. R2 is the measure of accuracy between NIRS values and laboratory values. The higher the R2, the better is the correlation.

$$SEP = \sqrt{\frac{\Sigma(y_i - \hat{y}_i)^2}{n-1}}$$

$$SEP(C) = \sqrt{SEP^2 - Bias^2}$$

Formula 7.3 *Formula 7.4*

Table 23: Statistical parameters for the precision assessment of the NIRS methods

Method	Bias	SEP	SEP(C)	R^2
Conductometer values	0,159	0.686	0.667	0.987
Cohumulone (HPLC)	- 0.023	0.236	0.234	0.972
n + Adhumulone (HPLC)	- 0.029	0.337	0.335	0.993
Alpha-acids (HPLC)	0.014	0.413	0.413	0.994
Colupulone (HPLC)	0.026	0.164	0.162	0.911
n + Adlupulone (HPLC)	0.068	0.227	0.216	0.928
Aeta-acids (HPLC)	0.030	0.279	0.277	0.946

Especially the conductometer values and the HPLC alpha acid values are already well correlated with the NIRS values. The NIRS method is somewhat worse for determining ß-acids. Calibrations are continuously improved by adding new data sets annually. Near-infrared spectroscopy is a very valuable method for hop breeding because it makes it possible to measure many samples per day. Also, it does not require solvents that are costly to dispose of. However, NIRS is still too imprecise as a method for hop delivery contracts. Thus, conductometric titration is used here.

7.8 Alpha acid stability of the new Hüll-bred varieties compared to annual fluctuations

Alpha acid data from 2012 to 2023 is now available for the new Hüll-bred varieties and can be visualized with the help of box plot representations. The representation of a box plot evaluation is briefly explained in Figure 75.

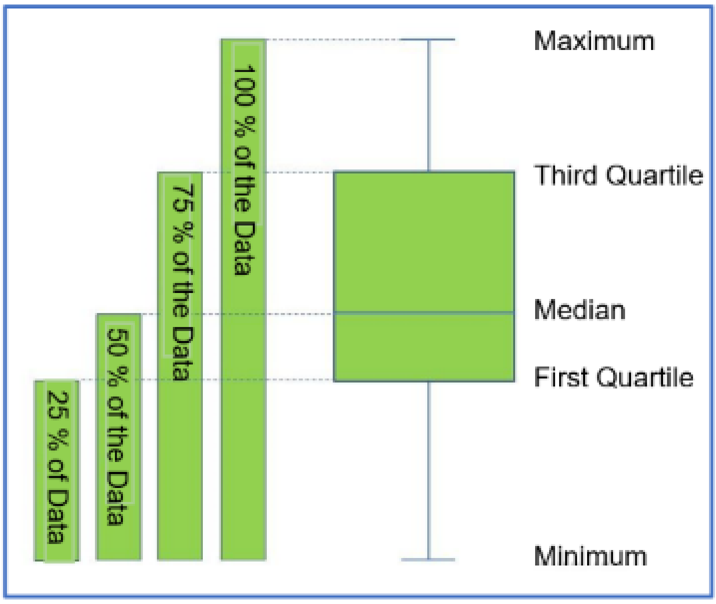


Figure 75: Explanation of a box plot representation

Figures 76 and 77 show box plot evaluations of the official AHA results. It is very clear from the illustrations that the new Hüll cultivars are much more stable against annual fluctuations than, for example, Perle and Northern Brewer.

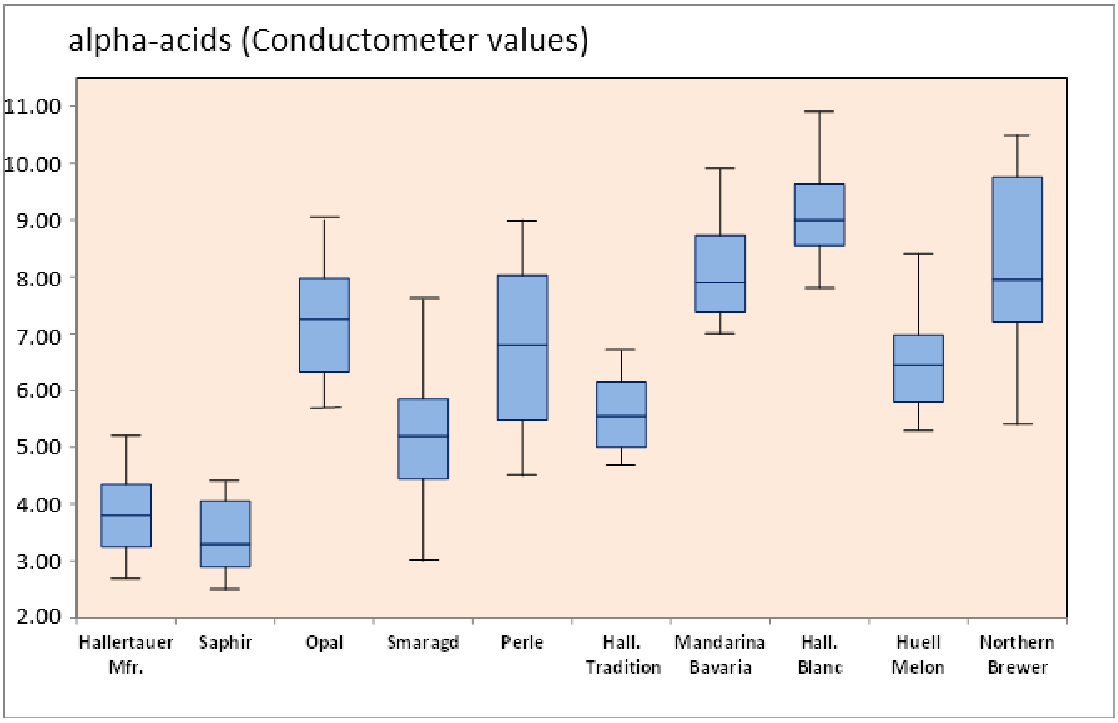


Figure 76: Box-Plot evaluation of aroma varieties

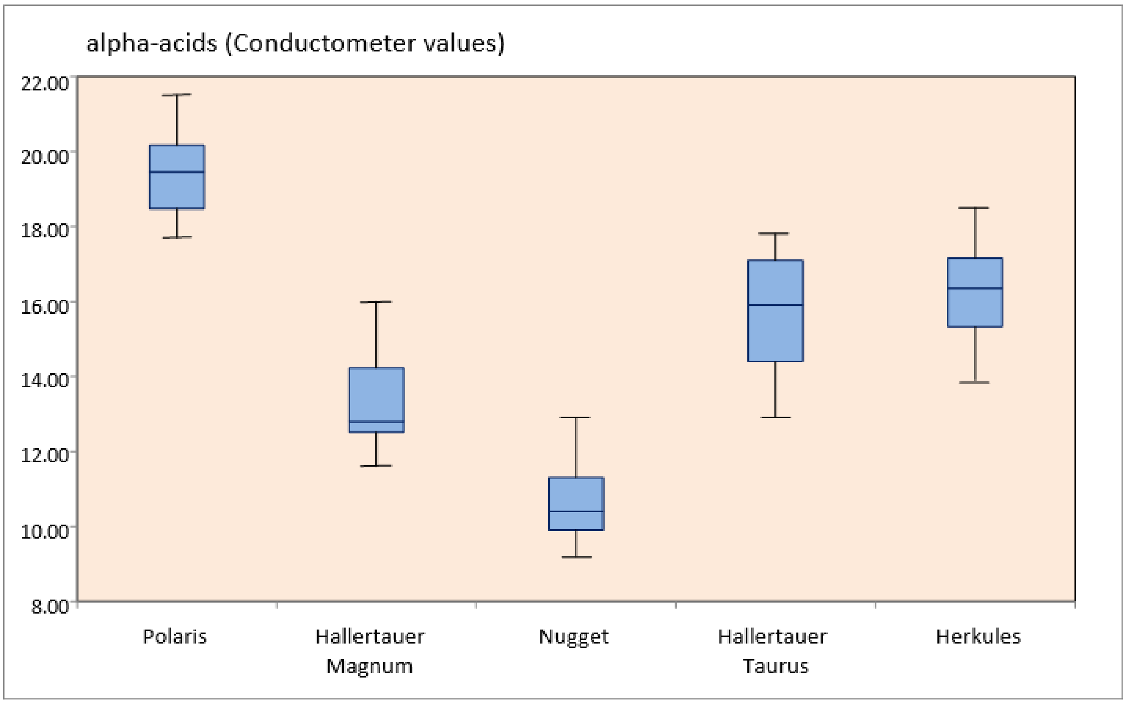


Figure 77: Box-Plot evaluation of bitter varieties

7.9 Establishing an analysis of alkaloids in lupins

The analysis of alkaloids in lupins was established for the IPZ 1b Günther Schweizer working group. The first step was the development of a suitable sample preparation method. The second step was the development of a GC method for analysis. Figure 78 shows the sample preparation procedure; Figure 79, the GC analysis.

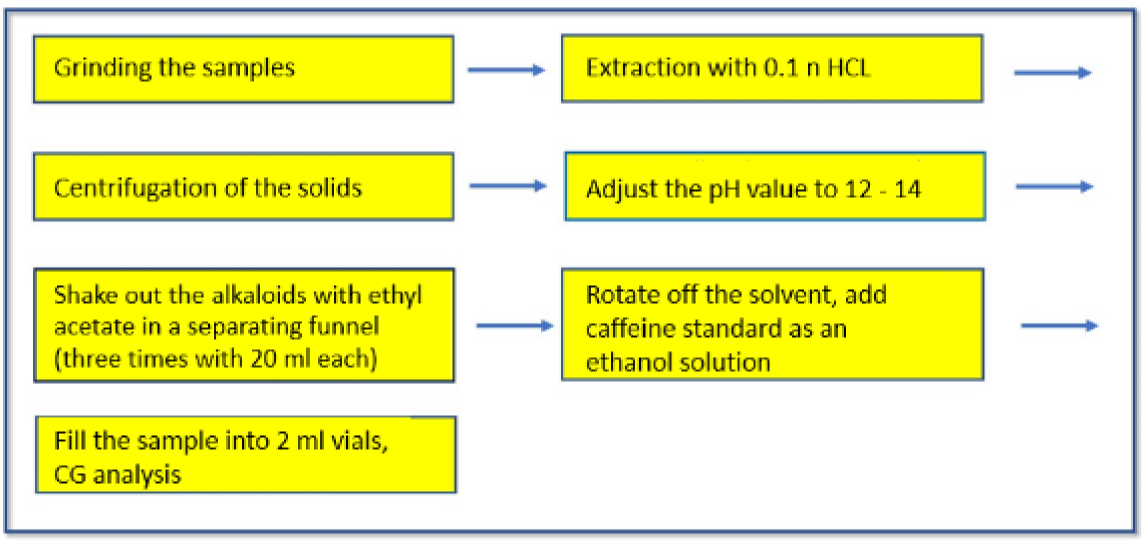


Figure 78: Sample preparation for alkaloid analysis

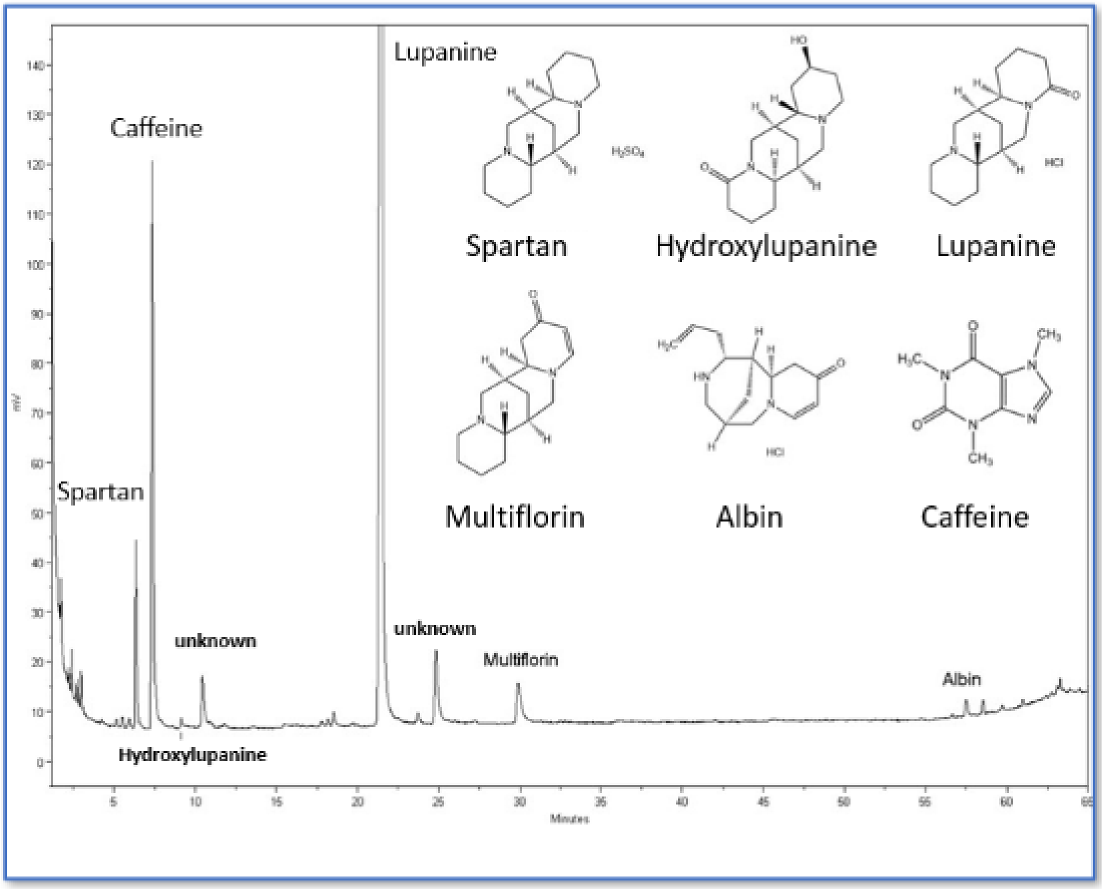


Figure 79: Gas chromatogram of alkaloids in lupins

The main compound is lupanine. Spartanine, hydroxylupanine, multiflorin, and albine were also identified. The quantitative evaluation is carried out using caffeine as an internal standard. There are still a few unknown peaks that need to be checked using standards. A total of 158 samples were measured in 2023.

7.10 Control of variety authenticity in 2023

Verifying the authenticity of a variety for the food control authorities is a mandatory task of the IPZ 5d working group, which funcins as an administrative assistance.

There were 14 variety checks for the food control authorities (district offices) for 2023, which produced 0 complaints.

8 Ecological Issues in Hop Production

Dr. Florian Weihrauch, Dipl.-Biol.

The task of this working group is to update the state of knowledge and apply research regarding environmentally friendly hop production. This includes diagnosis, observation, and monitoring of the occurrence of pests in hops and their natural enemies. The focus is on climate change and its effects on various biocenoses, as well as the development and evaluation of biological and other eco-friendly plant protection methods. The working group is funded primarily out of research funds for ecological issues in hop cultivation.

8.1 Further development of culture-specific strategies for ecological plant protection with the help of sector networks – hops division

Sponsors:	Bund Ökologische Lebensmittelwirtschaft (BÖLW e.V.) (*Organic Food Production Alliance BÖLW e.V.)* Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Ecology IPZ 5e)*
Financing:	Bundesanstalt für Landwirtschaft und Ernährung (BLE) über Bundesprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft (BÖLN-Projekt 2815OE095) *(Federal Office for Agriculture and Food (BLE) via the federal program for organic farming and other forms of sustainable agriculture) (BÖLN project 2815OE095)*
Project Management:	Dr. F. Weihrauch
Team:	Dr. F. Weihrauch, M. Obermaier
Cooperation:	Bund Ökologische Lebensmittelwirtschaft (BÖLW e.V.) (*Organic Food Production Alliance BÖLW e.V.)*
Duration:	August 15, 2017 to December 31, 2023 (Project extension))

Procedure and goals

The overall research project aims to create six networks working on issues in arable farming, vegetables, hops, potatoes, fruit, and viticulture, as they relate to plant health in organic farming. In each division, the coordinators serve as central contact hubs. The overall coordination is in the hands of BÖLW, and the hop division is coordinated by IPZ 5e in Hüll. The coordinator's tasks include building up the network as a stable group of commercial operations, giving advice to companies contemplating a switch to organic operations, identifying questions of plant health in the respective crop, recording and disseminating information about innovations and research needs, as well as formulating strategies for each crop.

Within the organic hop network, communication takes place primarily during two or three meetings a year and a special workshop open to all. An exchange of ideas and overall coordination between the various networks takes place during at least annual workshop. From the perspective of the hop division, the most important events in 2023 were the “hop cultivation day” as part of the Bioland Week (February 7, 2023), as well as a round table on current problems in organic hop plant protection in Hüll on March 30, 2023 with lively discussions and direct exchanges between the various stakeholders (28 participants). There was also the traditional summer excursion of the “Eco Hops Working Group,” with 53 participants visiting the Upper Austrian Mühlviertel, on July 25 and 26, 2023 (Figure 80).

The main goal of the research project is to pursue targeted management strategies and to rely less on input from phytomedically active substances (herbal medical products) in the cultivation system. The Federal Bureau of Agriculture and Nutrition (BLE) and the German Federal Department of Agriculture and Nutrition (BMEL) are both clients of the working group and expect to see progress and innovation, ideally involving the development of new management and cultivation systems, as well as a coherent work program. A “strategy paper” summarizes the conclusion of the first part of the research project. It was published at the end of 2022.

Figure 80: Group photo of the participants in the summer excursion of the organic hops working group in July 2023 to the Mühlviertel in Upper Austria

8.2 Development of an action catalog to support biodiversity in hop cultivation

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Ecology IPZ 5e)*
Financing:	Erzeugergemeinschaft Hopfen HVG e. G. *(HVG Hop Processing Group)*
Project Management:	Dr. F. Weihrauch
Team:	Dr. F. Weihrauch, Dr. I. Lusebrink, M. Obermaier
Cooperation:	Interessengemeinschaft Niederlauterbach (IGN) e.V. *(IGN Interest Community for Quality Hops Niederlauterbach)*
	AELF Ingolstadt-Pfaffenhofen, FZ Agrarökologie *(Center of Expertise for Agroecology)*
	Landesbund für Vogelschutz, KG Pfaffenhofen; *(The State Association for Bird Protection in Bavaria eV)*
	uNB, Landkreis Pfaffenhofen *(Nature conservation, Pfaffenhofen District)*
Duration:	March 1, 2018 to February 28, 2026 (Project extension))

Goal and background

The Bavarian state government declared 2019 and 2020 "years of biodiversity," but biodiversity is still a current and continuous concern. At the beginning of 2018, the hop producer group HVG, together with the LfL, began to initiate measures aimed at preventing the loss of species and promoting biodiversity in hop cultivation. This includes, for example, the evaluation of measures to promote biodiversity in and around the hop gardens; the creation of a working concept; the formulation and processing of individual topics; and the moderation of implementations in commercial hop growing — without diminishing the productivity of valuable arable land and of hop gardens under cultivation. Instead, the objectives are to discourage the agricultural use of marginal or unproductive land and to preserve buffer land that is currently not in use.

Method

The most important step was to build a cooperative network of as many affected associations, organizations, and institutions as possible to agree on a shared, constructive approach and on solutions. In addition to the LfL and the TUM, the following institutions and organizations have also been involved in the effort: the Agroecology Specialist Center Ingolstadt-Pfaffenhofen (AELF), the State Federation for the Protection of Birds and Nature (LBV), the Nature Conservancy (UNB) at the Pfaffenhofen district office, the Hop

Processing and Marketing Organization Niederlauterbach (ING), and all organizations headquartered in the House of Hops in Wolnzach.

Concept of the "Eichelberg biodiversity display"

One of the showcases of the concept is a cooperation with the ING in the classic hop-growing village of Eichelberg on the banks of the Ilm Valley. This is an almost entirely enclosed area of 85 hectares, most of which belongs to and is managed by three IGN member companies. This space is divided into 34 hectares (40%) under hop cultivation, 28 hectares (33%) of arable land, and the rest a mix of wooded areas, grassland, wild flower meadows, and other areas of random vegetation. Thanks to the committed and interested landowners and farmers, the "Eichelberg biodiversity display" offers exceptional opportunities for developing a showcase that proves that hop cultivation and biodiversity do not have to be mutually exclusive. Instead, these two objectives can coexist in harmony. In the fall of 2020, an action plan was developed, which moved into the implementation phase in the spring of 2021.

The focus of the initial work was the creation of new living and overwintering spaces for beneficial insects such as predatory mites (Figure 81). In the spring of 2022, these structures were then "inoculated" with predatory mites (*Neoseiulus californicus* and *Phytoseiulus persimilis*) from viticulture. To evaluate to which extent these beneficial insects can contribute to the biological control of spider mites, four hop gardens in the Eichelberg area were each divided into one part that was conventionally managed using acaricide and one part without acaricide but with beneficial insects. The development of spider mite (*Tetranychus urticae*) infestations in these areas is monitored on an annual basis. In addition, a test harvest is carried out every year in one of these gardens to compare the yield and quality of hops grown in the two halves.

Figure 81: Parthenocissus quinquefolia, also known as Virginia or Victoria creeper, a flowering plant in the grape family, serves as the natural habitat of beneficial insects in Eichelberg. These creepers take easily to climbing up hop trellises.

Another important objective of the Eichelberg project is public relations. Thus, a 2.5-km circular interpretive path with 16 information boards themed “Hops and Biodiversity” was created. The boards provide information on such topics as “the woodlark,” “virgin soils,” “spider mite control with beneficial insects,” and “antlions (also knowns as doodlebugs)” (Figure 83). The text for the information boards originated at AG IPZ 5e and and the boards were produced in cooperation with AELF, UNB, and LBV. The themed trail was inaugurated on July 12, 2023 in the presence of numerous attendees and the press. Since then, upon request, IPZ 5e has conducted several guided tours with explanations along the path (Figure 84).

Figure 82: This information board about “Lacewings and Diurnals” next to a pile of stones is an example of the themes covered on the Eichelberg “Hops and Biodiversity” trail.

Figure 83: A stone pile with a matching information board on the “Hops and Biodiversity” trail in Eichelberg.

8.3 Development of a technology for releasing predatory mites

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Ecology IPZ 5e)*
Financing:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Ecology IPZ 5e)*
Project Management:	Dr. F. Weihrauch
Team:	Dr. F. Weihrauch, Dr. I. Lusebrink, M. Obermaier, A. Baumgartner, M. Felsl
Cooperation:	Blüml (Hop Farm) GbR, Dürnwind Koppert Biological Systems
Duration:	May 2021 to October 2024

Background, Approach and Goal

The largest European producer of beneficial insects, Koppert Biological Systems in the Netherlands, has proposed a pilot project in the Hallertau to test and improve a technical solution for the release of predatory mites in hops. The aim is to devise an uncomplicated release mechanism for predatory mites that can control the common spider mite (*Tetranychus urticae*). Significantly, the costs and personnel efforts should be roughly the same as those required in the application of acaricides. During the 2021 season, the first tests were carried out with a specially designed device mounted on the back of a tractor that uses sawdust as a carrier material and six blow-out pipes at three height levels to distributes the predatory mites in the crop. It turned out that most of the beneficial insects did not end up on the hops but rather in the lane. Therefore, the approach was modified and tested in 2022. Very early in the growing season, at the beginning of May, only the freshly sprouted hop plants were treated at ground level using two blow-out pipes. This method proved potentially practical. Subsequently, a similar solution was tested in 2023 at a comparable date, on May 16 (Figure 84). This time too, the predatory mites landed on the rows of hops. There were no losses (Figure 85).

Based on years of experience of the Hop Research Center with predatory mites to control spider mites, a mixture of the two predatory mites, *Neoseiulus californicus* and *Phytoseiulus persimilis*, was used. This proved to be effective at a density of 100,000 predatory mites per hectare. The test was repeated in Dürnwind with HKS, on May 31, 2023. For comparison, one plot was left untreated and another was sprayed with a conventional application (Spirotetramat). For an additional control, there was also an application on bean leaves, which have served successfully as such in trials in previous years.

Figure 84: Predatory mites applied on freshly trained plants in mid-May 2023

Figure 85: Using sawdust as a carrier substance, the predatory mites are gently blown on the young hop bines

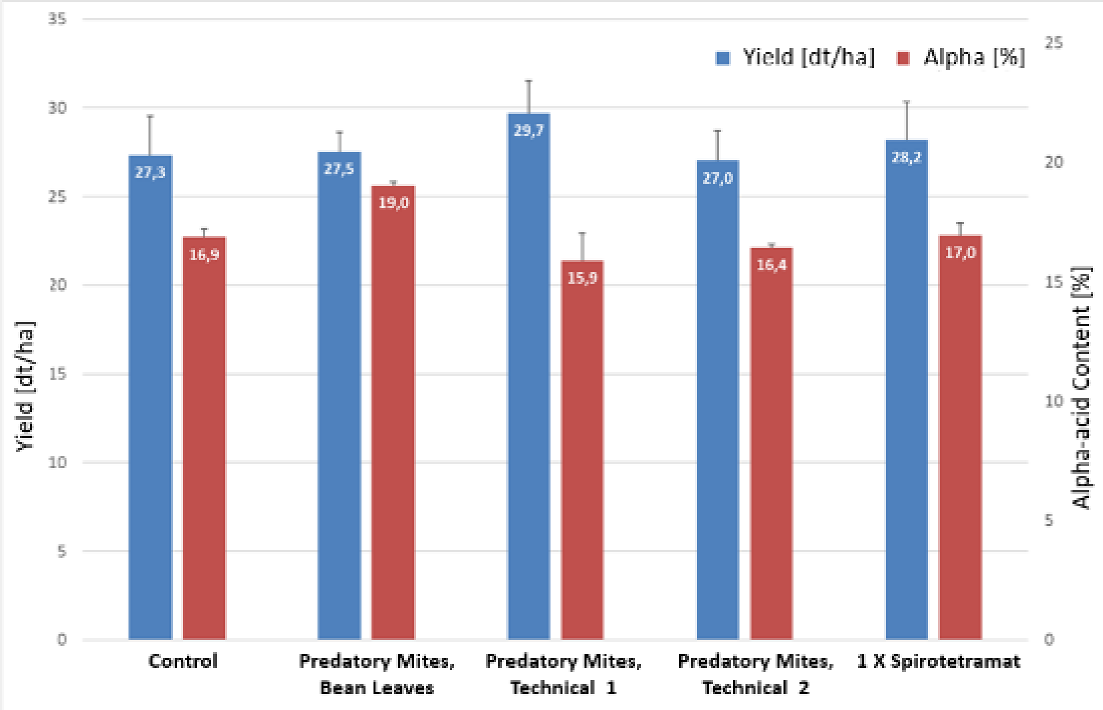


Figure 86: Results of the test harvest on September 13, 2023, in Dürnwind (variety HKS) in plots where predatory mites were used, compared with untreated and acaricide-sprayed plots

Results 2023

At the beginning of the 2023 growing season, there were practically no spider mite infestations; and even at harvest time, the average spider mite count did not exceed two mites per leaf. The mere marginal spider mite pressure at the test site was not much different from that in the rest of the Hallertau and in Tettnang; and there were no significant differences between the variants.

A test harvest on September 13, 2023 also showed no differences in spider mite infestations between the variants; and this result was also reflected in the yield and alpha acid content of the harvest. All predatory mite plots, as well as the untreated control, showed no differences compared to plots with conventional crop protection (Figure 86). As in previous years, a lack of acaricide use can be ruled out as a cause of damage.

Outlook

The technical application of predatory mites is competitive with the use of chemical-synthetic acaricides against spider mites. Only a few small adjustments may still be needed. For instance, it is still not clear which date is optimal for the application. Further deployment tests are planned at commercial farms in 2024, as well as more meticulous tests at Dürnwind. The 2023 results were not suitable for definitive conclusions yet, simply because of the overall late and very low spider mite infestation.

8.4 Induced resistance to spider mites in hops

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) (*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Ecology IPZ 5e)*
Financing:	Deutsche Bundesstiftung Umwelt (DBU), Förderinitiative 'Vermeidung und Verminderung von Pestiziden in der Umwelt', Förderkennzeichen: AZ 35937/01-34/0 (*German Federal Foundation for the Environment (DBU, Funding initiative "Avoidance and reduction of pesticides in the environment", Funding Number: AZ 35937/01-34/0))*
Project Management:	Dr. F. Weihrauch
Team:	Dr. F. Weihrauch, M. Obermaier, A. Baumgartner, M. Felsl
Cooperation:	20 practical businesses in integrated hop production Working group IPZ 5d, Hop Analytics
Duration:	June 2021 to May 2026

Background and goal

In hops, the common spider mite can build up very large populations very quickly during dry, hot summers, sometimes causing enormous losses in quality and yield. In recent decades, various plant protection experiments conducted by the Hop Research Center have shown that hop plants, after surviving severe spider mite infestations, are able to defend themselves against new, excessive spider mite infestations in subsequent years.

The InduResi project is investigating whether and to which extent heavy infestations of hop plants with these mites for one or two years reduce their susceptibility through "induced resistance" in subsequent years.

Method

Outdoor trials are being carried out in the Hallertau and in the Tettnang growing region of Baden-Württemberg. In the Hallertau, ten test gardens each with Hallertau Tradition (HTR) and Herkules (HKS), as well as six gardens with Spalter Select (SSE) are regularly assessed for spider mites. In Tettnang, there are five experimental gardens for the classic Tettnanger landrace (TET).

Each test garden contains a control plot and a regular commercial plot of approximately 500 m². The spider mite population is allowed to develop freely in the control plot. As is standard practice, the commercial plot is treated; and this should eliminate the mites. For the assessment, leaves from the lower, middle and upper portions of the bines are taken from the center of both plots. The corresponding infestation index (BI) is calculated based on the number of spider mites and their eggs. In addition, the beneficial insects, i.e. the insects and mites that prey on spider mites and their eggs, are also counted.

At the end of the season, a test harvest of both plots is carried out in one, two, or three of the most interesting gardens of each variety. Yields per hectare, alpha acid contents, and weights, as well as the cone quality are determined. The data obtained in this way is then statistically evaluated and examined for possible differences compared to the controls.

Results

Due to the humid weather with few hot days in 2021, the first year of the project, spider mite infestations were only minimal. In six of the ten HKS gardens, the number of spider mites in the control plot did not differ significantly from that in the test plot (see table). However, in the HKS garden, both plots did not reach the treatment threshold (BI = 0.5). At HTR gardens, seven gardens exceeded the treatment threshold and had higher BI in the control plots, and at SSE there was only one site where this was the case. In Tettnang, the BI in a test garden differed significantly, although there, the BI in the test plot was higher. One test harvest was carried out for each variety. No loss of yield could be determined, only the harvested HTR garden showed a loss in quality of the cones.

The second year of the project (2022) was ideal for spider mites. Because of the persistent dryness and heat, the pests were able to multiply quickly, and the infection pressure was high. There were ponly in three HKS gardens without a significant difference in BI between the two plots, although in these too the treatment threshold was exceeded towards the end of the season. In the HTR gardens, only two test gardens were spared from major spider mite infestations. There was no significant difference between plots for SSE in one garden, although in this garden both plots exceeded the treatment threshold. In Tettnang, there was a similar situation. Only one garden was largely spared from the spider mite. At the end of the season, two gardens of each variety were harvested in the Hallertau and one garden in Tettnang. The two harvested HTR gardens and one of the SSE gardens suffered yield losses. The subsequent cone assessment showed that even the regular plots were not completely free of spider mites, which is why the quality of the cones in all harvested test gardens suffered from the strong spider mite pressure of that year, both in the control and in the regular plots.

A wet, cold spring usually does not offer good starting conditions for the common spider mite. This is why 2023 was the year with the lowest spider mite infestation of the last five years (source: Hopfenring). For our project, this meant that the treatment threshold and a significant difference between the control and regular plots were reached in only one HKS garden, two HTR gardens, and one SSE and one TET garden. In the years before, the decision as to which garden would be harvested was made on the penultimate assessment date and took into account the extent to which there were differences in infestation levels between the two plots. This year, mainly test gardens were selected that had a heavy infestation in the previous year and had already been harvested in 2022. The only exception was Tettnang, where the garden there that had been harvested in previous years had no spider mite infestation whatsoever. No yield loss as a result of spider mites was found in any of the experimental harvests.

Finally, it should be mentioned that the data (Table 24) clearly shows that an increased spider mite infestation in a plot in one year does not mean that a high spider mite infestation will also occur in the following year.

Table 24: Differences in the infestation index (BI) between control and regular practice plots of all InduResi locations over the past three years. Text colored green means that there is a significant difference in BI between the two plots, but that both values are below the treatment threshold. Text colored red means that there is no significant (n.s.) difference between the two plots, but the treatment threshold is exceeded in both plots. Bold boxes mark locations where a trial harvest was conducted.

	Year		
Location	**2021**	**2022**	**2023**
HKS 01	K > P *** (X^2 (1) = 28.01; p < 0.001)	K > P *** (X^2 (1) = 65.25; p < 0.001)	n.s.
HKS 02	n.s.	K > P *** (X^2 (1) = 12.01; p < 0.001)	n.s.
HKS 03	n.s.	K > P *** (X^2 (1) = 114.58; p < 0.001)	K > P *** (X^2 (1) = 11.01; p < 0.001)
HKS 04	K > P * (X^2 (1) = 5.23; p = 0.022)	n.s.	n.s.
HKS 05	K > P *** (X^2 (1) = 37.04; p < 0.001)	n.s.	K > P ** (X^2 (1) = 6.95; p = 0.008)
HKS 06	**K > P *** (X^2 (1) = 34.53; p < 0.001) ▶**	K > P *** (X^2 (1) = 110.55; p < 0.001)	n.s.
HKS 07	K > P * (X^2 (1) = 6.15; p = 0.013)	**K > P *** (X^2 (1) = 69.32; p < 0.001) ▶**	**K > P ** (X^2 (1) = 6.70; p = 0.009) ▶**
HKS 08	n.s.	**K > P *** (X^2 (1) = 38.20; p < 0.001) ▶**	n.s.
HKS 09	K > P *** (X^2 (1) = 29.67; p < 0.001)	K > P *** (X^2 (1) = 13.93; p < 0.001)	n.s.
HKS 10	n.s.	n.s.	n.s.
HTR 01	K > P * (X^2 (1) = 6.20; p = 0.013)	**K > P *** (X^2 (1) = 79.26; p < 0.001) ▼**	**n.s. ▶**
HTR 02	K > P * (X^2 (1) = 4.47; p = 0.035)	K > P *** (X^2 (1) = 41.65; p < 0.001)	K > P ** (X^2 (1) = 10.51; p = 0.001)
HTR 03	n.s.	K > P *** (X^2 (1) = 20.48; p < 0.001)	n.s.
HTR 04	n.s.	K > P *** (X^2 (1) = 46.40; p < 0.001)	n.s.
HTR 05	K > P ** (X^2 (1) = 7.72; p = 0.006)	K > P *** (X^2 (1) = 52.34; p < 0.001)	K > P * (X^2 (1) = 6.37; p = 0.012)
HTR 06	n.s.	n.s.	n.s.
HTR 07	K > P ** (X^2 (1) = 9.86; p = 0.002)	K > P *** (X^2 (1) = 16.80; p < 0.001)	K > P ** (X^2 (1) = 7.67; p = 0.006)
HTR 08	K > P *** (X^2 (1) = 30.85; p < 0.001)	K > P *** (X^2 (1) = 11.26; p < 0.001)	n.s.
HTR 09	**K > P *** (X^2 (1) = 142.27; p < 0.001) ▶**	**K > P *** (X^2 (1) = 21.18; p < 0.001) ▼**	**K > P * (X^2 (1) = 4.72; p = 0.030) ▶**
HTR 10	K > P *** (X^2 (1) = 49.44; p < 0.001)	n.s.	n.s.
SSE 01	K > P *** (X^2 (1) = 12.49; p < 0.001)	K > P *** (X^2 (1) = 21.57; p < 0.001)	n.s.
SSE 02	n.s.	K > P *** (X^2 (1) = 16.07; p < 0.001)	K > P *** (X^2 (1) = 12.15; p < 0.001)
SSE 03	n.s.	K > P *** (X^2 (1) = 21.28; p < 0.001)	n.s.
SSE 04	n.s.	**n.s. ▼**	n.s.
SSE 05	**K > P *** (X^2 (1) = 11.10; p < 0.001) ▲**	**K > P *** (X^2 (1) = 107.11; p < 0.001) ▶**	**n.s. ▶**
SSE 06	n.s.	K > P ** (X^2 (1) = 8.64; p = 0.003)	n.s.
TET 01	**P > K ** (X^2 (1) = 9.36; p = 0.002) ▶**	**n.s. ▶**	n.s.
TET 02	n.s.	n.s.	n.s.
TET 03	n.s.	K > P *** (X^2 (1) = 23.66; p < 0.001)	n.s.
TET 04	K > P ** (X^2 (1) = 9.00; p = 0.002)	K > P * (X^2 (1) = 4.61; p = 0.032)	n.s.
TET 05	n.s.	K > P *** (X^2 (1) = 55.13; p < 0.001)	**K > P *** (X^2 (1) = 19.20; p < 0.001) ▶**

Abbreviations: K = control, P = practice, X2 = chi-square (the higher the chi-square value, the greater the difference between the plots)
Symbols: ▶ no difference between control and practice plots ▼ loss of yield in control plot ▲ higher yield in control plot: *** p < 0.001, ** p < 0.01, *p < 0.05, n.s. = not significant (Cumulative Link Mixed Models)

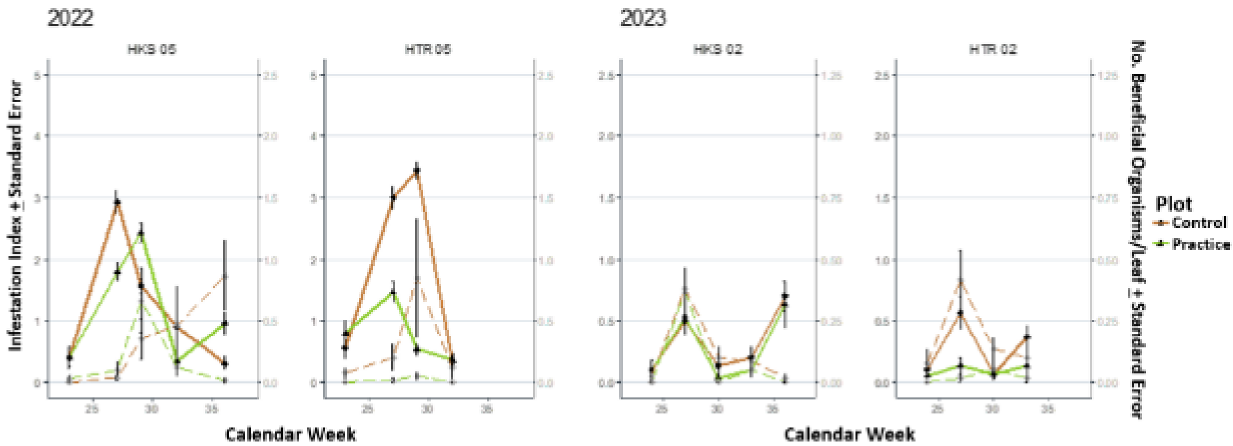


Figure 87: The development of the infestation index over the growing season is shown by a copper-colored line for the control plot and a green line for the regular plot. The dashed lines represent the number of beneficial insects per leaf over the same period of time

During the past two years, at one location each, we have observed that beneficial insects in the control plot have independently kept the spider mite population in check (Figure 87). In 2022, we found the larvae and pupae of the black ladybird *Stethorus punctillum*, predatory mite eggs, and flower bugs (*Orius sp.*; Figure 88) in the spider mite assessments. At these two locations (varieties HKS and HTR), the beneficial insects managed to reduce the number of spider mites to the same low level as in the regular plot. The pupae of the black ladybird do not eat any food themselves, but they are evidence that the larvae were there before. The only site in our project that reached the treatment threshold early in the growing season in 2023 also had numerous beneficial insects right from the start that kept the spider mites under control. In mid-June there were already a lot of predatory mite eggs and three weeks later there were also numerous larvae of the black ladybird beetle.

*Figure 88: Important beneficial insects in the control of the common spider mite. **A:** Larva of the black spherical ladybird* Stethorus punctillum, ***B:** Pupa of the black spherical ladybird, **C:** Black spherical ladybird and **D:** Nymphs and adult of the flower bug* Orius sp. *Image sources (CC BY-SA 2.0): **A** Maria Justamond, **B** Jack Kelly Clark, **C** Gilles San Martin, **D** Koppert Biological Systems.*

9 Publications and Technical Information

9.1 Public relations overview

	Number		Number
Internet contributions	4	Memberships	42
Posters	7	Internships	4
Seminars, symposiums, specialist conferences, workshops	6	Lectures	126
Guided tours, excursions	45	Radio and TV	8
Expert assessments and opinions	4	Publications	34
Working group meetings	1		

9.2 Publications

9.2.1 Working group meetings

Date	Event	Location	Target Group
March 1, 2023	Meeting: "Green Booklet Hops"	Hüll	Staff responsible for hops in federal states with hop cultivation

9.2.2 Education, training, and further education

Date	Event	Location	Target Group
February 27, 2023	Hop irrigation	Hüll	Hop growers
March 30, 2023	Round table plant protection in organic hop cultivation	Hüll	Organic hop growers
June 7, 2023	Advanced plant breeding: Breeding of clonally-propagated crops	Technical University of Munich	Master’s students
June 25 to June 29, 2023	Meeting of the Scientific and Technical Commission (WTK) of the International Hop Growing Office (IHB)	Ljubljana, Slovenia	International hop scientists
July 12, 2023	Opening of the “Hops and Biodiversity” theme trail	Eichelberg	Association and press representatives
July 25 to July 26, 2023	Summer excursion of the Organic Hops Working Group	Mühlviertel, Austria	Organic hop growers from Austria, Czechia, Germany, and France

9.2.3 Guided tours, excursions

Datum	Name	Subject/Title	Guest(s)	No.
January 16, 2023	Lutz, A.	Aroma rating of varieties	Brewery chief and master brewer, Becks Bremen (ABInBev)	4
January 16, 2023	Lutz, A.; König, W.; Dr. Kammhuber, K.	Hop breeding, analytics	Brewing students, Technical University of Munich (TUM)	25
January 16, 2023	Dr. Gresset, S.; Dr. Kammhuber, K.; Dr. Weihrauch, F.	An introduction to the Hüll Research Center focusing on hop breeding, ingredients in hops, and organic plant cultivation in hops	Agriculture technical students from TH Coligne *(Cologne University of Applied Sciences)*	25
January 16, 2023	Münsterer, J.	Insights into hop production at a farm operation	Agriculture technical students from TH Coligne *(Cologne University of Applied Sciences)*	25
February 23, 2023	Lutz, A.	Analytics, plant protection, organic hop cultivation, breeding	New employees in the House of Hops and in Hüll	8
March 8, 2023	Lutz, A.; Dr. Kammhuber K.; Euringer S.; Dr. Weihrauch F., König W.	Hop breeding, analytics, conventional and ecological plant protection	NaturFreunde Pfaffenhofen *(Friends of Nature Pfaffenhofen)*	40
May 16, 2023	Dr. Gresset, S.; Lutz, A.; Dr. Kammhuber, K.	Guided tour of the Hop Research Center	Suntory Brauerei	5
June 13, 2023	Lutz, A.; Dr. Gresset, S.	All areas of hop research	Employees of Bundessortenamt (BSA) *(Federal Plant Variety Office)*	10
June 13, 2023	Lutz, A.; Dr. Gresset, S.; Dr. Kammhuber K.; Stampfl R.	All areas of hop research	Test technician at LfL BaySG (Bavarian State Farms)	20
June 13, 2023	Lutz, A.; Dr. Gresset, S.; König, W.	Hop breeding and cultivation	Asahi Europe	4
June 15, 2023	Lutz. A.; Weihrauch F.	Organic hop cultivation	Students at BOKU Wien *(University of Natural Resources*	20

Datum	Name	Subject/Title	Guest(s)	No.
			and Life Sciences, Vienna)	
June 15, 2023	Lutz, A.; Dr. Gresset, S.; König, W.	Breeding, plant protection, general hop cultivation	BOKU *(University of Natural Resources and Life Sciences, Vienna)*	15
June 19, 2023	Lutz, A.; Stampfl, R.	General hop cultivation, plant protection, breeding	LWK *(Plant Protection Office)* fruit growing and testing specialist groups	20
June 22, 2023	Lutz, A.; Portner, J.	Irrigation and hop breeding	Water Management Office	5
June 23, 2023	Lutz, A.; Dr. Gresset, S.; Münsterer, J.; Fischer, E.; Lutz, K.; Weiß, F.; Baumgartner, A.; Dr. Krönauer, C.; Dr. Kammhuber, K.; Stampfl, R.	All areas of hop research	BarthHaas	120
July12, 2023	Lutz, A.	Guided tour of the hop research center	Mr. Skiba, internship supervisor at FOS Scheyern *(Scheyern Vocational High School)*	1
July 14, 2023	Dr. Gresset, S.	*Peronospora* prognosis model	LWS	12
July 19, 2023	Dr. Doleschel P.; Lutz A.	Guided tour of the hop research center, hop breeding, beer tasting	KG Pflanzenproduktion (KG Plant Production)	20
July 21, 2023	Weihrauch F.	Guided educational trail “Hops and Biodiversity”	Ring junger Hopfenpflanzer (Young Hop Growers e.V.)	70
July 24, 2023	Lutz, A.; Dr. Gresset S.; Portner, J.; Euringer S.	Guided tour of the hop research center, focusing on irrigation, plant protection and hop breeding	Andreas Mehltretter and employees	4

Datum	**Name**	**Subject/Title**	**Guest(s)**	**No.**
July 26, 2023	Dr. Gresset, S.	Organic hop cultivation	LWS	15
July 28, 2023	Dr. Gresset, S.	The Spalt hop growing area with hop irrigation	LWS	10
August 1, 2023	Weihrauch F.	Guided educational trail “Hops and Biodiversity”	Employees of the Hop Museum	15
August 2, 2023	Lutz, A.; Dr. Gresset S.	Hop breeding and new hop varieties	BayWa hop department	20
August 4, 2023	Lutz, A.	Guided tour of the Hüll Hop Research Center	Bulldog friends	20
August 8, 2023	Lutz, A.	Guided tour of the hop research center, hop breeding	Yakima Chief	4
August 14, 2023	Lutz, A.	Guided tour of the Hüll Hop Research Center and hop breeding	Tettnang hop planters	40
August 21, 2023	Lutz, A.	New high alpha variety Titan	BarthHaas hop growers	40
August 22, 2023	Lutz, A.	Guided tour of the hop research center with a focus on hop breeding	Brewing students at the TU Berlin (Technical University of Berlin)	35
August 23, 2023	Lutz, A.	Hop research and hop breeding	Hop Quality Group	3
August 25, 2023	Stampfl, R.	General hop cultivation, plant protection, breeding	Hop farmer from Argentina	2
August 26, 2023	Lutz, A.	Hop research and hop breeding	Home brewers	20
September 1, 2023	Stampfl, R.	Everything about hop growing	Lower Saxony State Chamber	8
September 4, 2023	Lutz, A.	Beer tasting	VDLUFA *(Association of German Agricultural Investigation and Research Institutes)*	50
September 4, 2023	Lutz, A.; Münsterer, J.	Experimental cultivation	HVG e. G. *(HVG Hop Processing Group)*	10
September 7, 2023	Lutz, A.	Everything about hop breeding	Agricultural traineeship, born in 1982	35
September 8, 2023	Lutz, A.	Hop research and hop breeding	Apprentices of the Meisels Brewery	20

Datum	Name	Subject/Title	Guest(s)	No.
September 22, 2023	Lutz, A.	Hop breeding and hop grading	Brewers	25
September 25, 2023	Lutz, A.	Hop research and hop breeding, beer tasting	Trade association	20
September 26, 2023	Lutz, A.	Rating of interesting breeding lines	Dan Carey, New Glarus Brewing Company	2
October 11, 2023	Lutz, A.	Hop research and hop breeding	Sapporo Brauerei	4
October 19, 2023	Lutz, A.; König, W.	Hop research and hop breeding	Food chemists	40
October 25, 2023	Lutz, A.	Guided tour of the hop research center for hop production in general	Architecture students at TUM (Prof. Niklas Fanelsa)	30
December 12, 2023	Lutz, A.	Hop breeding and hop grading	Hobby brewer and hop grower	25
December 13, 2023	Lutz, A.; Dr. Kammhuber, K.; König, W.	Guided tour of the hop research center, hop breeding and hop grading	Brewing students from the Doemens Academy	50

9.2.4 Internet contributions

Author	Title	Target Group
Fuß, S.	Dry matter and alpha acid monitoring for the most important hop varieties	Hop growers
Portner, J.	The Bavarian State Institute for Agriculture (LfL) and the Society for Hop Research (GfH) are presenting hops at the State Horticultural Show in Freyung	General public
Portner, J.	Hop growing information and warning service reports	Hop growers
Portner, J.	Production costs in hop cultivation	Hop growers

9.2.5 Posters

Author	Title	Event/Location	Organizer
Dr: Kammhuber, K.	The valuable ingredients of hops, their meaning and analysis	State Garden Show, Freyung	StMELF, LWG
Lutz, A.	Objectives in breeding new hop varieties	State Garden Show, Freyung	StMELF, LWG
Lutz, A.	Breeding a new Hüll hop variety	State Garden Show, Freyung	StMELF, LWG

Author	Title	Event/Location	Organizer
Lutz, A.	Breeding progress – The new Hüll aroma and high-alpha varieties	State Garden Show, Freyung	StMELF, LWG
Lutz, A.	The new Hüll aroma hop varieties	State Garden Show, Freyung	StMELF, LWG
Portner, J.	Yield stabilization in hops and positive environmental effects through irrigation and fertigation	LfL hop growing training trips, Schafhof	LfL-IPZ 5
Portner, J.	Climate change and specialty hops	LfL hop growing training trips, Schafhof	LfL-IPZ 5

9.2.6 Radio and TV

Broadcast Date	People	Title	Series	Channel
April 13, 2023	Portner, J.	Energy gain with hop photovoltaics	Evening show	BR
May 5, 2023	Dr. Gresset, S.; Lutz, A.	Start of the season at the Hop Research Center Hüll	Regionalstudio Pfaffenhofen	INTV
July 13, 2023	Fuß, S.	Hops and energy: Double harvest thanks to photovoltaics the poles	Abendschau / BR24	BR
September 1, 2023	Lutz, A.	Interview regarding historical development of hop cultivation in Germany	Beer blog by Franz D. Hofer	A Tempest in a Tankard
September 8, 2023	Portner, J.	What good is organic hop wire?	Our country	BR
September 13, 2023	Portner, J.	Hop garden without plastic: Search for organic twine wire is ongoing	Evening Show/BR24	BR
October 12, 2023	Lutz, A.	Hops in times of climate change	Regional News	BR
October 17, 2023	Lutz, A.; Kaindl, S.	Lost hops and malt? Europe's beers in danger	Arte Regards	ARTE

9.2.7 Publications

Publications
Fuß, S. (2023): Pflanzenstandsbericht April 2023. Hopfen-Rundschau, 74. Jahrgang; Ausgabe 05/2023, Hrsg.: Verband Deutscher Hopfenpflanzer e. V., 147
Fuß, S. (2023): Pflanzenstandsbericht August 2023. Hopfen-Rundschau, 74. Jahrgang; Ausgabe 09/2023, Hrsg.: Verband Deutscher Hopfenpflanzer e. V., 289

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Fuß, S. (2023): Pflanzenstandsbericht Juni 2023. Hopfen-Rundschau, 74. Jahrgang; Ausgabe 07/2023, Hrsg.: Verband Deutscher Hopfenpflanzer e. V., 209
Fuß, S. (2023): Pflanzenstandsbericht Mai 2023. Hopfen-Rundschau, 74. Jahrgang; Ausgabe 06/2023, Hrsg.: Verband Deutscher Hopfenpflanzer e. V., 180
Krönauer, C. (2023): CBCVd - Citrus bark cracking viroid im Hallertauer Hopfen. BrauIndustrie, Nr. 5 Mai 2023 108. Jahrgang, 16 - 17
Kammhuber, K. (2023): Die Möglichkeiten der Nahinfrarotreflektions-(NIR)-Spektroskopie zur lösungsmittelfreien, nachhaltigen alpha-Säurenbestimmung, Hopfenrundschau International, Jahresausgabe 2023/2024, Hrsg.: Verband Deutscher Hopfenpflanzer e.V., 84-89
Kammhuber, K. (2023): Ergebnisse von Kontroll- und Nachuntersuchungen für Alphaverträge der Ernte 2022, Hopfenrundschau, 08-74.Jahrgang, Hrsg.: Verband Deutscher Hopfenpflanzer e.V., 232-235
Krönauer, C. (2023): Workshop und Abendvortrag zum Citrus bark cracking viroid 2023. Hopfen-Rundschau, 05/2023, 74. Jahrgang, Hrsg.: Verband Deutscher Hopfenpflanzer e.V., 142 - 143
Lusebrink, I., Weihrauch, F. (2023): Herbivore-induced resistance of hop plants against spider mites – state of play. Proceedings of the Scientific-Technical Commission, IHGC, Proceedings of the Scientific-Technical Commission of the International Hop Growers´ Convention, Ljubljana, Slovenia, 25-29 June 2023, 34 - 34
Lutz, A., Kammhuber, K. (2023): New variety of hop: Titan - Optimised Resistance. Brauwelt, 2/23, Journal for the Brewing and Beverage Industry, Hrsg.: Brauwelt International, 73 - 76
Lutz, A., Kneidl, J., Ismann, D., Büttner, B., Seidenberger, R., Albrecht, T., Gresset, S. (2023): Optimizing hop production sustainability by breeding. Proceedings of the Scientific-Technical Commission, IHGC, Proceedings of the Scientific-Technical Commission of the International Hop Growers´ Convention, Ljubljana, Slovenia, 25-29 June 2023, 16 – 17
Lutz, K., Euringer, S. (2023): Hopfenwelke - Auf der Suche nach einem innovativen Krankheitsmanagement. BrauIndustrie, 2023/1, Hrsg.: Verlag W. Sachon, 20 - 22
Lutz, K., Euringer, S.; Lutz, A.; Fuß, S. (2023): Identification of hop cultivars tolerant to Verticillium wilt - Verticillium wilt in hops. Proceedings of the Scientific-Technical Commission, IHGC, Hrsg.: Scientific-Technical Commission of the International Hop Growers' Convention, 77 - 79
Münsterer, J. (2023): Innovationen zur Optimierung der Hopfen-Bandtrockner. Hopfenrundschau International, 2023/2024, Hrsg.: Verb. Deutscher Hopfenpflanzer e. V., 44 - 49
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Stampfl, R. (2023): Pflanzenschutztagung im Hopfenbau. Hopfenrundschau International, 2023/2024, Hopfenrundschau International, Hrsg.: Deutscher Hopfenpflanzerverband e. V., 14 - 18
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10 Our Team

The staff of the State Institute for Agriculture - Institute for Plant Production and Plant Breeding - Hüll / Wolnzach / Freising, in 2023 (AG = working group):

IPZ 5

Coordinator: Director, LfL, Dr. Peter Doleschel

Alexandra Hertwig
Birgit Krenauer

IPZ 5a

AG Hopfenbau, Produktionstechnik
(*Hop Cultivation, Production Technology*)
Managing Director: LD Johann Portner

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IPZ 5b

AG Pflanzenschutz im Hopfenbau
(*Plant Protection in Hop Cultivation*)
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IPZ 5c

AG Züchtungsforschung Hopfen
(*Hop Breeding Research*)
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Anton Hartung
LTA Brigitte Haugg
Agr.-Techn. Daniel Ismann
LTA Jutta Kneidl
LR Anton Lutz
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IPZ 5d

AG Hopfenqualität und -analytik
(*Hop Quality and Analytics*)
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IPZ 5e

AG Ökologische Fragen des Hopfenbaus
(*Ecological Issues in Hop Cultivation*)
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