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Annual Report for Harvest Year 2024

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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Foreword

In light of the increasing political tensions in the world, climate protection has taken a back seat. However, climate change will be one of the greatest challenges for hop cultivation in the future. Extreme weather conditions, such as long heat waves with numerous dry days, as well as extreme rainfall, hail, and storms, will become more common. With the planned establishment of an irrigation association in the Hallertau region, we are well on our way to counteract advancing climate change. But breeding is also required here. The new, modern, and innovative varieties bred at the Hop Research Center, in Hüll, in the Hallertau are already significantly more stable year-over-year in terms of yield and alpha acid content, even when faced with extreme weather fluctuations. It is now up to the brewers to put them to use.

The good harvest of 2024 coincides with high stock levels, making acreage reductions unavoidable. At 7,900 hectares, the Herkules variety now accounts for 39% of the total Hallertau acreage. The Titan acreage has tripled to more than 300 hectares, while the cultivation of Perle and Hallertauer Tradition is declining.

We have only the Earth as our planet on which to live. Therefore, we must use all resources sustainably to keep the Earth habitable and livable for future generations. The Hop Research Center makes many important contributions to the topic of sustainability in hop cultivation. For example, the IPZ 5a working group has been working for many years on optimizing hop kilning and has succeeded in significantly reducing CO2 emissions. A new project that will last five years will develop the fundamentals for building up humus in hop gardens.

Pesticides approvals are becoming more and more difficult to obtain. Therefore, it is imperative that we developed alternative, ecological strategies for plant protection. The IPZ 5e working group has already achieved some success in this area.

This annual report provides a comprehensive and detailed account of the work at the Hop Research Center. Since 2002, the annual reports have been available on our website not only in German but also in English. This is significant because creativity, imagination, and innovations arise from the intellectual exchange of scientists from all around the world; and this annual report intends to make its contribution to this international endeavor. We would like to take this opportunity to express our sincere thanks to the entire staff of the Center in Hüll.

Dr. Michael Möller	Dr. Peter Doleschel
Chairman of the Board	Head of the Institute of
Society for Hop Research	Crop Science and Plant Breeding

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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 acreage 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	1,040	19.84
2005	1,611	10.66	2024	1,009	20.11

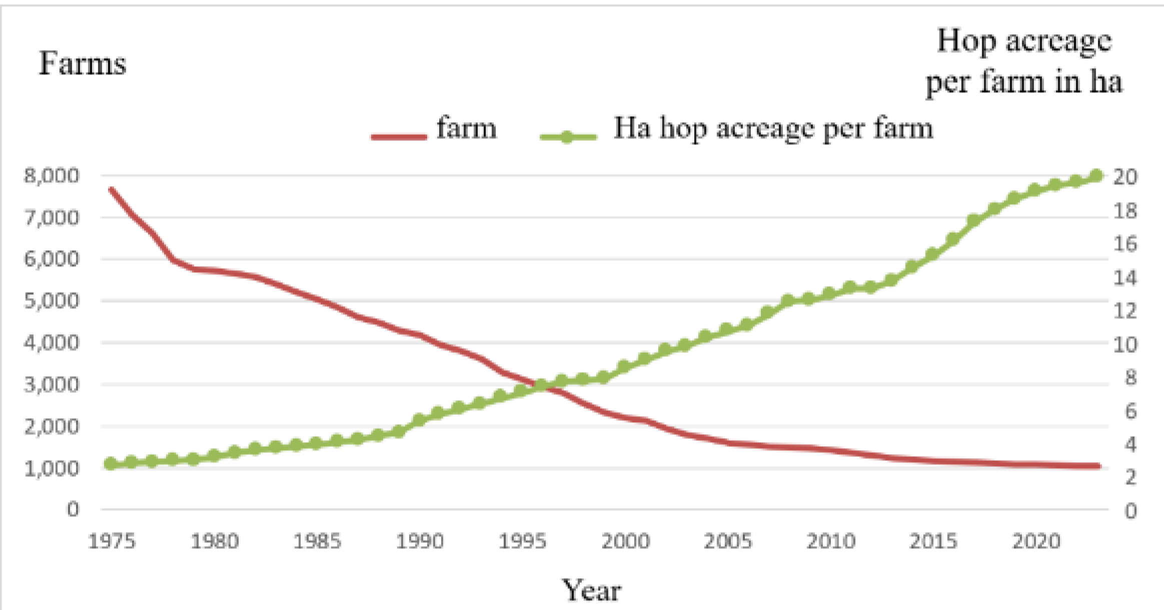


Figure. 1: Number of hop farms and their acreages in Germany

Table 2: 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 2024 to 2023				Increase/ Decrease 2024 to 2023			
	2023	2024	ha	%	2023	2024	Farm	%	2023	2024
Hallertau	17,129	16,815	- 314	- 1.8	841	814	- 27	- 3.2	20.37	20.66
Spalt	403	396	- 7	- 1.7	44	43	- 1	- 2.3	9.16	9.21
Tettnang	1,517	1,528	12	0.7	124	121	- 3	- 2.4	12.23	12.63
Baden, Bitburg, Rhine-Palatinate	18	17	- 1	- 3.4	1	1	± 0	± 0	17.70	17.10
Elbe-Saale	1,563	1,532	- 30	- 2.0	30	30	± 0	± 0	52.09	51.07
Germany	**20,629**	**20,289**	**- 340**	**- 1.5**	**1,040**	**1,009**	**- 31**	**- 3.1**	**19.84**	**20.11**

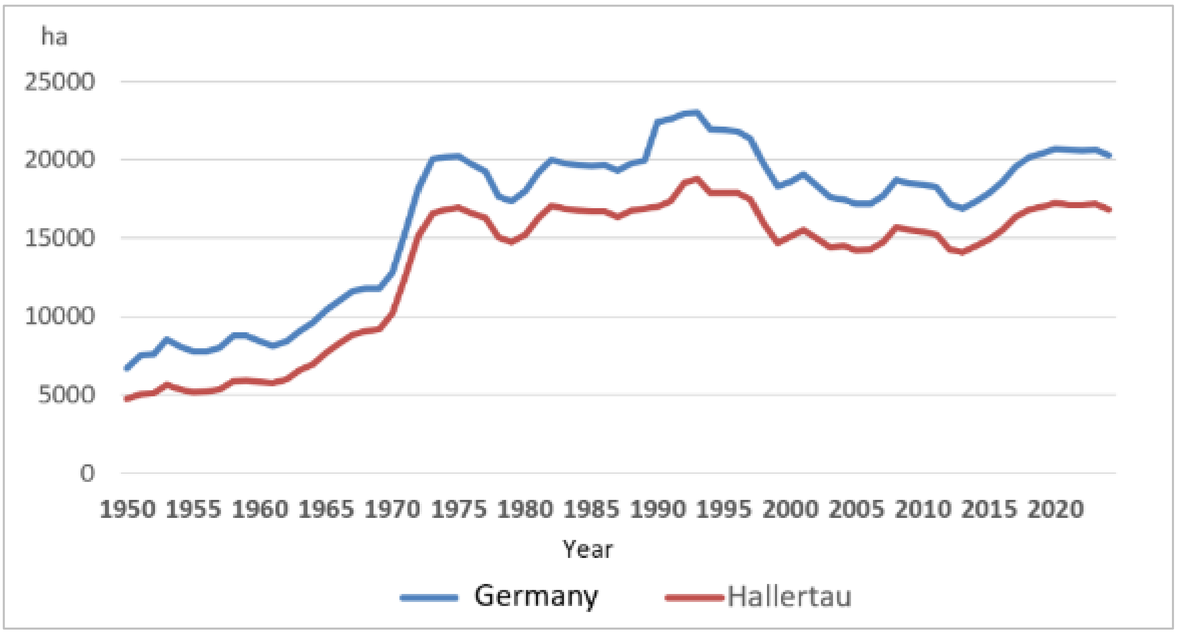


Figure 2: Hop cultivation areas in Germany and in the Hallertau

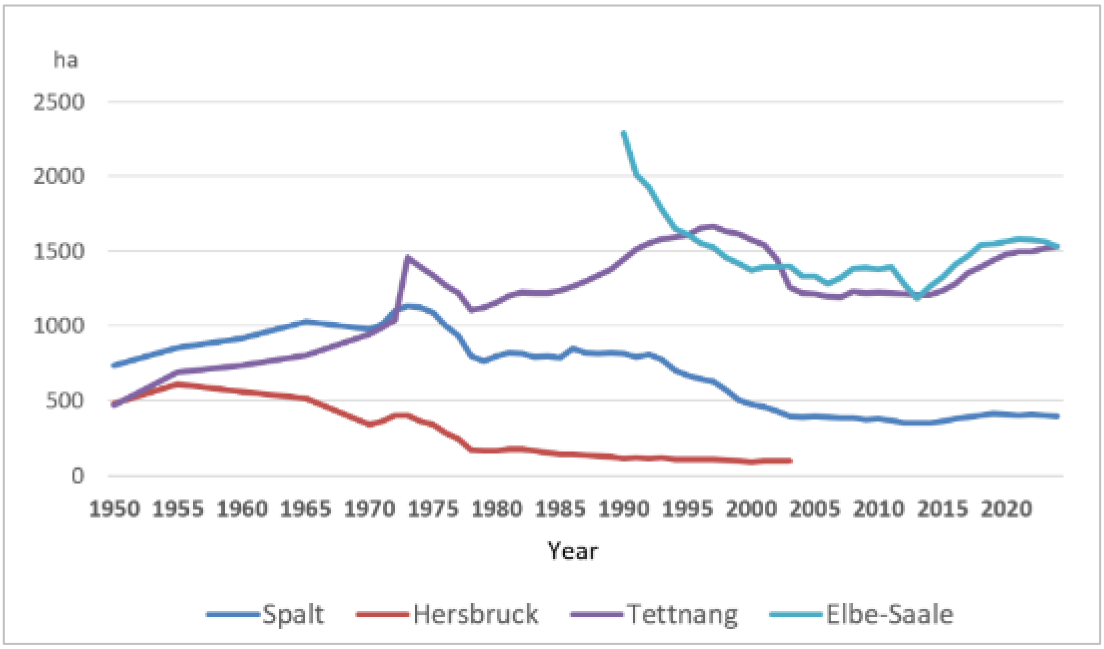


Figure 3: Hop cultivation areas in the Spalt, Hersbruck, Tettnang, and Elbe-Saale areas

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

1.1.2 Hop Varieties

The **hop cultivation area** in Germany decreased by only 340 ha, or 1.7%, in 2024. It is now **20,289** ha.

The share of **aroma varieties** declined again significantly by 815 hectares to 47.1%. For the first time in the history of German hop cultivation, aroma hop production was thus lower than bitter hop production in terms of area. With 37 different aroma varieties on 9,559 hectares, the statistics nevertheless demonstrate great diversity, even down to the 16 varieties with the smallest acreage, which cover a combined 70 hectares, or 0.7% of all aroma hop cultivation. Most of the major aroma varieties lost area. The largest area declines in this segment were for Perle (-375 hectares) and Hallertauer Tradition (-241 hectares). There were also significant clearings of Saphir (-38 hectares), Spalter Select (-29 hectares), Akoya (-28 hectares), Mandarina Bavaria (-27 hectares), and Hallertau Blanc (-21 hectares). The newer aroma varieties Tango (26 ha) and Amira (11 ha), as well as the old Hersbrucker Spät (8 ha) recorded slight increases in area.

The **bitter hop acreage** increased again significantly by 475 hectares to 10,730 hectares or 52.9%. Acreages of the older bitter varieties Hallertauer Magnum (-150 hectares), Hallertauer Taurus (-31 hectares), and Nugget (-10 hectares) declined again. The high-alpha varieties Herkules (419 hectares), Titan (228 hectares), and Polaris (27 hectares), on the other hand, continued to gain acreage. This makes Herkules undisputedly the main hop variety cultivated in Germany. It accounts for 39% (7,917 hectares) of total acreage.

Table. 3: Hop varieties in the German growing regions in hectares in 2024

Aroma Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Aischgründer Historia	0					**0**	**0.0**	**0**
Akoya	81		5	16		**102**	**0.5**	**-28**
Amarillo	73			2		**75**	**0.4**	**-15**
Amira	12					**12**	**0.1**	**11**
Ariana	49	4	2			**56**	**0.3**	**2**
Aurum			4			**4**	**0.0**	**0**
Brewers Gold	12					**12**	**0.1**	**-2**
Brokat	1					**1**	**0.0**	**0**
Callista	28	1	8	17		**54**	**0.3**	**-2**
Cascade	54	5	1	3	1	**64**	**0.3**	**-1**
Chinook	0					**0**	**0.0**	**0**
Comet	1					**1**	**0.0**	**-4**
Diamant	12	9	0			**21**	**0.1**	**1**
Hallertau Blanc	73	3	12	3		**91**	**0.4**	**-21**
Hallertauer Gold	5	2				**7**	**0.0**	**0**
Hallertauer Mfr.	425	22	142	12		**601**	**3.0**	**-14**
Hallertauer Tradition	2,257	36	106	60	2	**2,461**	**12.1**	**-241**
Hersbrucker Pure	6	4				**10**	**0.0**	**8**
Hersbrucker Spät	767	7	0			**775**	**3.8**	**-10**
Hüll Melon	37	5	7			**49**	**0.2**	**1**
Lilly	0					**0**	**0.0**	**0**
Mandarina Bavaria	143	3	11	4		**160**	**0.8**	**-27**
Monroe	8		2			**10**	**0.1**	**-1**
Northern Brewer	68			107		**175**	**0.9**	**-17**
Opal	118	1	3			**122**	**0.6**	**-15**
Perle	2,438	39	141	236	6	**2,861**	**14.1**	**-375**
Relax	2					**0**	**0.0**	**-2**
Rottenburger			1			**1**	**0.0**	**0**
Saazer	3			151		**154**	**0.8**	**-2**
Samt	1					**1**	**0.0**	**0**
Saphir	218	17	41	16		**292**	**1.4**	**-38**
Smaragd (Emerald)	42	1	14			**57**	**0.3**	**-1**
Solero	7		3			**10**	**0.0**	**-1**
Sarachi Ace	0					**0**	**0.0**	**0**
Spalter	0	100				**100**	**0.5**	**-6**
Spalter Select	390	78	31			**499**	**2.5**	**-29**
Tango	81	1	3	3	0	**89**	**0.4**	**26**
Tettnanger			632			**632**	**3.1**	**-13**
Total (ha)	**7,410.63**	**341.03**	**1,168**	**630**	**9**	**9,559**	**47.1**	**-815**
Percentage (%)	**36.5**	**1.7**	**5.8**	**3.1**	**0.0**	**47.1**		**-4.0**

Bitter Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Eureka (EUE05256)	12					**12**	**0.1**	**6**
Halletauer Magnum	1,029	1		590		**1,620**	**8.0**	**-150**
Halletauer Merkur		2		2		**3**	**0.0**	**-3**
Halletauer Taurus	112	2	0	3		**116**	**0.6**	**-31**
Helios				5		**5**	**0.0**	**5**
Herkules	7,409	47	327	126	8	**7,917**	**39.0**	**419**
Hüller Bitter	1					**1**	**0.0**	**1**
Nugget	90		2			**91**	**0.5**	**-10**
Polaris	424		25	140		**588**	**2.9**	**27**
Record	1					**1**	**0.0**	**0**
Titan	279	2	2	38	0	**322**	**1.6**	**228**
Xantia	17					**17**	**0.1**	**1**
Others	32		4	0		**36**	**0.2**	**-20**
Total (ha)	**9,404.15**	**54.95**	**360**	**903**	**8**	**10,730**	**52.9**	**475**
Percentage (%)	**46.4**	**0.3**	**1.8**	**4.4**	**0.0**	**52.9**		**2.3**

All Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Total (ha)	**16,815**	**396**	**1.528**	**1,532**	**17**	**20,289**	**100.00**	**-340**
Percentage (%)	**82.9**	**2.0**	**7.5**	**7.6**	**0.1**	**100.0**		**-1.7**

1.2 Volumes, Yields, Alpha Acid Values

The **2024 hop harvest** in Germany totaled 46,536,301 kg (46,536 metric tons; MT), This is almost 13% more than the previous year's harvest of 41,234,230 kg (41,234 MT).

The **yield per hectare** was 2,294 kg/ha, some 295 kg/ha higher than in the previous year. This is considered an above-average yield.

The average **alpha acid contents** were good in 2024; and most varieties exceeded the poor results of the previous year. However, for most varieties, they were still below long-term averages. This means that despite the good 2024 harvest, at least the theoretical alpha acid yield potential was not fully realized. The largest share of alpha production in Germany came from Herkules with an average alpha acid value of 15.8%, which was only slightly below the long-term average. Herkules produced 3,656 t of alpha acid in 2024, accounting for two-thirds of the total German **alpha acid production** of about 5,391 MT (29% higher than the previous year).

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

	2019	2020	2021	2022	2023	2024
Yield kg/ha	2,374	2,264	2,321	1,670	1,999	2,294
Cultivated area in ha	20,417	20,706	20,620	20,605	20,629	20,289
Total harvest in kg	48,472,220	46,878,500	47,862,190	34,405,840	41,234,230	46,536,301
Ø Alpha-acid content in %	10.9	11.6	13.0	10.8	10.1	11.6
Total German alpha amount in MT	5,260	5,460	6,240	3,720	4,170	5,391

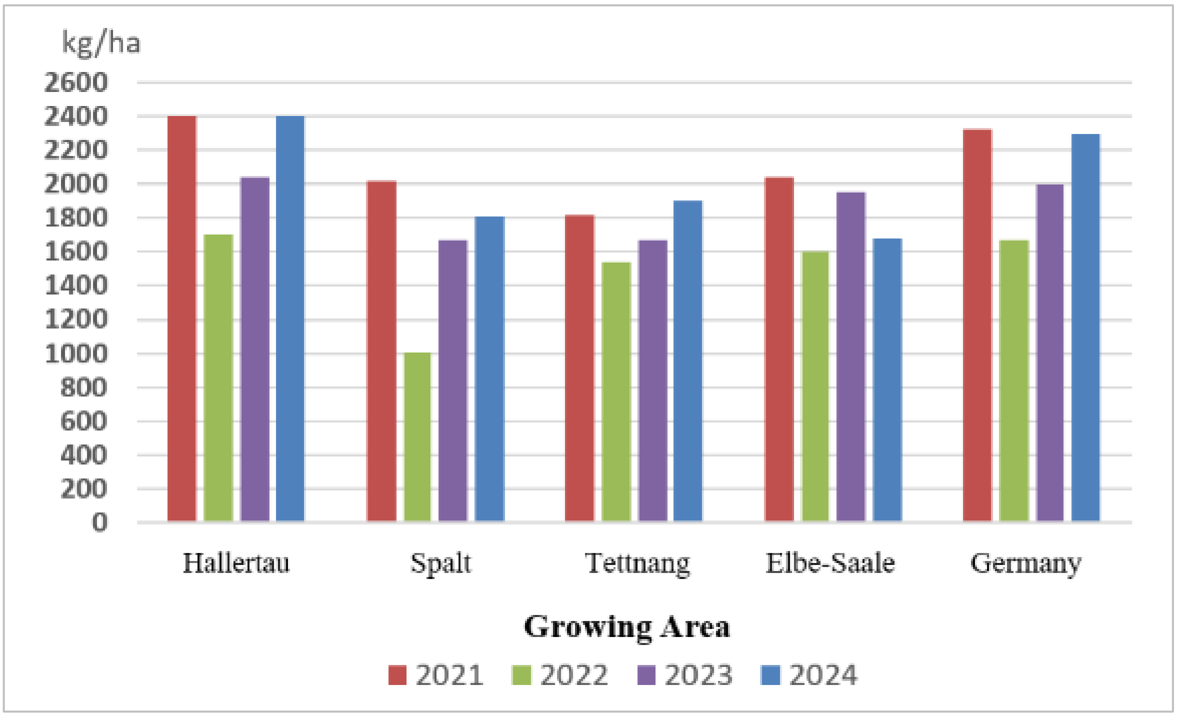
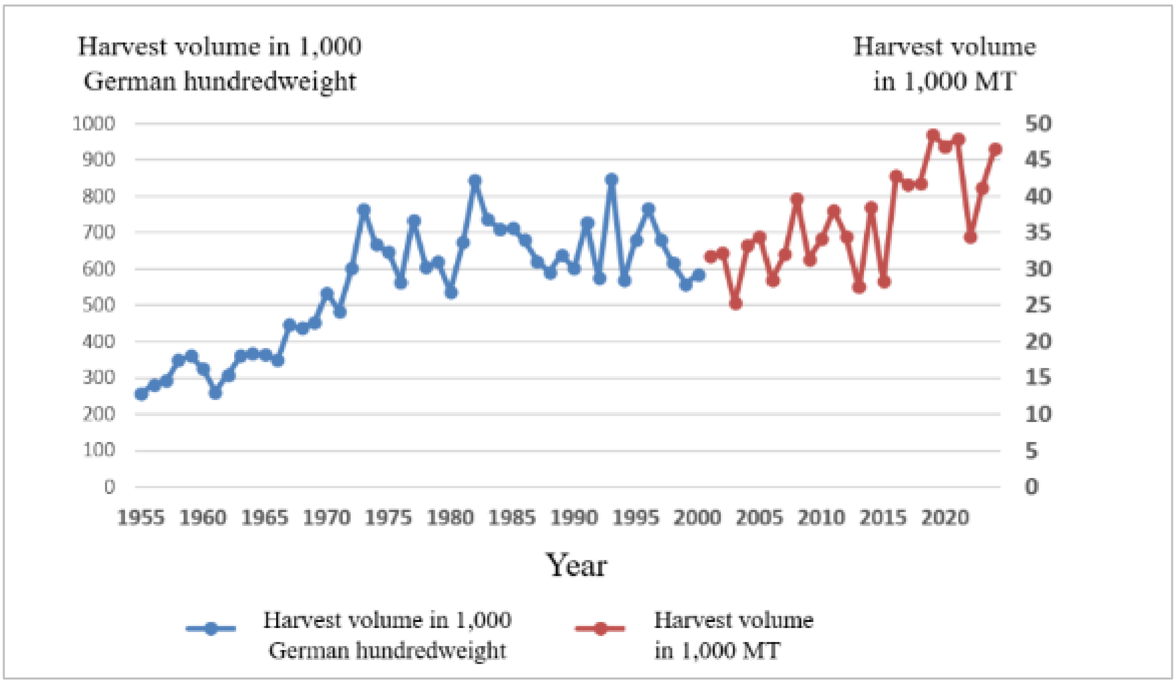
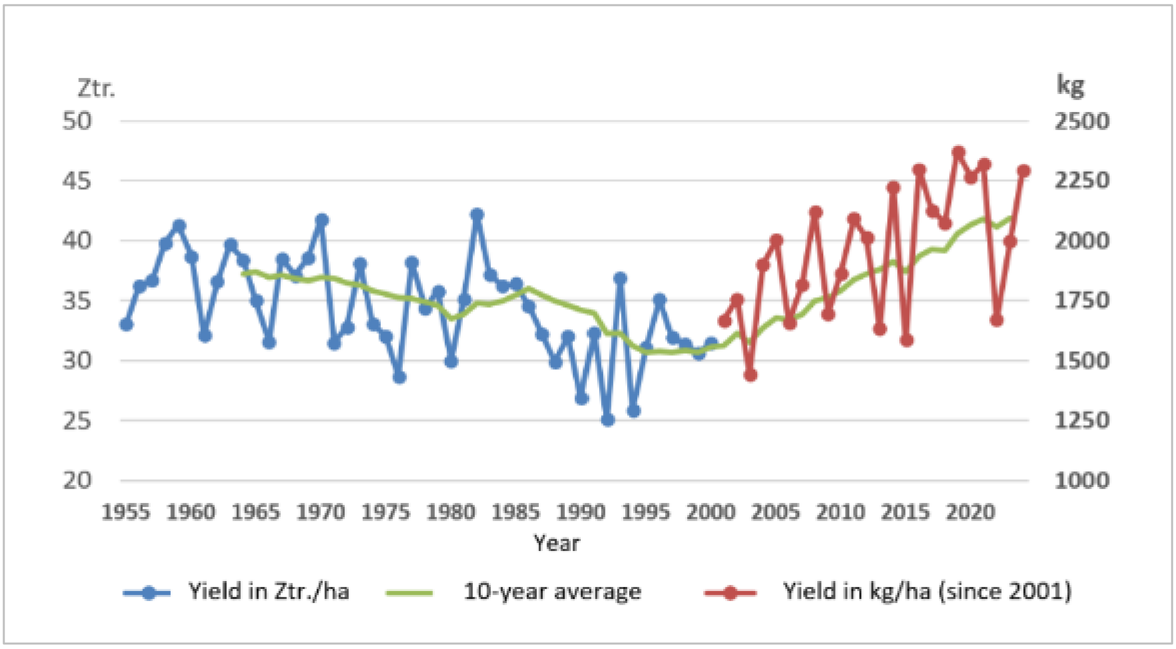


Figure 4: Average yields in the individual growing areas in kg/ha



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

Figure 5: Total harvest volume in Germany



Note: 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								
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Hallertau	2,383	2,179	2,178	2,441	2,338	2,400	1,704	2,040	2,397
Spalt	1,942	1,949	1,564	1,704	1,759	2,020	1,005	1,668	1,812
Tettnang	1,712	1,677	1,486	2,024	1,927	1,818	1,538	1,670	1,903
Bad. Rheinpf./ Bitburg	1,957	1,990	1,985	2,030	2,003	973	1,017	1,299	2,343
Elbe-Saale	2,020	2,005	1,615	2,150	1,906	2,038	1,704	1,956	1,677
∅ Yield/ha Germany (kg)	**2,299**	**2,126**	**2,075**	**2,374**	**2,264**	**2,321**	**1,670**	**1,999**	**2,294**
Total harvest Germany (MT)	42,766	41,556	41,794	48,472	46,879	47,862	34,406	41,234	46,536
Cultivated area Germany (ha)	18,598	19,543	20,144	20,417	20,706	20,620	20,605	20,629	20,289

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

Growing area/variety	2015	2016	2017	2018	2019	2020	2021	2022	2023	**2024**	**Ø 5 Year**	**Ø 10 Year**
Hallertau Hallertauer	2.7	4.3	3.5	3.6	4.1	4.5	5.2	3.1	2.9	**3.3**	**3.8**	**3.7**
Hallertau Hersbrucker	2.3	2.8	2.3	2.0	2.5	3.3	4.6	1.9	3.0	**2.5**	**3.1**	**2.7**
Hallertau Hall. Saphir	2.5	4.0	3.0	3.3	3.3	4.2	4.3	2.6	3.1	**3.2**	**3.5**	**3.4**
Hallertau Opal	5.9	7.8	7.2	6.4	7.3	8.5	8.7	6.1	6.7	**7.1**	**7.4**	**7.2**
Hallertau Smaragd	5.5	6.2	4.5	3.0	5.0	5.8	7.6	4.0	5.4	**4.5**	**5.5**	**5.2**
Hallertau Perle	4.5	8.2	6.9	5.5	6.7	7.4	9.0	4.9	6.0	**6.2**	**6.7**	**6.5**
Hallertau Spalter Select	3.2	5.2	4.6	3.5	4.4	5.2	6.4	3.3	4.7	**3.9**	**4.7**	**4.4**
Hallertau Hall. Tradition	4.7	6.4	5.7	5.0	5.4	6.3	6.1	5.2	4.9	**5.3**	**5.6**	**5.5**
Hallertau Mand. Bavaria	7.0	8.7	7.3	7.5	7.9	9.0	9.9	8.2	7.9	**9.0**	**8.8**	**8.2**
Hallertau Hall. Blanc	7.8	9.7	9.0	8.8	9.0	10.9	9.9	8.1	8.7	**9.7**	**9.5**	**9.2**
Hallertau Hüll Melon	5.8	6.8	6.2	5.8	6.6	7.2	8.4	6.3	6.9	**6.3**	**7.0**	**6.6**
Hallertau North. Brewer	5.4	10.5	7.8	7.4	8.1	9.1	10.5	6.4	7.5	**8.3**	**8.4**	**8.1**
Hallertau Polaris	17.7	21.3	19.6	18.4	19.4	20.6	21.5	18.5	18.0	**19.8**	**19.7**	**19.5**
Hallertau Hall. Magnum	12.6	14.3	12.6	11.6	12.3	14.2	16.0	12.2	11.8	**12.9**	**13.4**	**13.1**
Hallertau Nugget	9.2	12.9	10.8	10.1	10.6	12.0	11.1	9.9	11.9	**10.9**	**11.2**	**10.9**
Hallertau Hall. Taurus	12.9	17.6	15.9	13.6	16.1	15.5	17.8	14.6	13.8	**15.9**	**15.5**	**15.4**
Hallertau Herkules	15.1	17.3	15.5	14.6	16.2	16.6	18.5	15.4	13.9	**15.8**	**16.0**	**15.9**
Tettnang Tettnanger	2.1	3.8	3.6	3.0	3.8	4.3	4.7	2.6	2.6	**3.3**	**3.5**	**3.4**
Tettnang Hallertauer	2.9	4.4	4.3	3.8	4.3	4.7	5.0	3.2	3.3	**3.8**	**4.0**	**4.0**
Spalt Spalter	2.2	4.3	3.2	3.5	3.9	4.7	5.2	2.8	3.0	**3.6**	**3.9**	**3.6**
Spalt Spalter Select	2.5	5.5	5.2	2.9	4.1	4.7	6.4	2.8	5.4	**4.4**	**4.7**	**4.4**
Elbe-S. Hall. Magnum	10.4	13.7	12.6	9.3	11.9	11.9	13.8	12.0	14.2	**12.3**	**12.8**	**12.2**

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

2 Weather and Plant Development 2024

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

2.1 Weather and Plan Development

The 2024 hop year began with an unusually warm spring. It allowed for the plants' emergence and early pruning while soils were dry. This also created ideal conditions for budding. Starting around mid-April, however, the weather turned cold and wet. There was even some light frost at the end of the month. This slowed down growth, pruning, and training, especially in late-developing varieties. May, on the other hand, was warm and also overly humid; and the plants made up for some of the delays. At the beginning of July, therefore, most hops were well developed in spite of some early difficulties; and there was abundant early flowering—except on less favorable sites and soils that were structurally damaged by wet conditions. There, the first yellowing of the lower leaves appeared by the end of July. With 24 "hot" days (defined as temperatures >30 °C) and less than 140 mm of rainfall, July and August pushed the water-loving hop plants to their physiological limits, especially on less favorable sites. These evolving heterogeneities in the plants' development were already noticeable and turned out to be early indicators of significantly different harvest yields in different locations. A spell of true summer weather until the beginning of September accelerated ripening and the formation of beer-critical compounds. As a result, in 2024, harvesting started already at the end of August, a few days earlier than normal.

With over 500 mm of rainfall during the key portions of the growing season between March and August, Hüll in the Hallertau, for instance, received sufficient aggregate rainfall, but the distribution over time was uneven. Rainfalls were particularly heavy in several locations on May 31 and June 1 along the Paar, Ilm, and Abens rivers, where they caused major flooding and significant damage to approximately 200 hectares of hops. More importantly, however, many hop gardens suffered more from the heat and drought at the end of July, which lasted well into August. Hop sites with good soil structures and water retention capabilities had a clear advantage this year and were able to achieve good yields even without irrigation.

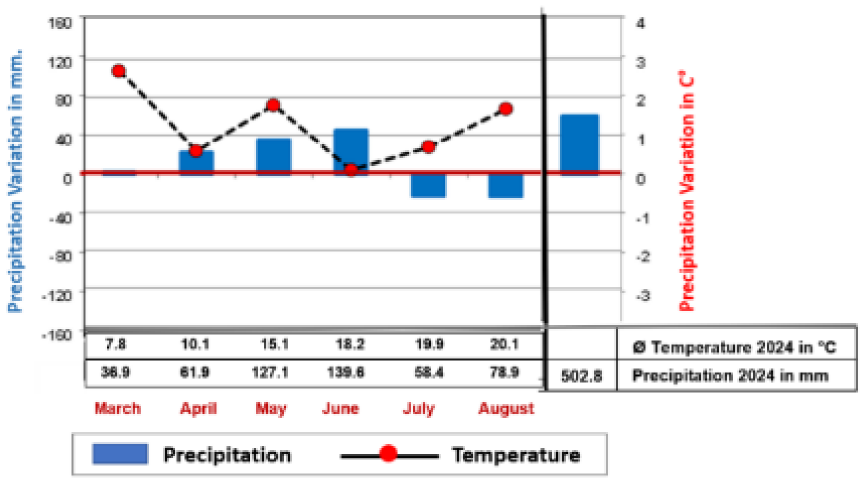


Figure 7: Weather during the 2024 growing season in Hüll by months, as a deviation from the 10-year average, "0."

2.2 Diseases and infestations

Lovage weevils (*Otiorynchus*), also known as the hop-root weevil, appeared only locally and could be controlled with the pesticide Exirel, which the regulatory bodies approved for emergency use. Hop flea beetles (*Psylliodes*), on the other hand, caused considerable damage to shoots and mature plants in several areas.

Initially, primary downy mildew (*Pseudoperonospora humuli*) infections occurred only sporadically during the cold snap in the spring. Abundant rainfalls in May, on the other hand, and the rise in temperatures provided changed conditions for more severe outbreaks of both primary and secondary downy mildew infections. The number of zoosporangia counted in the spore traps quickly reached control threshold levels and remained a menace throughout the rest of the season. This required nine regionally coordinated downy mildew control campaigns between late May and early September—roughly twice as many as in 2023.

The fungal disease powdery mildew (*Podosphaera macularis*), too, was frequently detected in many hop gardens and required regular control measures until shortly before harvest. In spite of the blanket regulatory approval of Luna Sensation as a counter measure throughout the season, and of Vegas on an emergency basis, growers still had to struggle to keep the pathogen under control. This resulted in significant color deterioration in late-harvested hops.

The abundant rainfall from spring into summer also favored the recurrence of the dreaded *Verticillium* wilt.

The main hop pests, the hop aphid (*Phorodon humuli*) and the common spider mite (*Tetranychus urticae*), appeared relatively early in 2024, starting in mid-May. The warm, humid weather subsequently favored the colonization and proliferation of the hop aphid. Thus, initial control measures needed to be applied in early June. The main countermeasures were Movento SC, from mid-June to early July. Treatments were successful in most cases in the Hallertau region, which is why hops remained largely free of aphids from the flowering stage onward.

The common spider mite infestation was slowed naturally with the onset of rainy weather. Therefore, there was little need for double treatments against them. Often, just a targeted acaricide, such as Movento, was sufficient to keep the pathogen in check. Over the course of the hot summer, however, the population recovered in many locations, making further spider mite controls necessary from late July to early August.

In 2024, monitoring of the spread of the Citrus Bark Cracking Viroid (CBCVd), which was first detected in the Hallertau in 2019, continued. Fortunately, the infestation still appears to be very limited, as it spreads slowly. Currently, there are no counter preparations available and control requires very drastic hygiene measures.

2.3 Out-of-the-ordinary events in 2024

The heavy rainfall and flooding in southern Bavaria at the end of May and the beginning of June was memorable; and damage to hop gardens added up to roughly 200 hectares. Affected growers were compensated by the State Ministry for Agriculture after a comprehensive damage assessment by the Hop Growers Association.

Also noteworthy was the high level of plant protection required for hops in 2024. Especially the main diseases, downy and powdery mildew, were prevalent throughout the season, from emergence to harvest, prompting regular control measure campaigns. These kept growers busy with plant protection campaigns during breaks in the rain. Once again, this year demonstrated conclusively that summary prohibitions by legislators and regulators of tried-and-true plant protection preparations must not be based on mere abstract thinking. Rather, the intensity and frequency of pesticide use needs to be conditioned on the weather and the resulting occurrence of pathogens.

Figure 8: Flooded hop garden in early June (Photo: T. Langwieser)

Many growers will also remember a severe thunderstorm on the evening of August 14, which downed bines in many hop gardens. It even caused some larger hop gardens in the Hallertau and Kinding regions to collapse entirely.

Figure 9: Harvesting a collapsed hop garden (Photo: H. Franz)

Table. 7: Weather data for 2024 (monthly averages and monthly totals) compared to the 10 and 30** year averages in Hüll*

Month		Temperature at 2 m elevation			Relative Humidity (%)	Precipitation (mm)	Days w/ Precip. ≥0.2 mm	Sunshine (hours)
		Mean (°C)	Min.∅ (°C)	Max.∅ (°C)				
January	2024	0.6	-3.2	5.3	97.4	58.5	13	48
∅	10-y	0.5	-3.0	4.0	95.6	56.9	16.8	33.9
	30-y	-2.3	-5.9	1.1	86.7	50.8	14.8	47.1
February	2024	6.4	2.6	10.8	96.7	53.6	15	58
∅	10-y	1.9	-2.6	6.8	89.5	41.3	11.6	82.8
	30-y	-1.0	-4.9	3.1	81.4	46.8	13.3	72.1
March	2024	7.8	2.5	14.0	91.4	36.9	12	122
∅	10-y	5.1	-0.7	11.1	81.9	34.7	11.9	161.5
	30-y	2.8	-1.7	7.8	78.9	47.7	13.8	132.2
April	2024	10.1	3.9	16.9	87.0	61.9	14	164
∅	10-y	9.5	2.7	15.2	76.8	39.3	10.3	203.5
	30-y	7.1	1.9	12.8	73.8	60.8	14.1	164.3
May	2024	15.1	9.1	21.5	86.3	127.1	14	212
∅	10-y	13.3	7.5	19.2	79.6	91.6	14.4	205.1
	30-y	11.9	6.1	17.7	73.9	82.3	15.4	203.6
June	2024	18.2	12.5	24.8	91.6	139.6	16	183
∅	10-y	18.1	11.4	24.6	77.6	93.9	12.0	251.9
	30-y	15.1	9.0	20.8	74.6	103.5	15.3	212.3
July	2024	19.9	13.3	27.7	89.4	58.4	15	232
∅	10-y	19.2	12.4	26.1	78.9	81.2	12.9	247.8
	30-y	16.7	10.5	23.1	74.3	90.5	14.1	236.8
August	2024	20.1	13.5	28.0	91.3	78.9	19	236
∅	10-y	18.4	12.2	25.3	83.8	102.1	12.1	230.3
	30-y	16.0	10.2	22.6	78.2	91.7	13.8	212.4
September	2024	14.8	10.0	20.9	95.1	184.2	18	148
∅	10-y	14.2	8.2	20.9	88.4	47.6	10.4	179.1
	30-y	12.7	7.4	19.1	80.7	67.9	11.6	175.0
October	2024	11.1	7.4	15.2	99.4	36.1	19	63
∅	10-y	9.8	4.9	15.2	93.4	54.9	12.0	113.2
	30-y	7.6	3.2	13.1	84.2	51.1	11.0	117.2
November	2024	4.0	1.2	7.3	99.1	34.5	14	34
∅	10-y	4.6	1.1	8.7	96.4	57.8	13.3	52.3
	30-y	2.6	-0.6	6.1	85.5	57.5	14.4	52.9
December	2024	1.2	-1.2	3.9	99.8	46.1	15	23
∅	10-y	2.0	-1.3	5.9	96.8	60.3	15.8	35.1
	30-y	-0.9	-4.3	1.8	86.5	52.2	15.0	38.7
∅ Year	**2024**	**10.8**	**6.0**	**16.4**	**93.7**	**915.8**	**184**	**1,523**
10 – Year Mean		**9.7**	**4.4**	**15.3**	**86.6**	**761.6**	**153.5**	**1,796.5**
30 – Year Mean		**7.4**	**2.6**	**12.4**	**79.9**	**802.8**	**166.6**	**1,664.6**

* The 10-year average covers the period between 2014 and 2023

** The 30-year average covers a reference period between 1961 and 1990

3 Research and Ongoing 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 (dry substance) and alpha acid monitoring – Aphid, Spider Mite, and Powdery Mildew Monitoring	2024-2028	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (StMELF) *(The Bavarian State Ministry for Food, Agriculture and Forestry)*	Hopfenring e.V.
IPZ 5a J. Portner A. Schlagenhaufer	Investigations into soil moisture measurement and irrigation control for resource-efficient hop irrigation (I+II)	2023-2026	Erzeugerorganisation HVG e. G. *(HVG Hop Processing Group)*	P. Razavi, Irriport GmbH
IPZ 5a J. Portner S. Fuß	R&D subcontract to support HSWT (TU Munich at Weihenstephan-Triesdorf) in data collection on disease and pest infestation, as well as conducting trial harvests and quality assessment of hops in the Agri-PV (Agri-Photovoltaics) project "HoPVen"	2024-2026	Weihenstephan-Triesdorf (HSWT) Bundesanstalt für Landwirtschaft und Ernährung (BLE) *(Federal Office for Agriculture and Food)*	HSWT Weihenstephan-Triesdorf (Dr. M. Beck, M. Riedl)
IPZ 5a J. Portner S. Fuß	R&D subcontract in the agri-PV project “HoPVen” to assess the economics and support the expert survey	2024-2025	The Fraunhofer Institute for Solar Energy Systems (ISE) Bundesanstalt für Landwirtschaft und Ernährung (BLE) *(Federal Office for Agriculture and Food)*	The Fraunhofer Institute for Solar Energy Systems (ISE) (M. Trommsdorf)
IPZ 5a J. Portner N.N.	Model and Demonstration Project (MuD) "Humus Buildup in Hop Cultivation"	2024-2030	Bundesanstalt für Landwirtschaft und Ernährung (BLE) *(Federal Office for Agriculture and Food)*	Hopfenring, e.V. (S. Arnold) 10 Demonstration Farms

Working Groups Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5a J. Portner	Series of studies to determine alpha degradation after hop harvest as a function of storage time and temperature	2024	Erzeugerorga-nisation HVG e. G. *(HVG Hop Processing Group)*	IPZ 5d &. 1e
IPZ 5a J. Portner J. Münsterer	Development of a new drying process for hops optimized for renewable energy sources	2024-2026	Erzeugerorga-nisation HVG e. G. *(HVG Hop Processing Group)*	Christian Euringer GmbH

Permanent tasks: Product-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	Supportive advice on the construction of community irrigation systems in hops	Permanent task	Hopfenverwertungsge nossenschaft (HVG) *(Hop Processing Cooperative)*
5a	Preparation and updating of advisory documents	Permanent task	
5a	Dissemination of advisory strategies and exchange of information with group advisory services	Permanent task	Hopfenring e.V.
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	
5a	Optimization of techniques and processes to prevent soil erosion and promote soil fertility in hop cultivation	Permanent task	IAB bodenständig (https://boden-staendig.eu/)
5a	Investigations into the nitrogen fertilization effect of hop bine chips	From 2019	Hop Farms
5a	Testing various materials as a replacement of plastic cords on the “string wire”	2022-2024	Various suppliers of string wire Hop farms
5a	Fertilizer trials to minimize nitrogen in the hop varieties Herkules and Perle	From 2023	Gesellschaft für Hopfenforschung e.V. (GfH) (Pachtfläche) *(Society for Hop Research, e.V.; leased area)*
5a	Energy savings during drying and conditioning	2023-2024	Various farms
5a	Testing of coated slow-release fertilizers	2023-2024	Hop farms

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 Lebensmittelsicherheit (BVL) *(The Federal Office of Consumer Protection and Food Safety)*	BfR, BVL, DLR RP
IPZ 5b S. Euringer, C. Krönauer F. Weiß	CBCVd-Monitoring	2024	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (StMELF) *(The Bavarian State Ministry for Food, Agriculture and Forestry)*	IPZ 5c, IPS 2c
IPZ 5b S. Euringer, C. Krönauer, F. Weiß	CBCVd Research project	2023-2026	Erzeugerorganisation Hopfen HVG e.G. *(HVG Hop Processing Cooperative)*	IPZ 5a, IPZ 5c, IPZ 5d, IPS 2c
IPZ 5b S. Euringer, K. Lutz	Fighting hop wilt	2023-2026	Bayerisches Staatsministerium 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)*
IPZ 5b S. Euringer, K. Lutz	*Verticillium* gardens Niederlauterbach (2015-2021), Engelbrechtsmünster (2016-2022), and Gebrontshausen (2020-2027)	2015-2027	Erzeugerorganisation Hopfen HVG e.G. *(HVG Hop Processing Cooperative)*	IPZ 5c
IPZ 5b S. Euringer, K. Lutz, F. Weiß	Evaluation of vegetation indices for the detection of *Verticillium* in hops using short-range remote sensing with UAS/drone-based hyperspectral sensors	2024-2025	Wissenschaftliche Station München e.V. *(Scientific Station Munich e.V.)*	Katholische Universität Eichstätt (KU Eichstätt) *(Catholic University Eichstätt)*

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	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 permits according to Art. 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 Mgt Project Operations	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	2016-2025	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);*	IP 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);*

Working Groups Project Mgt Project Operations	Project	Durati on	Cost Allocation	Collaborators
			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 Cooperative)*	Hopfengut Lautitz, Sachsen (*Hop Farm Lautitz, Saxony*); Agrargenoss. Querfurt, Sachsen-Anhalt *(Agricultural Cooperative Querfurt, Saxony-Anhalt)*
IPZ 5c Dr. S. Gresset	Establishment of a phenotyping platform for the assessment of aphid tolerance in hops	2024-2025	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. Forster, P. Hager, B. Haugg IPZ 1a: Dr. R. Seidenberger IPZ 5b S. Euringer, A. Baumgartner
IPZ 5c Dr. S. Gresset	Development of a high-throughput marker system for sex determination in hop breeding	2022-2024	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

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

Ongoing third-party funded research projects of IPZ 5d (Hop Quality and Analysis)

Working Group Project Management Project Operations	Project	Duration	Cost Allocation	Collaborators
IPZ 5d Dr. K. Kammhuber S. Beck S. Weihrauch B. Wyschkon M. Hainzlmaier	Analysis of alkaloids for the project: "BitterSweet - Stabilizing alkaloid levels at a low level to ensure sustainable cultivation of white lupine"	2023-2026	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (StMELF) *(The Bavarian State Ministry for Food, Agriculture and Forestry)*	Dr. G. Schweizer, IPZ 1b Dr. C. Riedel, IPZ 4a Dr. G. Schwertfirm, IPZ 1b

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	AIW ITP

3.5 IPZ 5e – Ecological issues in hop cultivation

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

Working Group Project Management Project Operations	Project	Duration	Cost Allocation	Collaborators
IPZ 5e Dr. F. Weihrauch Dr. I. Lusebrink M. Kremer	Development of a catalog of measures to promote biodiversity in hop cultivation	2018-2026	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Processing Cooperative)*	IGN Nierderlauterbach; AELF PAF, FZ Agraökologie *(Center of Expertise for Agroecology)* UNB am Landratsamt PAF; LBV, KG PAF *(Nature Conservation Authority, District of Pfaffenhofen ad Ilm)*
IPZ 5e Dr. F. Weihrauch Dr. I. Lusebrink M. Kremer	Induced resistance in hops to spider mites	2021-2026	Deutsche Bundesstiftung Umwelt (*German Federal Foundation for the Environment) DBU* (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 2024

Soil analyses for available nitrogen and N_{min} are a central component in determining fertilizer requirements. They are also mandatory for hop gardens in the so-called "red zones."

In 2024, approximately half of the hop farms in the Bavarian hop-growing regions of the Hallertau and Spalt participated in N_{min} analyses. 2,098 hop gardens (2023: 2,590) were examined for N_{min} content. The average N_{min} content in the Bavarian hop-growing regions was 30 kg N/ha in 2024, which is 23 kg lower than in the previous year. As is the case every year, there were large fluctuations from one farm to the next, as well as between individual hop plots, and between different varieties cultivated by the same farm.

According to the German Fertilizer Ordinance (DüV), every hop farm must calculate its nitrogen (N) fertilizer requirements 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 zones**, which are not obliged to carry out N_{min} assessments or did not collect N_{min} results for all plots, were permitted to use regionalized averages listed in Table 8.

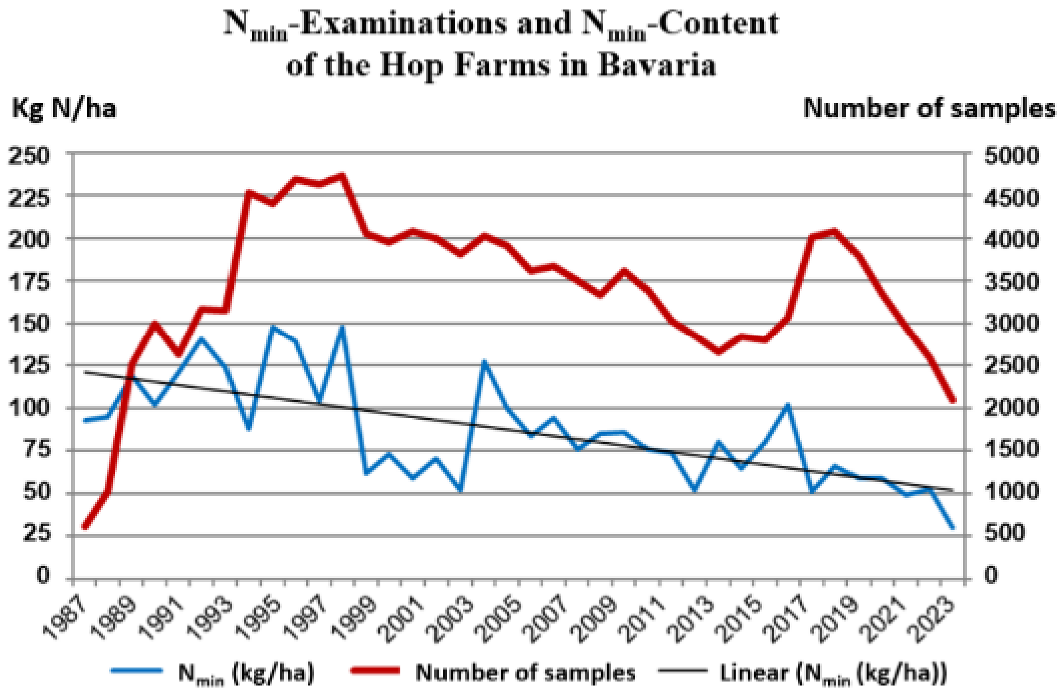
Table 8: Number of samples, preliminary, and final N_{min} values for 2024 in the various hop growing districts and regions (current as of April 10, 2024)

Country/Region	Number of tests	Preliminary N_{min}-value (As of March 14, 2024)	**Final N_{min}-value**
Eichstätt (including Kinding)	124		**28**
Freising	260	33	**27**
Hersbruck	38		**55**
Kelheim	808	34	**31**
Landshut	124	39	**36**
Pfaffenhofen (and Neuburg-Schrobenhausen)	657	30	**28**
Spalt	87	35	**32**
Bavaria	**2098**	**33**	**30**

Hop growers without their own N_{min} test values were permitted to calculate their nitrogen requirements using the provisional N_{min} averages for their district or growing region. Since the final N_{min} value in all districts and cultivation areas was no more than 10 kg N/ha higher than the preliminary N_{min} value, a previously calculated fertilizer requirement assessment did not need to be adjusted again. However, a recalculation was beneficial in all districts, as the correction resulted in a higher fertilizer requirement.

For farms in the Eichstätt district and the Hersbruck region, no preliminary N_{min} value was assessed last year. Thus, fertilizer requirements had to be calculated using the final N_{min} value.

Farms in the **"red zones"** had to test at least 3 plots for N_{min} in 2023. If additional hop areas were in the red zone, 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 requirements for these areas because of ecological risks associated with nitrate!



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

Figure 10: N_{min} investigations, N_{min} amounts and the trend line for N_{min} values in hop gardens in Bavaria over the years

4.2 Testing of coated long-term nitrogen fertilizers

Background:

Increasing weather extremes and, above all, prolonged periods with precipitation during the growing season are becoming increasingly challenging for conventional nitrogen fertilization of hops. If precipitation fails to materialize during crucial phases of the growing cycle when hops typically take up nitrogen (May to July), the fertilizer distributed in the fields is simply not available to the plants when they need it. This can lead to yield losses. During heavy rainfalls, on the other hand, nitrogen fertilizer can seep deep into the soil or just wash away and thus are also out of reach for the hop plants. Field trials were designed to determine if a single application of coated, slow-release fertilizers distributed in the spring can prevent transient nitrogen deficiencies in hops and ensure sufficient yields.

Methodology:

Two field trials were conducted with Herkules, each on light soils (loamy sand) in the municipalities of Wolnzach and Geisenfeld. The trial was designed as a strip trial with four trial variants and three replications each. In the first variant (A), the pre-calculated fertilizer requirement of 180 kg N/ha was divided into three, as is customary practice, and distributed as three calcium ammonium nitrate (CAN) applications (first application in mid-April; second, in mid-May; and third, in mid-June). The other variants received a slow-release urea-based fertilizer (trade name: Agrocote 44-0-0 | 2-3 M) as the nitrogen source, which, according to the manufacturer (ICL), was designed to release nitrogen evenly over a 2- to 3-month period. To ensure the same conditions for all plots, the slow-release fertilizers were always mixed with 36 kg N/ha in the form of KAS (20% of 180 kg N/ha). Three trials using the slow-release fertilizer were set up as shown in the table below. Variant B was designed to find out if a single application of slow-release fertilizer would provide the hops with the nutrients they need. Variant C was designed to replicate commercial practices by combining the first two applications into one in April, and applying the remaining fertilizer using fertigation or a nutrient solution. Variant D was designed to determine if slow-release fertilizers could be used to reduce the total amount of nitrogen to 80% without reducing yield.

Table 9: Experimental variants of the fertilization trial with long-term fertilizers differentiated according to individual doses and total amounts of nitrogen applied

Var.	Variant	Appl. 1	Appl. 2	Appl. 3	Total
A	3 X 60 N KAS	60 N	60 N	60 N	180 N
B	36 N KAS, 144 N slow-release	180 N			180 N
C	36 N KAS, 84 N slow-release, 60 N Fert	120 N		60 N	180 N
D	36 N KAS, 108 N slow-release	144 N			144 N

In crop year 2024, there was abundant rainfall during the period when hops take up nitrogen. Heavy rainfall in late May and early June even caused water-logged sols. Monthly precipitation at the Stadelhof weather station, which is not far from the two trial sites, was 139 mm in May; 118 mm in June; and 69 mm in July.

The Hop Research Center in Hüll collected and analyzed 15 plants or 30 bines for each of the three replications. Thus, a total of 90 bines were evaluated.

Results:

The harvest results from the Geisenfeld site are shown in Figure 11. Variants A and C, in which the fertilizer applications were distributed over 3 and 2 applications, respectively, produced higher yields than variants B and D, in which N was applied only once, in the form of slow-release fertilizers.

These results, however, could not be replicated at the second site, in Wolnzach. There, the variants with the slow-release fertilizers (variants B, C, and D) showed higher yields than variant A, which received three applications of KAS (Figure 12). Thus, these experiments do not allow any conclusions about the effects of different fertilizers on alpha acid content.

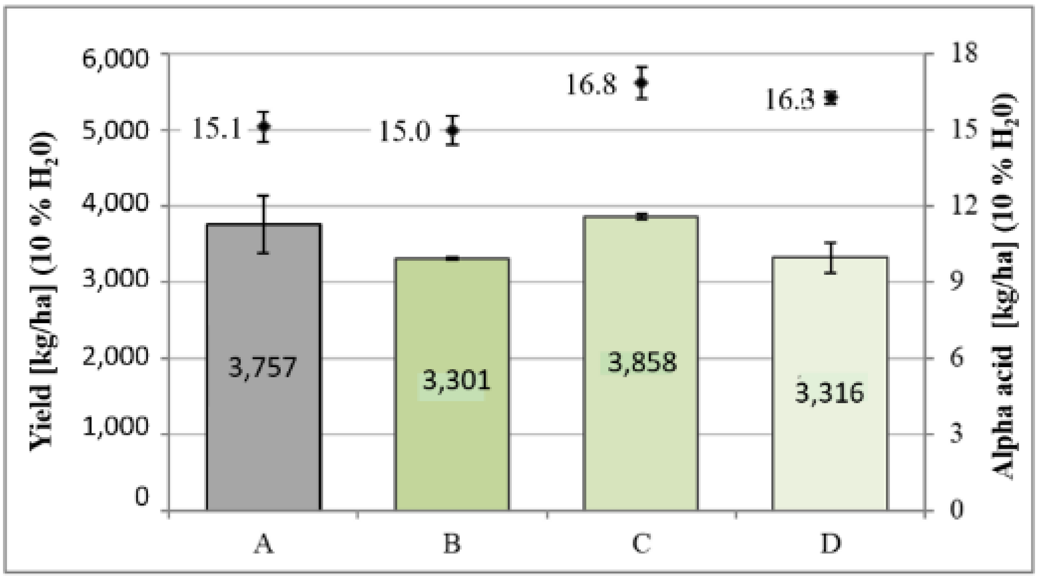


Figure 11: Cone yield in kg/ha and alpha acid content in % depending on the fertilizer variant, variety Herkules, loamy sand, site Geisenfeld, 2024

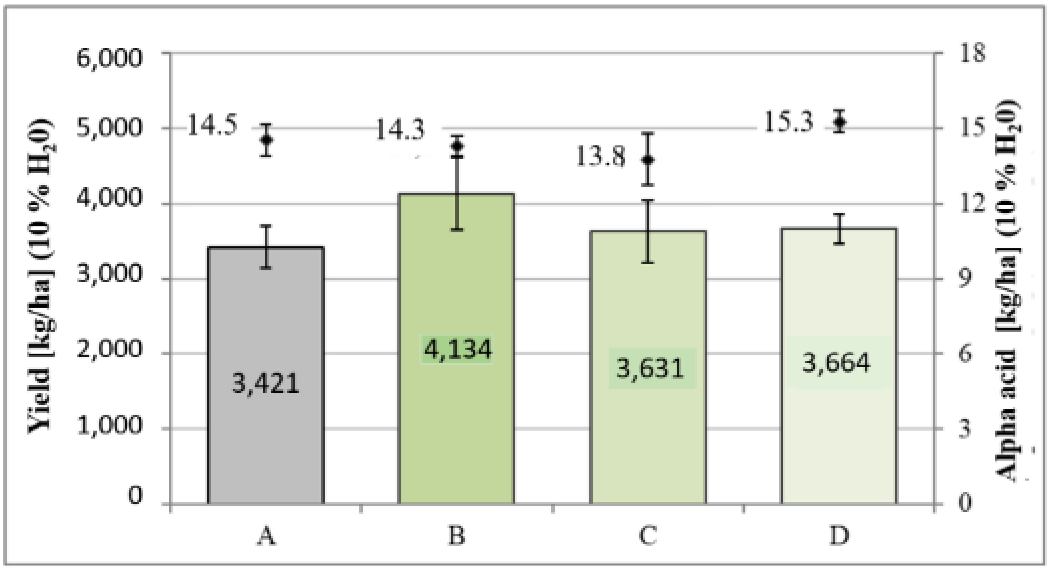


Figure 12: Cone yield in kg/ha and alpha acid content in % depending on the fertilizer variant, variety Herkules, loamy sand, location Wolnzach, 2024

One explanation for the differences between the sites may be that the test area near Geisenfeld was under water for several days in early June 2024 because of flooding of the Ilm River. Consequently, this year's results do not permit any clear conclusions regarding the effectiveness of slow-release fertilizers compared to conventional nitrogen fertilizers. Therefore, the testing of slow-release fertilizers will continue in 2025.

4.3 Nutrient removal by key hop varieties

Background

As part of various research projects conducted by the "Hop Cultivation and Production Technology" working group between 2017 and 2020, a large number of plots from various trials in Hüll were harvested and analyzed in precise quantities annually. During these trial harvests in Hüll, the cone yield per hectare and the alpha acid content were determined, as well as the amount of fresh and dry mass of cones and bine chips, and the N content of the dry mass. In addition, in the 2021 harvest, cone and bine chip samples from plots fertilized with the requisite nutrient levels were analyzed for additional macro- and micronutrients to gain insights into the nutrient removal of the key hop varieties.

Methodology

The tests included cone and bine chip samples from 128 test plots harvested in Hüll in 2017, 2018, 2019, and 2020. The samples came from 12 different locations in the central Hallertau region and from three different varieties (Herkules, Perle, Hallertauer Tradition). Only the Herkules and Perle varieties will be discussed below, because most of the tests focused on these.

During the test harvests, both the fresh and dry matter yield of the cones and bine chips was determined. At the same time, cone samples were taken from the baling conveyor and bine chip samples from the waste conveyor to determine the dry matter content, nutrient content, and alpha acid content. The samples were first weighed wet and then dried at 60 °C to a residual moisture content of approximately 10% and then weighed again. For the nutrient content analysis, the bine chip samples were separated from the wire, then coarsely macerated with a hammer mill, and eventually finely ground with a centrifugal mill (sieve size: 0.5 mm). The cone samples only needed to be ground once. At the time of the nutrient analysis in the laboratory, the residual moisture content was determined at 105 °C, and the test results were corrected for the water content. This procedure allowed for the determination of exact removal rates for all nutrients in both the cones and the bine chips.

The entire methodology used for the experimental harvest of fertilizer trials in Hüll was described in detail in the dissertation "Needs-based nitrogen nutrition of hops through fertilizer systems with fertigation" (Stampfl 2021).

A total of 258 samples were analyzed for their respective nutrient contents in the dry matter using the following methods:

- Dumas VDLUFA:
    - Sulfur
    - Nitrogen
    - Carbon

- ICP OES (Optical Emission Spectrometry):
    - Calcium
    - Potassium
    - Sodium
    - Magnesium
    - Phosphorus

- Cobalt
- Copper
- Iron
- Manganese
- Molybdenum
- Nickel
- Aluminum
- Zinc
- Boron

Results:

The results show that there are different macronutrient removals by variety, broken down into cone and residual plant removal (Figure 13). The quantitatively most significant nutrients are calcium, potassium, nitrogen, magnesium, phosphorus, and sulfur, in that order. Yields increase with increasing nutrient removals.

The various nutrients reside at different ratios at different locations within the plant. While more than half the absorbed phosphorus is contained in the cones, the larger proportion of magnesium and calcium, for example, is bound in the residual plant matter. For nitrogen, potassium, and sulfur, the ratio between residual plant and cone matter is relatively balanced. Looking at individual results, as the cones harbor relatively more nitrogen and potassium than the residual plant, yields increase, too.

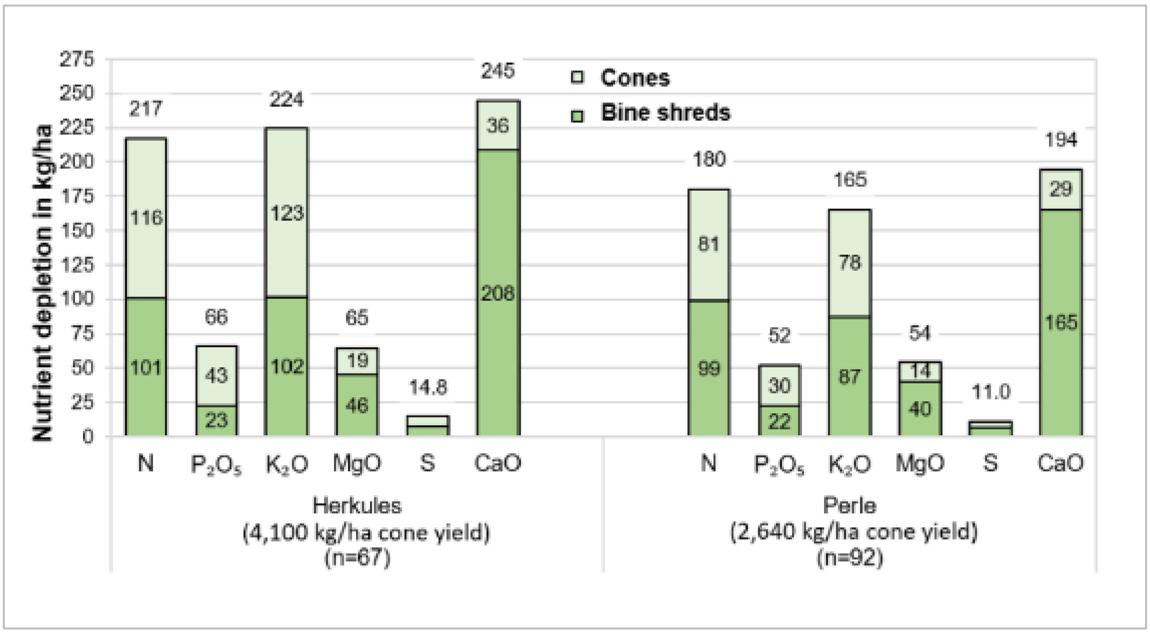


Figure 13: Macronutrient removals by Herkules (n=67) and Perle (n=92) expressed as a fraction: the amounts that went into the cones divided by the amounts that went into the remaining plant matter, in kg/ha (nitrogen, phosphate, potassium oxide, magnesium oxide, sulfur, calcium oxide). The values are mean values per variety and based on needs-based fertilization trials from 2017-2020, at 12 locations (light and medium-heavy soils), yields per plot without extraneous influences.

The two graphs below show the removal of various micronutrients by the cones and the remaining plant matter. The main micronutrient absorbed by the plants is iron. The trace elements molybdenum, cobalt and nickel shown in Figure 15 are absorbed by the hops only to a very small extent. Except for zinc, molybdenum, and nickel, most of the trace elements are stored in the residual plant matter, and only small portions in the cones. Zinc and boron are known to be essential for hop health. Herkules absorbed an average of 242 g of zinc and 305 g of boron per hectare, whereas the Perle took up 185 g of zinc and 210 g of boron per hectare.

For copper, the fluctuations between individual results were relatively large and can probably be attributed to copper residues in plant protection preparations. Therefore, the plant's natural copper uptake from the soil would probably be lower than shown here.

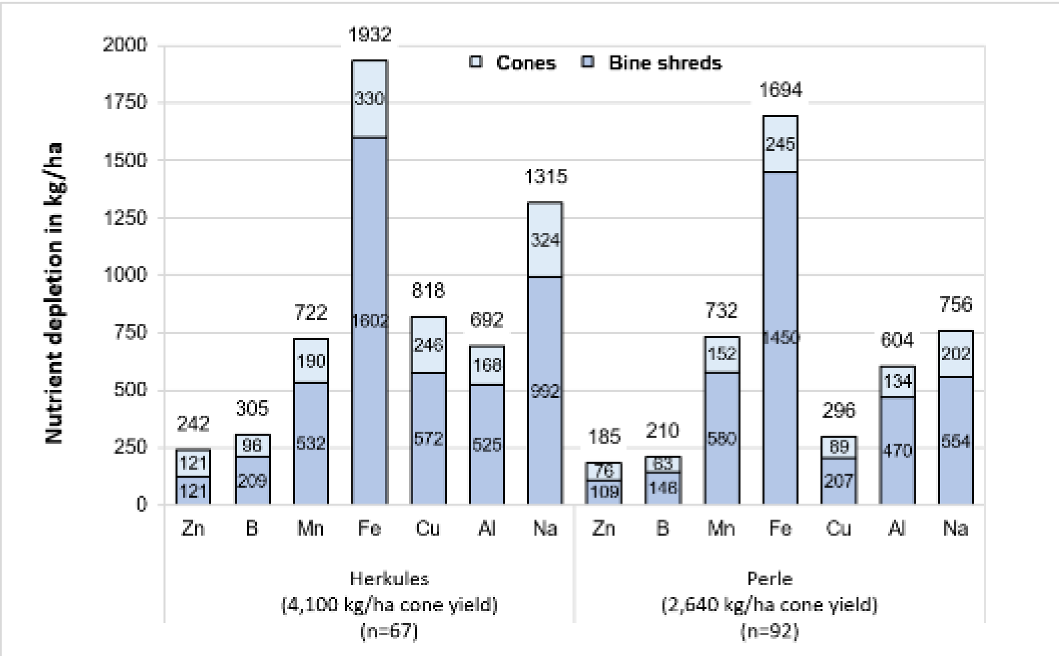


Figure 14: Micronutrient removals by Herkules (n=67) and Perle (n=92) expressed as a fraction: the amounts that went into the cones divided by the amounts that went into the remaining plant matter, in kg/ha (zinc, boron, manganese, iron, copper, aluminum, sodium). The values are mean values per variety and based on needs-based fertilization trials from 2017-2020, at 12 locations (light and medium-heavy soils), yields per plot without extraneous influences.

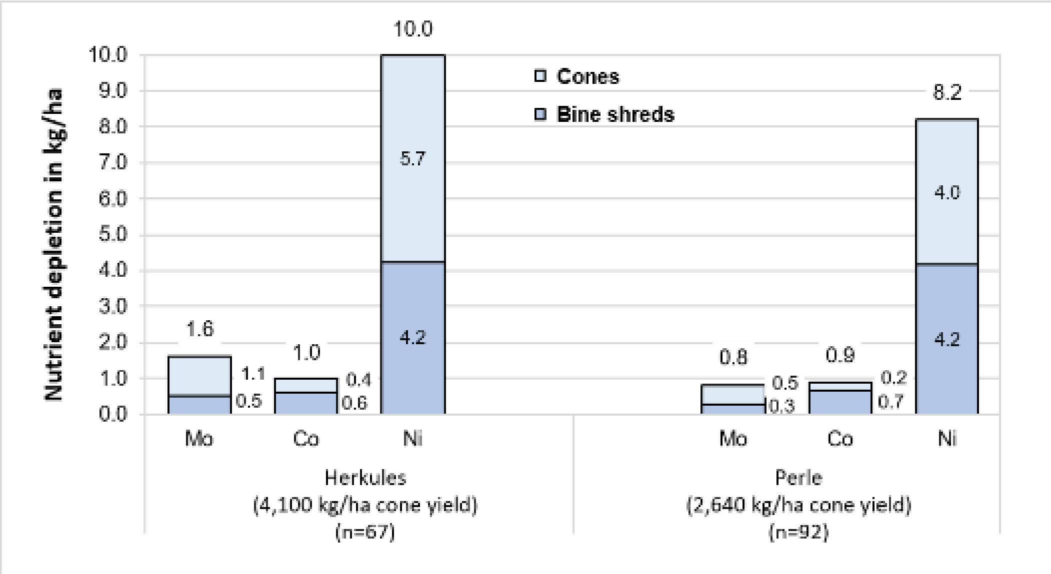


Figure 15: Micronutrient removals by Herkules (n=67) and Perle (n=92) expressed as fractions: the amounts that went into the cones divided by the amounts that went into the remaining plant matter, in ***g/ha*** *(molybdenum, cobalt, nickel). The values are mean values per variety and based on needs-based fertilization trials from 2017-2020, at 12 locations (light and medium-heavy soils), yields per plot without extraneous influences.*

The following tables show average total nutrient removals depending on the cone yield for the examined varieties.

Table 10: Averages of macro- and micronutrient removals from hops in ***kg or g per dt*** *of cone yield, broken down into cones and residual plant matter. These values are from needs-based fertilization trials from 2017 to 2020, at 12 locations (light and medium soils). Note, a German "Dezitonne" (dt) = 100 kg*

Macronutrient	Nutrient absorption in kg/dt of cones		
	Cones	Residual plant	Total
Nitrogen (N)	2.9	3.1	6.0
Phosphorus pentoxide (P_2O_5)	1.1	0.7	1.8
Potassium oxide (K_2O)	3.0	2.9	5.9
Magnesium oxide (MgO)	0.5	1.3	1.8
Sulfur (S)	0.2	0.2	0.4
Calcium oxide (CaO)	1.0	5.6	6.6
Carbon (C)	47.8	72.5	120.3

Micronutrient	Nutrient absorption in g/dt of cones		
	Cones	Residual plant	Total
Zinc (Zn)	2.97	3.60	6.,57
Boron (B)	2.44	5.56	8.0
Manganese (Mn)	5.13	16.8	22.0
Iron (Fe)	8. 95	48.7	57.6
Copper (Cu)	4.79	11.1	15.9
Aluminum (AL)	4.79	15.8	20.6
Sodium (Na)	7.91	23.3	31.2
Molybdenum (Mo)	0.03	00.1	0.04
Cobalt (Co)	0.01	00.2	0.03
Nickel (Ni)	0.15	0.13	0.28

Test results vs. our current understanding of nutrient removal rates by hops

The last comprehensive adjustment of our understanding of nutrient removal/absorption rates by hops was in 2007. It was based on studies from around the turn of the millennium. Comparing these data with more recent findings, it is fair to conclude that the variety spectrum and yield expectations for hops in German growing regions have changed significantly since then. The 2007 adjustments were primarily based on rates for varieties that were important at that time, including Hallertauer Magnum, Spalter Select, and Hallertauer Tradition, as well as such old landraces as Tettnanger.

Since then, the variety spectrum has shifted toward higher-yielding and agronomically more efficient varieties; and Herkules, which was not yet cultivated back then, is now the most important variety, with Perle and Hallertauer Tradition ranking second and third in cultivation acreage in Germany. Thus, average yields have increased significantly. Table 11 shows updated values for nutrient removals in kg/dt cone yield based on more recent studies (2017-2021), which differ from the understanding reflected in the above tables.

A comparison of the two series of studies shows that there are hardly any differences in the nutrient uptake by the cones, whereas the residual plant matter takes up fewer nutrients per dt of cone yield than we used to think. This is the result of changes in the variety spectrum. Such newer varieties as Herkules have significantly more favorable ratios between cones (dry weight) and residual plant matter (also dry weight). In other words, today's plant can produce the same cone yield with less residual plant matter and fewer "wasted" nutrients.

Table 11: Key nutrient removals/absorptions by hops in kg per dt cone yield divided into cones and residual plant matter based on several recent tests

Investigations from 2017-2021

Nutrient	Nutrient absorption in kg/dt of cones		
	Cones	Residual plant	Total
Nitrogen (N)	2.9	3.1	6.0
Phosphorus pentoxide (P_2O_5)	1.1	0.7	1.8
Potassium Oxide (K_2O)	3.0	2.9	5.9
Magnesium oxide (MgO)	0.5	1.3	1.8
Calcium Oxide (CaO)	1.0	5.6	6.6

Updated understanding valid nutrient removals/absorptions

Nutrient	Nutrient absorption in kg/dt of cones		
	Cones	Residual plant	Total
Nitrogen (N)	3.0	4.8	7.8
Phosphorus pentoxide (P_2O_5)	1.0	1.0	2.0
Potassium Oxide (K_2O)	2.6	4.7	7.3
Magnesium oxide (MgO)	0.5	1.7	2.2
Calcium Oxide (CaO)	1.0	9.0	10.0

As for sulfur removal/absorption, current assumptions pegged it at an average of 12 kg/ha for an average yield, which is consistent with data for Herkules and Perle, which have rates of 13 kg/ha.

Because hops are relatively sensitive to zinc and boron deficiencies, these two trace elements are considered essential. Current tests show that values are 211 g/ha for zinc and 257 g/ha for boron. The current fertilizer recommendations are significantly higher for zinc (an average of 1.4-2.0 kg/ha) and only slightly higher for boron (an average of 300 g/ha). If bine chips are returned to the fields as fertilizer, therefore, the additional requirement for both nutrients is reduced by more than one-half. Thus, an update of these fertilizer recommendations seems advisable.

Outlook:

These extensive studies provide new insights and demonstrate that a changing variety spectrum calls for continuous updates of fertilizer recommendations. This is especially true as more nutrient-efficient varieties, such as Herkules, are being cultivated. This has an effect on current fertilizer legislation, which is based on older empirical studies. To help with such updates, the study presented here has established a broad database, especially for nitrogen and phosphorus requirements.

4.4 Effects of different nitrogen fertilization levels on yield and biomass of hops using fertigation

Editing: F. Weiß (Master's thesis)

A. Schlagenhaufer; S. Fuss; Dr. J. Stampfl

Duration: May 1, 2020 to December 31, 2020

Background and Objectives

Nitrogen, the most important macronutrient for hops, is strictly regulated by fertilizer legislation designed to curb the potential environmental effects, such as the leaching of nitrate into the groundwater or its contribution to climate-relevant greenhouse gases. Therefore, fertilizer must be dispensed as efficiently as possible, while still providing the plants with the correct amount when they need it. Excess nitrogen is a waste. Not enough, on the other hand, reduces yields.

A great step in the right direction is fertigation, a form of fertilization via irrigation water. It is by now common knowledge that this method is extremely efficient and enhances yields. This has been demonstrated in a previous research project entitled "Improving Nutrient Efficiency in Hops through Fertigation Fertilization Systems."

To further test this hypothesis, fertigation was integrated into various fertilization systems in commercial hop gardens, at various nitrogen fertilization levels to develop guidelines for optimizing such systems.

Methodology

For this investigation, three hop gardens belonging to two commercial farms were selected as test sites. The farms worked these gardens as they normally do, but skipped their fertilizations. Two sites grow Perle, one on sandy and one on clay soil. The other site grows Herkules on clay soil.

The irrigation and fertigation program was left to the investigators. A drip line was placed in the furrows between the plants. The first two fertilizer applications followed the usual practice. From a labor-efficient perspective, fertigation to provide the plants with the remaining nitrogen fertilizer requirement is only possible with above-ground irrigation starting at the beginning of June. The distribution and the amounts of fertilizer amounts are shown in Figure. 16. The timing, amounts, and distribution of fertigation fertilizer were based on the previous research. The nitrogen uptake of the hop plant correlates with biomass production, with the timing and amounts of the fertigated fertilizer applications being selected according to the nitrogen uptake pattern of hops (variants B, C, and D). Furthermore, a variant with constant weekly fertigated nitrogen amounts was established as a reference (variant E). A zero control was omitted. Instead, a low-fertilization reference variant with only initial applications was established (variant A). All variants were randomly replicated four times in the field.

Variant	Month	April				May					June				July				August					Total [kg N/ha]	Fertigation [kg N/ha]
	Calendar Week	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	24	35		
A	90kg N				50					40														90	0
B	90kg N +50kg N Fert.				50					40			4	8	13	13	8	4						140	50
C	90kg N +90kg N Fert.				50					40			8	15	23	23	15	8						180	90
D	90kg N +130kg N Fert.				50					40			11	22	33	33	22	11						220	130
E	90kg N +130kg N Fert. constant				50					40			15	15	15	15	15	15						180	90

Figure 16: Overview of fertilizer quantities and application timing for different test variations. The first two applications were in the form of granular fertilizer, while the fertilizer applications marked in green were weekly fertigations

To control irrigation, sensors to measure soil moisture were installed at all locations. Irrigation was adjusted based on soil moisture values and the weather forecast. In addition, a SPAD meter was used during the period of greatest biomass formation from mid-June to the end of July to determine the status of the plants' nitrogen supply.

20 bines from 10 plants were harvested per plot, with all three shoots reaching full trellis height. Accordingly, 4 x 20 bines were harvested per variant. Harvesting was carried out mechanically using standard technology. After harvest, samples were also taken from the perennial rhizomes to detect possible differences in nitrogen content. Differences in the nitrogen content of the rhizomes are an indication of the reserves the plants can access for healthy growth the following year.

The LfL analyzed the alpha acid contents using the EBC 7.2 method. The nitrogen content of bine chips, cones, and rhizomes was analyzed in a contract laboratory using the Dumas combustion method.

N_{min} samples were taken at each plot in the spring and fall. Sampling was carried out at three depths (0-30 cm, 30-60 cm, and 60-90 cm) according to the LfL standard for sampling hops.

Results

Fertigation increased yield compared to the irrigated reference as a control (90 kg N from the first and second fertilizer application); it also tended to produce marginally, but not statistically significant higher yields with increased N applications (Figure 17). These results are valid for both hop varieties at all locations.

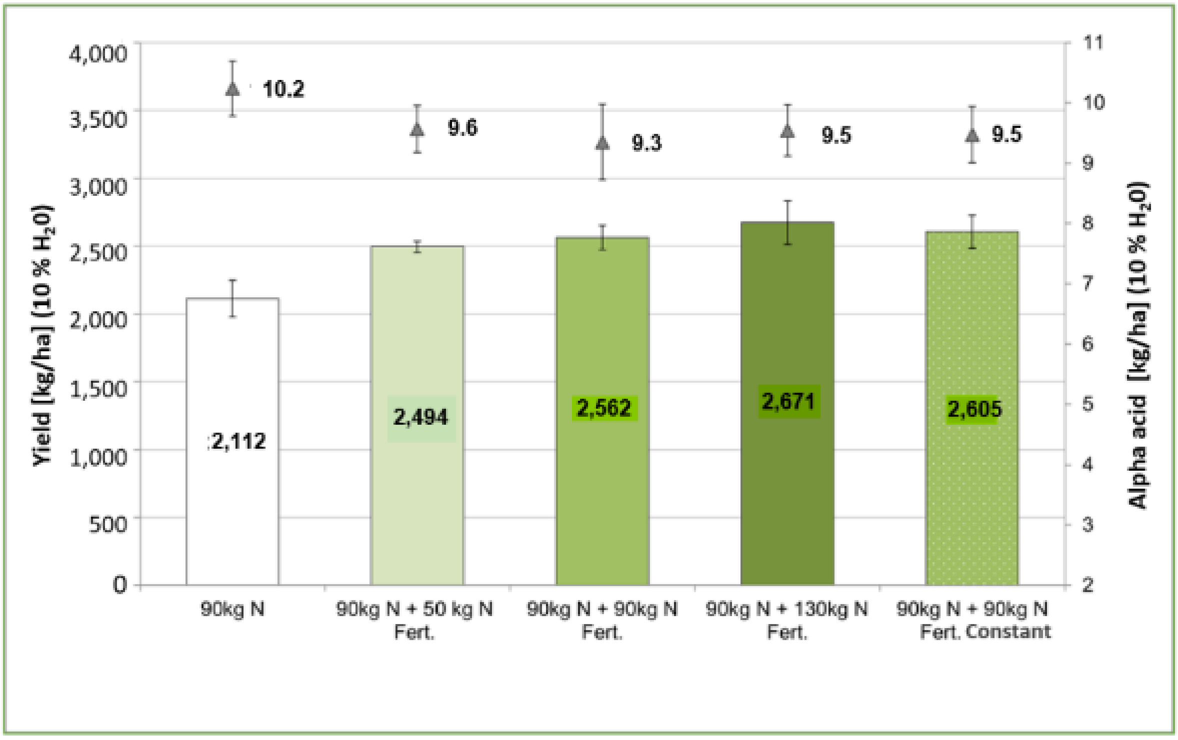


Figure 17: Cone yield and alpha acid content depending on N fertilization, variety Perle, sandy loam, 2020

As the total fertilizer application rate increases, the respective N uptake of the entire plant also increases. This increase occurs primarily in the bines. It went from just under 70 kg N ha^{-1} to over 100 kg N ha^{-1} (Figure 18). In contrast, the N uptake of the cones remained at 70 to 80 kg N ha^{-1} in the fertigation variants. These results are also transferable to both varieties and all locations.

The increased N uptake as a result of increased fertilization also led to increased DM (dry matter) formation, especially in the bines. However, this increase in biomass had no significant impact on yield. In the more highly fertilized variants of Herkules, which is highly susceptible to powdery mildew (*Podosphaera macularis*), the number of diseased cones even increased.

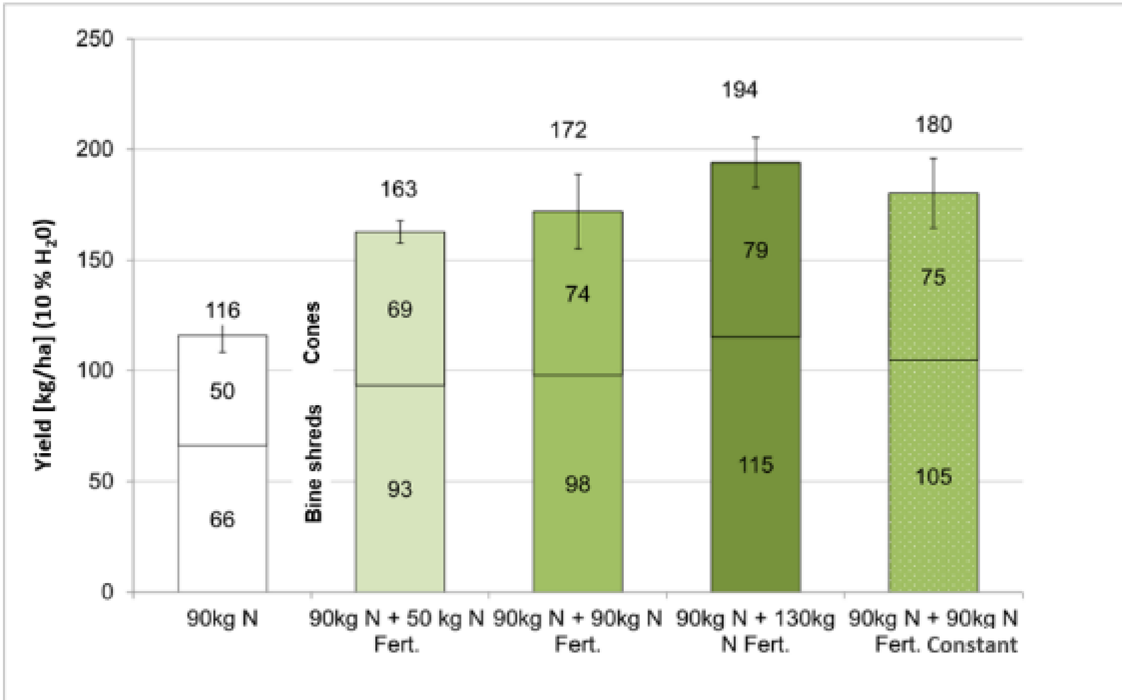


Figure 18: N removal of cones and bines of Perle under different fertilization conditions using fertigation, sandy loam, 2020

The N content of the rhizomes was 2% for the fertigation variants. This was approximately 0.5% above that for the reference variant with only 90 kg N/ha. While the N content of the Perle rhizomes was higher than that of the Herkules rhizomes, statistically it was not possible to differentiate between the two.

The N_{min} values varied considerably depending from one site and one soil type to the other. Absolute statements, however, are not yet possible because the trials lasted for only one season. Compared to the low-fertilization reference, post-harvest N_{min} were higher in the Perle variants with a total of >180 kg N ha^{-1} the Herkules variants with a total of 220 kg N ha^{-1}. The highest N_{min} contents were in the 0-30 cm range, and the lowest in the 60-90 cm range.

4.5 Research project for the development of an optimized hop kilning process with renewable energy

Sponsors: Erzeugerorganisation Hopfen HVG e. G.
(HVG Hop Processing Cooperative)

Project Management: LD J. Portner, IPZ 5a, Wolnzach

Editing: LR J. Münsterer, IPZ 5a, Wolnzach

Collaboration: Christian Euringer GmbH

Duration: April 1, 2024 to December 31, 2026

Initial situation and objectives

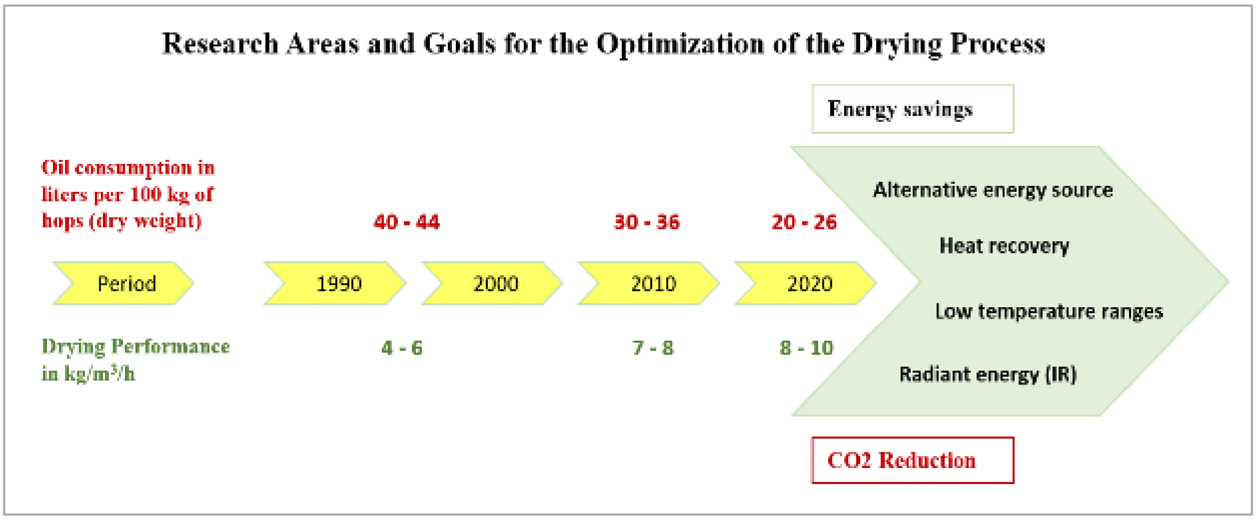


Figure 19: Research areas and objectives in hop kilning

In recent years, it has been possible to cut the energy consumption of hop kilns almost in half by significantly increasing the kiln performance. This is the result of research into optimal drying parameters. These include air velocity, bed height, drying temperature, and improvements in measuring techniques. However, these improvements still relied on designs that are based entirely on fossil fuels.

Currently, however, there is a growing demand for using more renewable energy. In the hop industry, this is only possible through the development of new, adaptive hop kilning processes involving lower kilning temperatures and better monitoring of the energy supply and better energy reclamation.

Description of the research project

A special experimental kiln needs to be designed that makes it possible to provide precisely controlled air for convection drying for the first time throughout the entire process. This requires adjusting, for instance, such factors as enthalpy, water content, temperature, and water vapor partial pressure to ensure energy-efficient and product-appropriate hop kilning.

This prototype will be built with an eye towards real-world industrial conditions. Using an adapted air flow and specially composed air, the kilning temperature will be significantly reduced while avoiding condensation.

Unlike in conventional kilning systems, the new design will allow custom-tailored air to be targeted evenly across the entire drying surface in all layers. Laboratory tests to avoid uncontrolled airflows through multiple layers or within just the drying level will be replicated in production systems.

By making use of latent heat in the form of water vapor in the system, the amount of energy in the drying air can be increased while maintaining a constant drying temperature. This results in a faster rise in the cone temperature and thus an acceleration of the drying process.

This also means that a suitable air mixing device must be developed that can supply the appropriate composition of the drying air, as well as recover heat from the drying process. The lower temperature level of this new drying process requires less primary energy, so that the total heat demand can be covered mostly or entirely by renewable energy.

To ensure that electrical energy from solar panels, for instance, can be used, this type of energy needs to be integrated into the system. Heat transfer in the form of direct heat radiation is a suitable method for this. The practical relevance of this form of energy can be tested within the framework of this research project.

Any new findings can form the basis for the future resource-efficient and economical use of renewable energy in belt and tray drying systems. It will reduce the CO2 footprint of hop production by taking a major step toward carbon neutrality in hop farming operations.

4.6 Model and demonstration projects for humus formation in hop cultivation

Sponsor:	Bundesanstalt für Landwirtschaft und Ernährung (BLE) *(Federal Office for Agriculture and Food)*
Financing	Bundesministerium für Ernährung und Landwirtschaft (BMEL) *(Federal Ministry of Food and Agriculture*
Project Management and Coordination:	J. Portner
Regional Support:	S. Arnold (Hopfenring e.V.)
Scientific Support:	Julius Kühn-Institut (Professional support)
	Thünen-Institut (Economic support)
Duration:	April 1, 2024 to March 31, 2030

Objective

The aim of the model and demonstration project (MuD), funded by the Federal Ministry of Food and Agriculture (BMEL), is to implement and scientifically monitor innovative and long-term agronomic measures for humus conservation and humus buildup in selected hop farms throughout Germany. The demonstration farms play a key role as multipliers and learning centers for disseminating successful measures in practice. Humus conservation and buildup in hop soils is thus intended to make an important contribution to preserving the terrestrial carbon sink.

Background

Humus in agricultural soils is of great importance for soil life and fertility, water balance, nutrient availability, and erosion reduction. In addition, humus in the soil binds large amounts of carbon. Thus, soil is the largest terrestrial store of organic carbon. This also applies to Germany, where agricultural soils (mineral soils and peat soils) store around 2.5 billion tons of carbon. A loss of organic carbon (Corg) in the soil due to mineralization is accompanied by the emission of CO2. In agricultural soils, this loss can be prevented and, if necessary, further CO2 can be bound through agronomic measures that ensure the input of organic matter into the soil or slow down decomposition (mineralization). Sustained increases in humus content can only be achieved over longer periods and within a limited scope.

Implementation of the MuD humus build-up in hop cultivation

In the summer of 2024, the Hop Cultivation and Production Technology Working Group (IPZ 5a) of the Bavarian State Research Center for Agriculture (LfL) in collaboration with the Hopfenring e.V. invited hop farms from all across Germany to become so-called model and demonstration farms, leading to the selection of 10 hop farms for the project. The selection criteria included data about the farm, the soil, management, and motivation. The selection also tried to be representative of the distribution of hop growing across Germany. From the Hallertau, 6 farms participated; from Spalt, 1 farm (both Bavaria); from Tettnang (Baden-Württemberg), 2 farms; and from the Elbe-Saale region (Saxony), 1 farm. To determine the current humus content on these farms, the first step is to conduct detailed soil tests on three hop fields per farm in the fall/spring 2024/25. The success of these measures can be monitored using comparison plots that continue to be farmed conventionally. In addition to recording the amount of humus buildup in these hop gardens, the project will also study the economic viability of any measures. Scientific support for the MuD project comes from the Julius Kühn Institute (JKI) and the Thünen Institute. Another key goal is to network with other MuD humus projects in other agricultural sectors, such as in arable farming, viticulture, fruit and vegetable cultivation. The project will initially last for six years. It is projected to end in the spring of 2030, at which point a review will determine if the project should be extended.

Measures

At the start of the project, the regional support team conducted a detailed analysis of the farms to identify their individual potential for humus preservation and humus buildup. They then worked with the farm to determine the measures to be implemented on three commercial plots and associated reference plots. The focus was on cover cropping, reduced and gentle soil tillage, and the management of hop harvest residues (bine chips). The introduction of organic matter from outside the field or farm must not be a focus of these measures and is only permitted in exceptional cases. To assess the effectiveness of humus-promoting measures, knowledge of the current condition of the soils in terms of physical, chemical, and biological parameters is of utmost importance. To demonstrate humus buildup, it is necessary to determine organic matter stocks (unit kg/m2 or t/ha), as the organic matter content alone does not provide quantitative information. For this purpose, the bulk density had to be determined using soil sampling rings at representative locations in the field. Changes in humus content will be evaluated through repeated testing at the end of the project. In addition, the available nitrogen content in the soil (N_{min}) will be analyzed annually in autumn and spring. If the MuD project contributes to the increased implementation of humus-promoting measures in hop cultivation, German hop growers will make a further contribution to sustainable hop production and to improving the carbon footprint.

The project is funded by the Federal Ministry of Food and Agriculture (BMEL) based on a resolution of the German Bundestag. The Federal Office for Agriculture and Food (BLE) is responsible for the project, funding codes 2822HUM201 (LfL) and 2822HUM202 (HR).

4.7 LfL projects within the framework of the Production and Quality Initiative

Between 2024 and 2028, the Bavarian State Office for Agriculture will collect, record, and evaluate representative yield and quality data for selected agricultural crops as part of a production and quality initiative for agriculture in Bavaria. For the IPZ Hops research area, these activities were carried out by the joint partner Hopfenring e.V. The objectives of the hop projects are briefly described below, along with a summary of the results for 2024.

4.7.1 Monitoring and analysis of hop quality data regarding dry matter and alpha acid content to determine optimal harvest maturity and to save energy during hop drying

Between August 13 and September 24, 2024, we harvested and dried separately one bine each of the aroma varieties Hallertauer Mfr., Hallertauer Tradition, Perle, Hersbrucker Spät, and Tango, as well as of the high-alpha varieties Hallertauer Magnum, Herkules, and Titan, on several dates (aroma varieties 5 and bitter varieties 7) from 10 commercial hop gardens throughout the Hallertau region. By determining the water removal and analyzing the dry matter and alpha acid content in an accredited laboratory, the dry matter content of the green hops and the alpha acid content at 10% moisture content were determined the following day and submitted to the LfL Hop Advisory Service for evaluation. The results were averaged, presented in tabular and graphic formats, and posted online with commentary. From the results and illustrations, farmers were able to derive information on the optimal harvest maturity of the most important hop varieties.

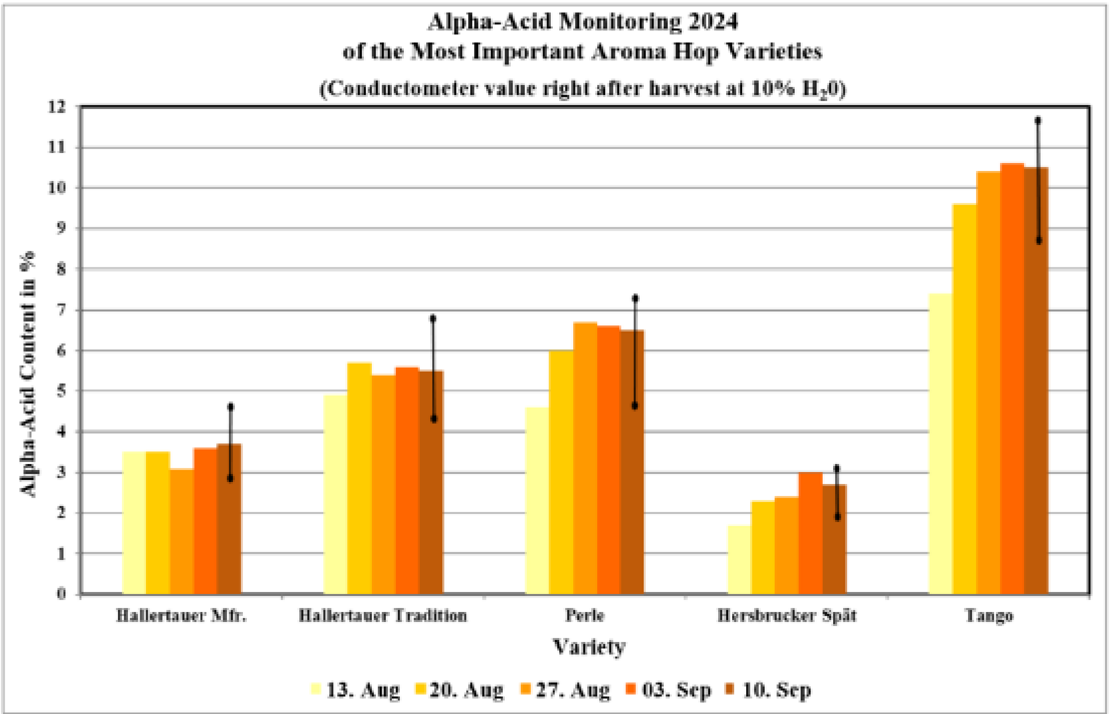


Figure 20: Monitoring the development of alpha acid contents in 2024 for the most important aroma varieties

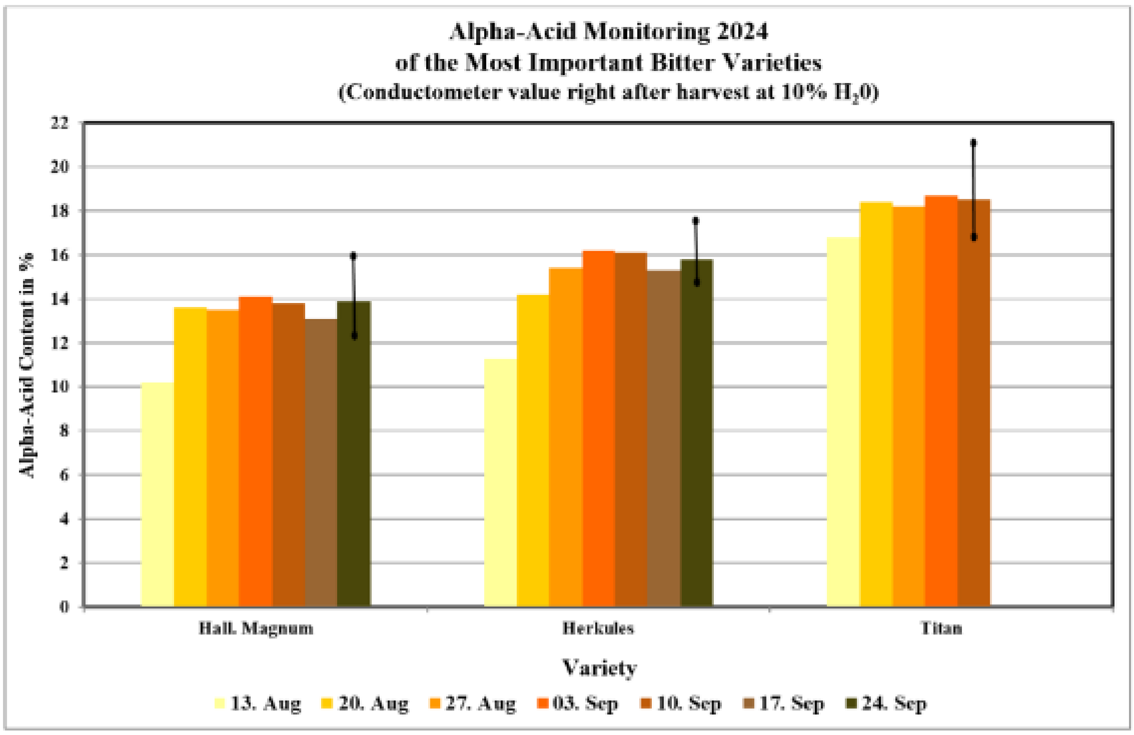


Figure 21: Monitoring the development of alpha acid contents in 2024 for high-alpha varieties

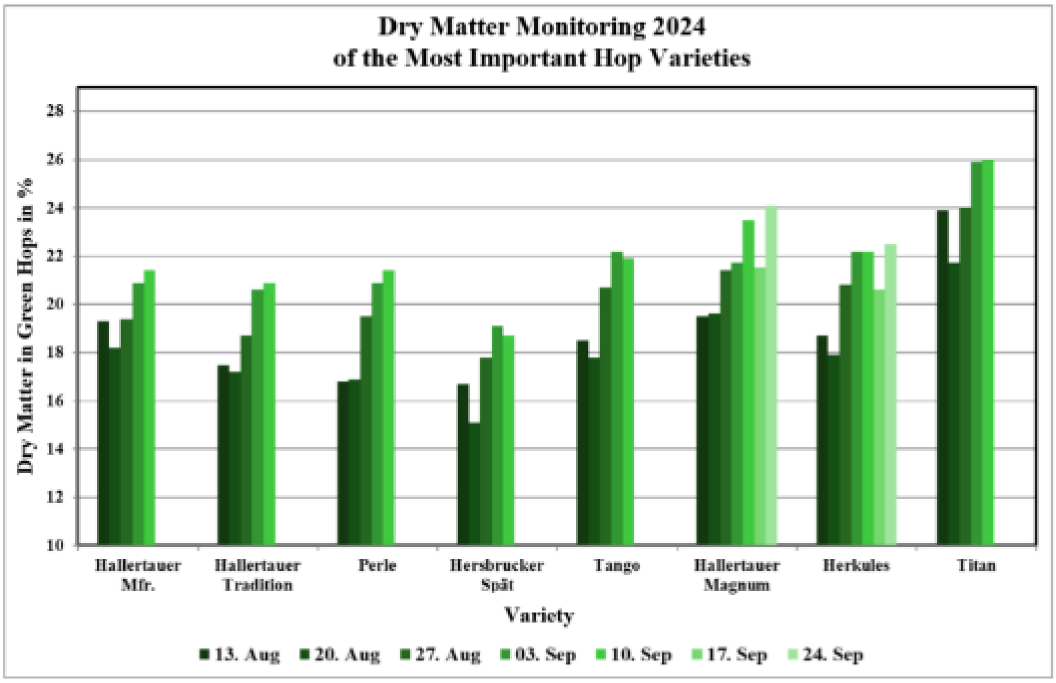


Figure 22: Monitoring of the development of dry matter contents in 2024 of the most important hop varieties

The following graphic overviews compare the alpha acid levels for Perle and Herkules in 2023 and 2024 with the average of the last 10 years, depending on the staggered harvest dates. This allows for a better assessment of the alpha acid levels of the individual varieties compared to previous years. The following figures show that the alpha acid levels for Perle and Herkules were significantly higher in 2024 than in the poor previous year and almost reached the long-term average values.

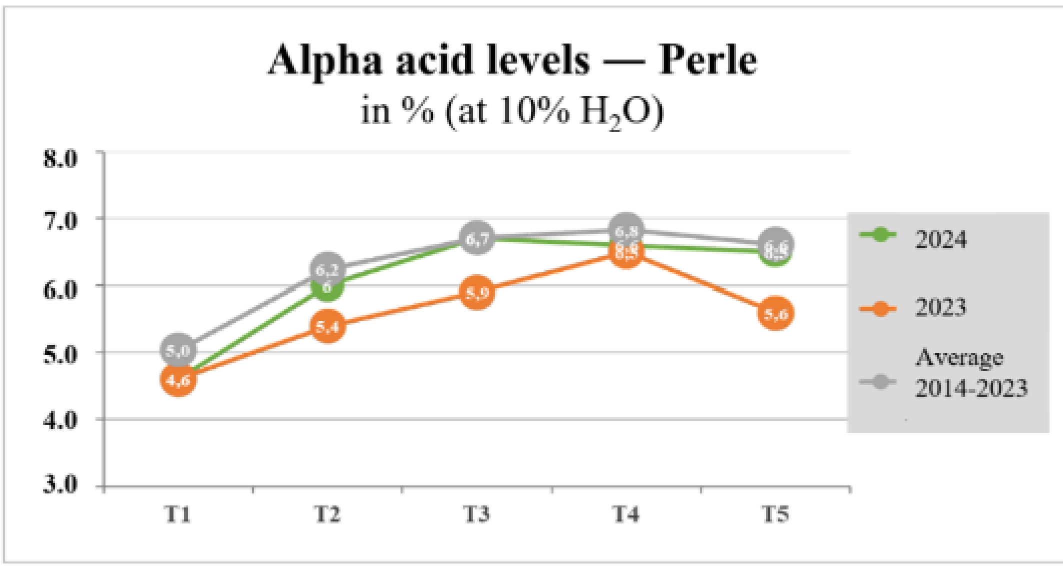


Figure 23: Development of alpha acid content in the monitoring of Perle compared to previous years

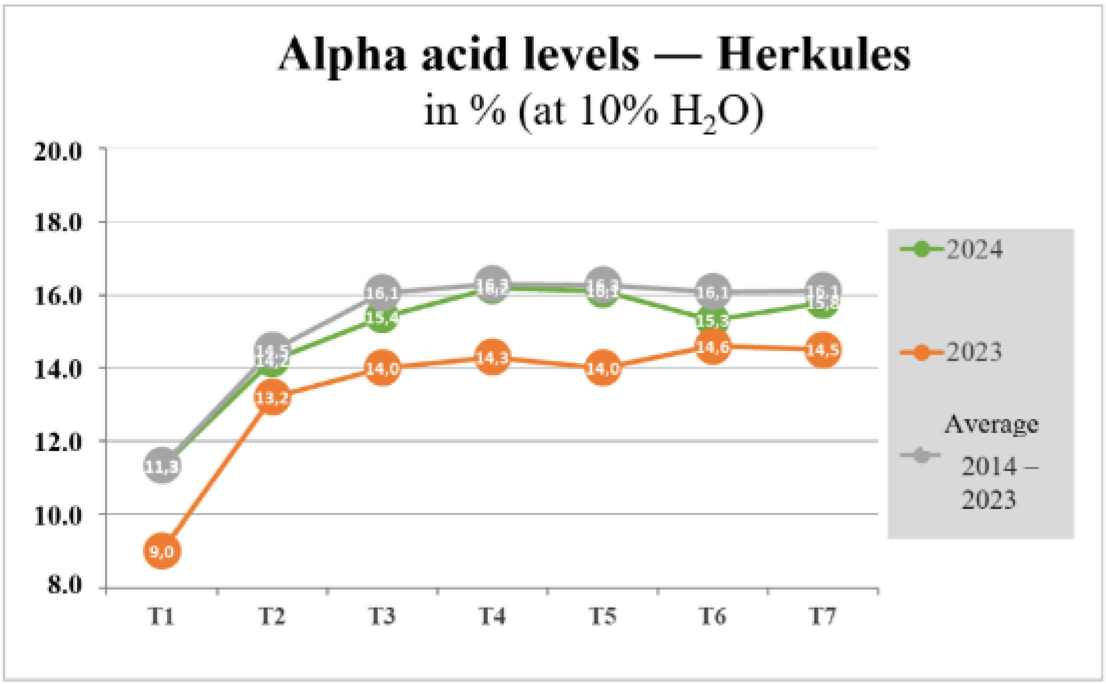


Figure 24: Development of alpha acid content in monitoring of Herkules compared to previous years

4.7.2 Annual survey and investigation of disease and pest infestation (selected pathogens) in representative hop gardens in Bavaria for targeted control and reduction of pesticide use

To assess aphid, spider mite, and powdery mildew infestations, it is necessary to survey and assess the infestation situation in commercial hop gardens precisely. This information can then be used to formulate advisory statements and control strategies.

For this purpose, assessments of infestation of hop aphids, common spider mites, and powdery mildew were carried out on 15 dates at weekly intervals between May 13 and August 19, 2024, in 33 representative hop gardens (including 3 organic hop gardens) cultivating different varieties in the Hallertau (26), Spalt (5), and Hersbruck (2). The average infestation with aphids (number), spider mites (infestation index), and powdery mildew (infestation frequency and severity) was determined.

The results of the infestation progression were incorporated into the advisory statements and control strategies. An overview of the progression of the spider mite infestation index is shown in the following figure. At the start of the assessment in mid-May, the initial infestation with the common spider mite was already comparatively high, but during the rainy summer, it did not cause any problems, even though the infestation numbers increased slightly again due to weather conditions during the cone break-out and harvest. This allowed the necessary control measures to be targeted and limited only to what was necessary.

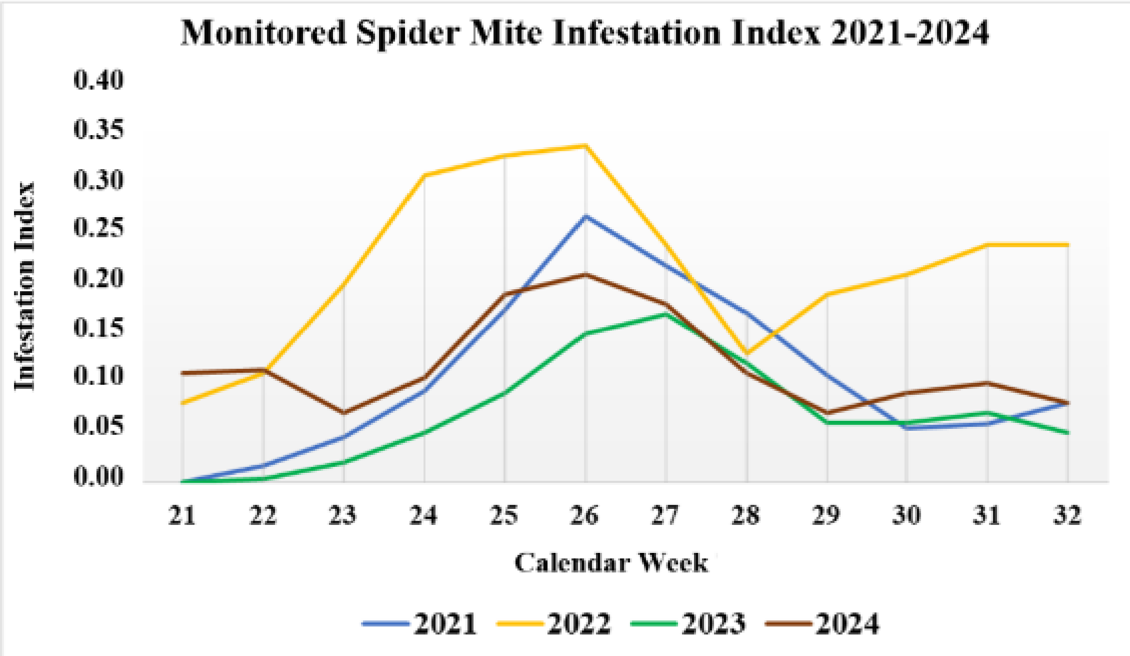


Figure 25: Course of the spider mite infestation index as an average across all 33 monitored sites

4.7.3 Chain analyses for neutral quality assurance in the determination of alpha acids for hop supply contracts

For years, hop supply contracts have included a supplementary agreement that takes the alpha acid content of the delivered hop batches into account when calculating payment. Alpha acid content is determined in state laboratories, company laboratories, and private laboratories depending on the available testing capacity. The procedure (sample splitting, storage) is precisely defined in the specifications of the "Working Group for Hop Analysis," as are the laboratories that perform the follow-up tests and the permitted tolerance ranges for the analysis results. To ensure the quality of alpha acid analysis in the interest of hop growers, chain analyses are organized, conducted, and evaluated by the Bavarian State Office for Agriculture as a neutral body.

As part of the project, the Hop Ring is responsible for sampling a total of 60 randomly selected hop batches on nine to ten dates in the Hallertau region and providing the samples to the LfL laboratory in Hüll.

4.8 Consulting and Training Activities

In addition to applied research in the field of hop production technology, the Hop Production Technology Working Group (IPZ 5a) is tasked with preparing test results for network consulting and practical applications, making them directly available to hop growers through specialized consultations, teaching, working groups, training sessions, seminars, lectures, print media, and the internet. The organization and implementation of the downy mildew warning service and the updating of warning service notices are also part of its responsibilities, as is the collaboration with hop organizations and the training and technical support of the network partner, the Hopfenring.

The following is a summary of the training and consulting activities during the past year:

4.8.1 Information in written form

- The "Green Booklet" Hops 2024 - 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 run was 2,000 copies, distributed by the LfL to the ÄELF (Early Harvesters' Association) and research institutions, and by the Hallertau Hopfenring to hop growers.
- The LfL used an established Hopfenring fax network to distribute time-sensitive cultivation instructions and warnings in 34 faxes via the Hopfenring fax (2024: 69 transmissions in Hallertau, Spalt and Hersbruck; 950 subscribers).
- Advice and specialist articles for hop growers and the brewing industry were published in seven monthly issues of the Hopfen-Rundschau and two articles 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 between May 7 and September 3, 2024. The service was available for warnings, instructions, and inquiries via an answering machine (Tel. 08161 8640 2460) or the internet. The service was updated 82 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

- Review of 3 projects written by master’s degree students as part of their degree requirements
- 9 lessons about hop cultivation at the Pfaffenhofen Agricultural School
- 1 study day during the summer semester at the agricultural school in Pfaffenhofen Agricultural School
- 2 seminars and 2 workshops for hop growers on the subject of hop drying and conditioning
- 4 meetings of the “Hop Management” working group

5 Plant Protection in Hops

5.1 Official Effectiveness Tests

Management: S. Euringer

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

In the 2024 trial year, nine trials were conducted in accordance with the GEP (Good Experimental Practice) standard in the official product testing program. Furthermore, several greenhouse trials were conducted on powdery mildew and plant tolerance. The GEP trials covered six indications. A total of 19 new products or combinations were tested in 31 trial units on approximately 4.2 hectares.

Table 12: GEP trials of the Official Product Testing 2024

Indication	New Products/Variants	Total Experimental Units
Lovage weevil	3	5
Hop aphid	5	7
Powdery mildew	7	9
Residue tests (herbicide)	2	4
Verticillium	1	2
Strippable residues	1	4
Total	**19**	**31**

5.1.1 New test sprayer for official product testing

The application technique in hop cultivation is hardly comparable to that in arable farming. Instead, it presents several special challenges, especially in experimental settings. Due to the application height of 7 m and the associated application technique (fan sprayer), a much larger plot must be selected in hop cultivation than in arable farming to prevent possible drift into the net plot/assessment area.

Due to the completely randomized block system of the experimental setup, soil compaction is an issue in hop cultivation. Because of the random distribution of individual plots within the respective blocks, the previous experimental system resulted in a large number of passes per lane. The equipment had only a single spray tank. This ensured that the plots of the individual experimental units were treated one after the other. As a result, some of the spray rows saw much more traffic than others, which, under unfavorable weather conditions, caused increased soil pressure and structural damage. With the new experimental technology, which has been in use since 2024, the plots can be treated sequentially with just one pass per spray row/line. This new spray technology, funded by HVG e.G., has revolutionized experimental work at the Hop Research Center. It enables both more soil-friendly and more precise experimental work. The experimental plots could be treated not one after the other, but almost simultaneously, thus reducing the influence of time differences of applications significantly.

Figure 26: Multi-chamber test sprayer of the official product test

5.2 Resistance and efficacy tests against hop aphids in a spray tower

Management: S. Euringer

Editing: A. Baumgartner, M. Felsl, S. Robin, R. Stampfl

Hop aphids attack all hop varieties every year. However, the disappearance of many important insecticides from the market makes it significantly more difficult to vary active ingredients to avoid resistance. Repeated use of the same or similarly operating active ingredients leads to selections among pest populations with resistances against these ingredients. Therefore, current and new active ingredients are being tested in spray tower trials for resistance in hop aphids. Results in laboratory trials already produce consistent results and resistance can be detected early. Four active ingredients were tested in 2024. However, it is still possible that such laboratory results may not apply to field conditions, which is why these lab results are not being published.

5.3 Enzyme-linked immunosorbent assay (ELISA) for the identification of hop mosaic virus (HpMV), apple mosaic virus (ApMV) and arabis mosaic virus (ArMV) hop infections

Management: S. Euringer

Editing: S. Robin, A. Baumgartner, M. Felsl

Viral diseases are widespread in all hop-growing regions. To identify and detect virus-infected plants, the ELISA test was reintroduced at the Hüll Hop Research Center.

Table 13: Results of ELISA tests in 2024

	Total number of plants	ApMV		HpMV		ArMV		Total Plants	
		n.n.	positive	n.n.	positive	n.n.	positive	n.n.	positive
Mother plants for hop propagation	201	200	1	199	2	/	/	198	3
Breeding material IPZ 5c	586	578	8	564	22	/	/	556	30
Additional samples for a bachelor's thesis	89	39	50	53	36	89	0	26	63
	10	3	7	6	4	/	/	2	8

* n.n. = undetectable

Samples with a result close to the detection threshold are considered positive to minimize the risk of potentially infected material entering the replication process.

Of the 787 plants tested, 33 were rejected. The healthy plants were provided to the GfH's contract propagator as breeding material and mother plants.

The processing of 99 additional samples and additional testing for ArMV was carried out as part of a bachelor's thesis (supervised by K. Lutz) on the occurrence and severity of symptoms of virus infections in hops in the Hallertau region.

5.4 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 Cooperative)

Project Management: S. Euringer

Team: Dr. C. Krönauer, F. Weiß

Duration: April 1, 2023 to March 31, 2026

Collaboration: Molekulare Diagnostik: Virologie IPS 2c
(Molecular Diagnostics: Virology)

Züchtungsforschung Hopfen IPZ 5c, B. Forster, P. Hager, B. Haugg
(Hop Breeding Research)

Beratung und Produktionstechnik: IPZ 5a
(Consulting and Production Technology)

Slovenian Institute of Hop Research and Brewing: Dr. S. Radišek

Viroids are infectious particles consisting of single-stranded, circular RNA. The citrus bark cracking viroid (CBCVd) is a pathogen in hops that causes severely stunted growth, chlorosis, and smaller, malformed cones, which lead to severe yield losses. CBCVd was first detected in the Hallertau region in 2019. Since 2023, according to the International Committee on Taxonomy of Viruses (ICTV), CBCVd has been classified as a member of the genus *Cocadviroid*; and the correct species name is *Cocadviroid rimocitri*.[1]

The CBCVd research project is divided into five project areas: field hygiene, remediation, establishment of a variety garden, yield assessment, and pathogen biology. The aim of the CBCVd research project is to use the findings to create an evidence-based basis for the future management of CBCVd in agricultural practice.

The field trials will be conducted in a 1.9-hectare hop garden, which is suitable as a test area because of its history of severe CBCVd infestation. Pot trials will also be conducted in the greenhouse in Freising.

In spring 2023, a variety garden was planted to monitor the susceptibility to CBCVd of more than 20 hop varieties and breeding lines currently cultivated worldwide. In 2024, just one year after planting, some plants were already detectably infected with CBCVd. The spread and differences in the symptoms in the different varieties will be recorded throughout the project.

A sub-area of approximately one hectare will be used to test whether it is possible to cultivate a new crop on a previously CBCVd-infested plot and have the new plants stay healthy. The third of four remediation sections was cleared in autumn 2024. The other two sections were cleared in 2023 and 2022 and have been undergoing remediation for one and two years, respectively. Replanting is planned for the spring of 2026.

On a further 0.5 ha, three field sections will be compared to determine if there are differences in the rate of the spread of CBCVd infections after three years of normal cultivation, cultivation with the best possible disinfection, and minimal cultivation.

To assess the specific damage caused by CBCVd infections, a trial harvest was conducted in 2024. For this purpose, the cones of both CBCVd-symptomatic and visually healthy plants of Herkules were mechanically harvested under field conditions. In addition to the fresh weight, the relevant components were determined. The results are part of M. Fischer's bachelor's thesis and are expected to be available later in 2025.

Information on the CBCVd research project, CBCVd monitoring, and a leaflet on field hygiene in hop cultivation are available on the LfL website. Based on our previous findings, hop growers will receive advice on preventing CBCVd infections, as well as support with containment measures. Detailed test results are planned to be published at the end of the project period in 2026.

References

1) International Committee on Taxonomy of Viruses (ICTV). Retrieved on January 10, 2025, from https://ictv.global/taxonomy//

5.5 Sprayable mulch material for weed control in hop cultivation

Collaboration: Technologie- und Förderzentrum im Kompetenzzentrum für nachwachsende Rohstoffe (TFZ)
The Technology and Support Center in the Competence Center for Renewable Resources (TFZ)

TFZ Project: Spritzbares Mulchmaterial im Wein- und Obstbau
(Sprayable mulch material in viticulture and fruit growing)

Financing: Bayerisches Staatsministerium für Ernährung, Landwirtschaft, Forsten und Tourismus, (StMELF)
Kennzeichen G2/N/18/09
(*Bavarian State Ministry of Food, Agriculture, Forestry and Tourism)*

Initial situation and objectives

In hop cultivation, in line with integrated pest management, many measures relying on herbicides are already being replaced with mechanical measures. For example, the previous year's weed population is removed at the early bine trimming stage; and a few weeks later, any newly emerging weeds and some of the redundant hop shoots are mechanically removed. As the season progresses, the plots are tilled as soon as possible to deal with any remaining shoots as well as any newly sprouted weeds and grasses. Tilling is then repeated throughout the season, which covers newly emerged weeds again with soil. Between the first tilling and the second tilling, as well as after the second tilling, superfluous hop bines are trimmed and thinned out—especially the lower leaves and side shoots, as well as any newly emerging ground shoots. Therefore, with less mass to treat, herbicide applications can be reduced to as little as one-third of the permitted amount per hectare. Growers currently have three herbicides at their disposal, in addition to non-chemical measures such as hand defoliation or flame-treating: Quickdown (US MRL 0.02 ppm; efficiency is currently unknown); Beloukha (no JP MRL); and Vorox F, approved up to BBCH 55.

If such green mass reduction is performed by hand defoliation, it is also beneficial to seal the furrows between the rows of hops with Vorox F after the second tilling. This requires a graduated approach depending on the hop growing patterns, the shading, and the weed pressure in the field. This ensures the workability of the plot in the fall or the following year. This measure is difficult to implement if the weed pressure is too high. In addition to the Vorox F treatment, growers can use Fusilade Max (grass-type weeds other than annual panicle) and U46 M-Fluid (other weeds). Both can be used only in hop plots cultivated for the European market.

Alternatively, a self-degrading, two-component mulch material can form a physical barrier that suppresses the germination and growth of weeds without the use of herbicides. In combination with manual defoliation, this would represent a permanently and completely herbicide-free process. Furthermore, it would mitigate any lack of available herbicide.

As a result of the physical barrier function, sprayable mulch material could also control flea beetles, which lay their eggs primarily after the first and before the second tillage. Because the new flea beetle generation appears only after the second tillage, a physical barrier of the spray mulch applied to the entire first-time tillage area could also for prevent new flea beetles from reaching the surface.

Another benefit of sprayable mulch material is its suitability for organic farming, as the Federal Office of Consumer Protection and Food Safety has determined, because such material does not fall within the scope of European Union Regulation No. 1107/2009 covering plant protection products [Menger et al. 2022].

Methodology

The test site was located at Stadelhof on loamy, sandy soil. It was set up a few days after the second tilling as follows:

Table 14: Test variants at the Stadelhof site

Image No.	Test	Variety	Shoots	Type of pretreatment
Spray mulch 5 mm				
1a – 1d	1	Perle	Removed from the spray area and stapled to the center.	Hand-defoliated (no herbicide use in 2024))
2a – 2d	2	Herkules		
3a – 3d	3	Herkules		Chemical hop cleaning* 1. Hop cleaning: Vorox F (20 g/ha) 2. Hop cleaning: Beloukha (5.3 l/ha) Each with Innofert (250 l/ha), wetting agent
4a – 4d	4	Herkules	Removed from the spray area and stapled to the center.	
Zero-controls (no spray mulch)				
0 1a – 0 1d	1	Perle		Hand-defoliated (no herbicide use in 2024)
0 2a – 0 2d	2	Herkules		
0 3a – 0 3d	3/4	Herkules		Chemical hop cleaning* 1. Hop cleaning: Vorox F (20 g/ha) 2. Hop cleaning: Beloukha (5.3 l/ha) Each with Innofert (250 l/ha), wetting agent

* The application rate refers to row treatments: Vorox F 20 g (application rate: 60 g/ha) and Beloukha 5.3 l (application rate: 16 l/ha) were applied exclusively to the furrows area.

For the second hop thinning in the "chemically defoliated" variants, Beloukha (pelargonic acid) was chosen as the herbicide, as pelargonic acid only has a "burning effect" and causes no long-term damage.

The sprayable mulch material was applied a few days after the second tilling, on June 26, 2024, using a special application device from the TFZ (Figure 27). The two components, listed in Table 15, are transported in a separate pipeline system to the static mixer, where they are combined and applied immediately to the field surface [Kirchinger et al. 2023], in a roughly approximately 5 mm thick layer. This ensured good wetting of the slightly clumped soil. The application was carried out in two steps, each covering half of the furrow area (Figure 26).

Figure 27: Application device "SAM" (system for the application of mulch material) equipped with one tank per component, a separate piping system, and a mixer for application in the furrow

Figure 28: Application of the two-component 5 mm thick and 1.2 m wide mulch material along the second half of the furrow in VG3

The sprayable mulch was applied in the "hand-defoliated" variant to Perle and Herkules in the furrow area of 14 plants each. Furthermore, the "chemical hop trimming" procedure was applied repeatedly to 14 Herkules plants in two adjacent furrows. In trial section four, the chemically defoliated side shoots were attached manually without tools between the two bines before the mulch application (Figure 29). The aim was to ensure the most homogeneous wetting of the furrows and to avoid any potential spray "shadow" caused by side shoots. Likewise, the drooping side shoots in the two "hand-defoliated" variants were attached away from the spray area to the middle of the two bines. In trial section three, the treatment was carried out leaving the side shoots naturally drooping.

Figure 29: Photo taken on the day of application (June 26, 2024) Herkules variants chemically defoliated; left side of furrow shoots (VG 3) not removed from the spray area; right side of furrow (VG 4) side shoots removed from the spray area and attached to the center

A simple repetition was chosen because this was the first time the mulch material had been used on hops, and therefore there was no previous experience with the hops' compatibility with the mulch material. Accordingly, a smaller area was treated to limit any potential damage to the hop crop. The application time extended over approximately 4.5 hours, during which the two components were mixed by hand, the application device was refueled several times, and the application was carried out on the test plots. The application itself went out quickly, but given the current state of technology, a person had to walk behind the tractor to monitor the application arm and occasionally adjust it.

Information about the mulch material. The sprayable mulch material consists of renewable raw materials [Megner et al. 2024]. It is applied using two liquid components that are mixed together shortly before application to the field surface. The contact of the two liquids causes the material to gel immediately [Follak et al. 2024]. The mulch material then hardens, forming a layer that is difficult for weeds and grasses to penetrate. All ingredients are harmless to human health and environmentally friendly according to the REACH regulation (Registration, Evaluation, and Authorization of Chemicals). After the growing season, microorganisms biodegrade the mulch material completely [Menger et al. 2022].

Table 15: Recipe for sprayable mulch material Hop trial 2024

Component	Ingredient	Function	Share in Mass-%
A	Rapeseed oil	Base	30.8
	Sodium alginate	Gelling agent	1.3
	Calcium sulfate	Gelling aid	1.5
	Cellulose fibers	Filler	2.4
B	Starch	Binder	12.5
	Water	Solvent	45.6
	Glycerin	Plasticizer	4.6
	Sodium phosphate	Gelling Control	0.3
	Sodium benzoate	Preservative	1.1
	Sorbitol	Humectant	2.3

The first assessment to evaluate the weed-suppressing effect of the mulch material took place on July 1, 2024, in trial units one to four. Trial unit zero was not included until August 8, 2024. The final assessment was on September 6, 2024. This involved a photographic assessment of previously marked points numbered as "Image No." in Table 14. The images were recorded in a standardized manner using a frame loaned from the TFZ, to which the camera could be attached using an adapter. This ensured a consistent distance between the camera and the soil surface. At the same time, the assessment frame marked the subsequent evaluation area for the image software.

Figure 30: Image taken on 1 July 2024 in Perle (1a) using a scoring frame

The soil cover level at the assessment sites was calculated using the "Canopeo" image software, allowing for an objective evaluation of the weed suppression effect. The soil cover level was calculated by analyzing all green pixels in the image, which were then compared to the total number of pixels in the photograph.

Harvest results were collected only for Herkules. Twenty bines were harvested from each of the different variants.

Results

The sprayable mulch cover demonstrated good effectiveness against the growth of weeds and grasses in the trial, as shown in the subsequent analysis by the TFZ using image software. In the zero variant, which is shown here as a summary of all variants, a significantly higher percentage of soil cover was monitored over time compared to the mulch variants. A more differentiated analysis revealed a greater effect in the slimmer Perle stand due to less shading than in the Herkules variety, as can be seen from the images taken on February 19, 2025.

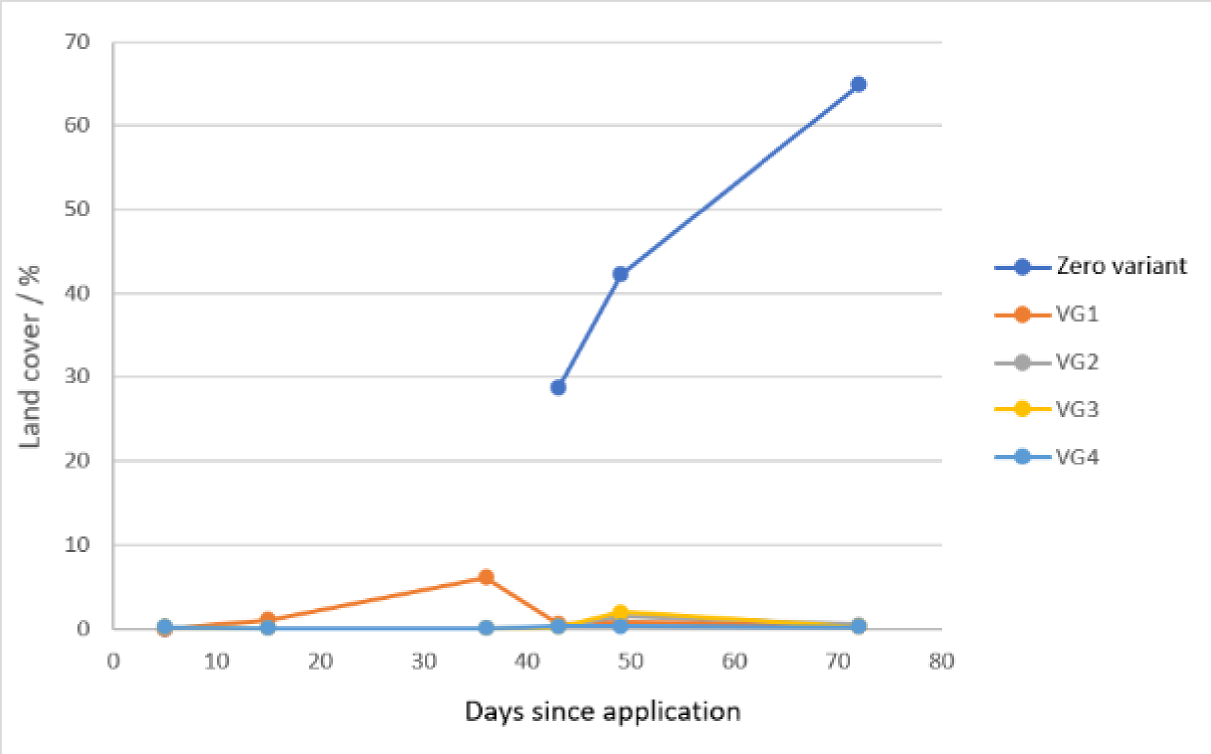


Figure 31: Development of the soil cover ratio of the different variants (zero variant = no spray mulch, VG1 = Perle hand-defoliated spray mulch (SM); VG2 = Herkules hand-defoliated SM, VG3 = Herkules chemically defoliated SM, VG4 = Herkules chemically defoliated SM) from 1 July 2024 to 6 September 2024

February 19, 2025: Perle (furrow 28, gap 3-4 spray mulch, gap 1-2, no spray mulch)

February 19, 2025: Herkules spray mulch (Furrow 28, gap 12-14)

February 19, 2025: Herkules no spray mulch (Furrow 29, gap 12-14))

The yield determinations should be viewed with extreme caution because of the small area and the fact that they were only repeated once, which is not very meaningful. The yield determination was carried out because bines showed damage from the mulch material. The yield loss due to the damage was to be recorded in terms of yield. The damage appeared to occur primarily in areas where the mulch material converged and accumulated on the bine, as shown in the following figure.

Figure 32: Accumulation of mulch material on the bine five days after application in chemically defoliated Herkules

Damaged bine in the chemically-defoliated Herkules with spray mulch (VG 4) on September 6, 2024.
Left picture: shoots and right picture: bine

Damaged bines in VG 4 on September 6, 2024

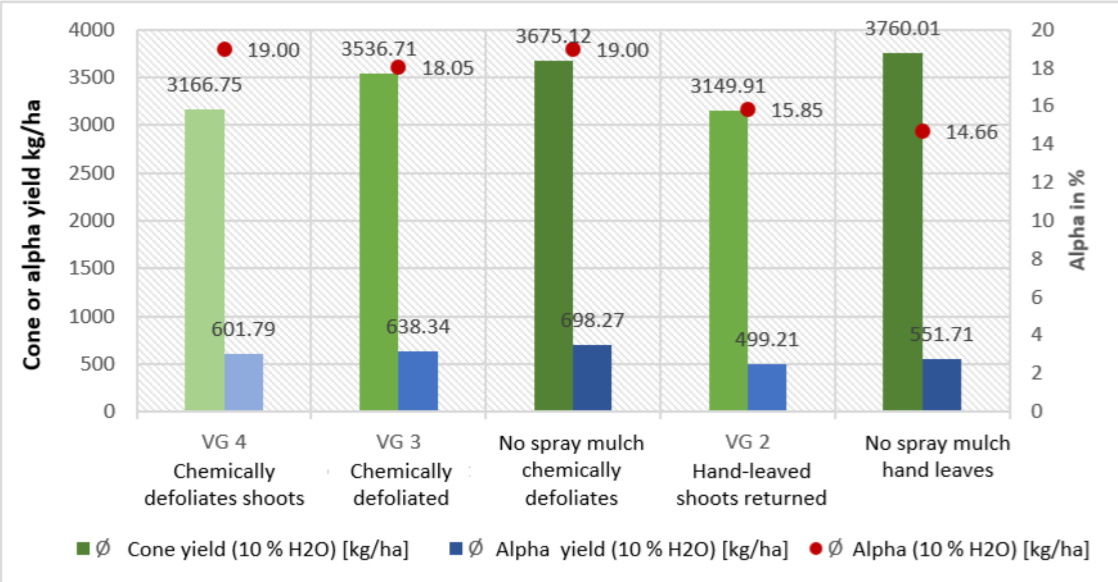


Figure 33: Yield representation of Herkules in the different variants compared to a neighboring variant not treated with spray mulch – starting point 20 harvested bines per variant

Because of the small size of the test area, a reasonable assessment of flea beetle infestation was not possible. However, observations indicate cracks in the material at the edges of the lumps probably did not create a sufficient barrier. Flea beetle damage was observed on the plants. However, this damage could also have been caused by flea beetles from adjacent untreated plots.

In summary, weed suppression worked well under given test conditions at Stadelhof. The indication of flea beetle does not appear very promising based on current knowledge, but further trials with an adapted test setup are required for final clarification. The practical suitability of this method is not yet established because the preparation and application of the mulch material is still too time-consuming, and the material costs are currently very high. However, the most critical issue right now appears to be that some of the bines were damaged or even died as a result of the application.

Literature

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Menger A., Kirchinger M., Remmel E. (2022): Schule und Beratung, Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten, ISSN: 0941-360X

5.6 CBCVd Monitoring 2024

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, Forsten und Tourismus, (StMELF) Kennzeichen G2/N/18/09 (*Bavarian State Ministry of Food, Agriculture, Forestry and Tourism)*
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 1, 2024 to December 31, 2024
Sampling Period	July 2024 to August 2024

Planning and Execution

Citrus bark cracking viroid (CBCVd, *Codadviroid rimocitri*) causes noticeable dwarfism and severe yield losses in hops. The LfL therefore conducts annual monitoring of infections to develop strategies for control and prevention in the Hallertau region. In the 2024 CBCVd monitoring, 232 fields from 66 farms were examined. In addition to hop farms that had proactively registered for monitoring because of plants with symptoms, 50 suppliers to the Hallertau biogas plant were randomly selected to participate in the monitoring, as in the previous year. A total of 579 hectares were searched for plants exhibiting the characteristic symptoms of CBCVd infection. These include cracked bines, stunted growth, smaller leaves, and misshapen cones. Aerial photographs were also taken with a camera drone. Areas that had been infested with CBCVd in recent years and thus not harvested are still classified as CBCVd-positive and were not sampled. Also, it is very unlikely to find latent infestations in areas with a very uniform stands and no weak plants. Thius, they were not sampled either and were and classified as CBCVd-negative. On the remaining areas, leaf samples from seemingly infected plants were collected and tested for CBCVd infestation using qPCR. The sample locations and area findings were digitally recorded in a geographic information system app and evaluated using R.

Findings

Because of the frequent and heavy rainfall during much of this year, the symptoms of CBCVd-infected hop plants were less pronounced and comparatively difficult to detect. In contrast to the previous two years, the plants frequently reached the height of the trellises, before there were signs of CBCVd. Nonetheless, strong spreads of CBCVd were observed on individual farms that generally implement little or no control measures.

One success of the monitoring efforts in recent years is that no CBCVd-infected plants were found this year on three farms that had begun to experience infestation in previous years.

The successful prevention of the spread is the result of extensive harvesting measures in previous years and a low initial infestation. This once again highlighted the crucial importance of removing infected plants as early and completely as possible for infection control. In order to continue to monitor the spread of CBCVd and to be able to offer appropriate advice, voluntary CBCVd monitoring is planned again in 2025.

Table 16: Figures and results of the CBCVd monitoring 2019 - 2024

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

1) After the initial infestation was detected, comprehensive monitoring was no longer possible in 2019. Therefore, the spread of CBCVd is assumed to have been under-reported in 2019.

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

Year	**2019[1)]**	**2020**	**2021**	**2022**	**2023**	**2024**
Number of samples tested	320	2312	416	513	249	172
- of which are CBCVd positive	67	157	77	56	43	33
Number of farms inspected[2)]	17	431	162	194	64	66
- Farms with initial CBCVd detection	3	4	3	3	1	1
- Farms with CBCVd detected in the respective year	3	7	9	12	12	11
Number of fields inspected[2)]	54	650	310	407	226	232
- of which are CBCVd positive	12	28	39	41	52	59
Total area inspected [ha]	106	1868	726	1204	520	579
- of which are CBCVd positive [ha]	44	83	109	110	147	160
- Cleared area formerly CBCVd positive[ha]	2	6	9	3	4	nd

5.7 Innovative strategies for controlling *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, and Forsten (StMELF) (*Bavarian State Ministry of Food, Agriculture, and Forestry)* Erzeugerorganisation Hopfen HVG e. G. *(HVG Hop Processing Cooperative)*
Project Management:	S. Euringer
Team:	K. Lutz, F. Weiß, B. Forster, P. Hager, B. Haugg, Team IPZ 5b
Collaborators:	AG Züchtungsforschung Hopfen (IPZ 5c) *(Hop Breeding Research)* AG Mikro- und Molekularbiologie (*Micro-and Molecular Biology* (AL 1c): Dr. V. Flad, B. Munk KU Eichstätt- Katholische Universität Eichstätt-Ingolstadt (Catholic University Eichstätt-Ingolstadt): Dr. M. Stark Slovenian Institute of Hop Research and Brewing (IHPS): Dr. S. Radišek
Duration:	October 30, 2023 to October 31, 2026

Objectives

The pathogen that causes hop wilt (*Verticillium nonalfalfae*) spreads through the soil, seedlings, and harvest residues. According to current knowledge, infected plants cannot be cured.

The aim of the project is to develop practical strategies through field trials to reduce *Verticillium* infestations using an on-farm approach. Existing measures will be evaluated and combined with new approaches to create a unified concept.

Current status of implementation

<u>Work package 1: Remediation measures</u>

In three hop fields, the hop bines were removed from the field, and non-host plants (cereals/corn) were planted for two years. Host hops and dicotyledonous weeds were removed mechanically; and dicotyledons, chemically when necessary. Two of the three test fields were planted first with rye and then with corn; the third field was planted with rye for two years.

The hop gardens were replanted in autumn 2023 and spring 2024 with the *Verticillium*-tolerant varieties Titan and Herkules, respectively. During the assessment of the young plants in 2024, only six hop plants showed *Verticillium* symptoms in one of the three hop gardens. The infected hop bines will be removed from the plot for the 2025 season.

The trials show that a two-year rehabilitation in the absence of dicotyledonous host plants significantly reduced the infection pressure in the fields, thus achieving the objective returning the plots back to health for replanting. The hop gardens will be assessed regularly until 2026 to evaluate the long-term success of the rehabilitation.

Work package 2: Breeding wilt-tolerant varieties

In a trial plot called the Gebrontshausen Selection Garden, where the wilt tolerance of varieties and breeding lines is tested, significant differences between cultivars were observed during bi-weekly assessments in 2024. Findings about the wilt tolerance of these varieties compared to the tolerant reference variety Herkules will be published later in the research project.

Work Package 3: Field assessments using remote sensing

See 5.8

Work Package 4: Innovative approaches to *Verticillium* management

At the start of *Verticillium* infestations in hop gardens, the spread of the fungus can still be significantly slowed by promptly removing the symptomatic plants. In years with favorable infection conditions (only a few days above 30 °C, precipitation >100 mm/month), almost all infected hop bines can be identified. This results in fewer diseased plants in subsequent years, and the area can be managed economically and sustainably in the long term.

Work Package 5: Detection of *Verticillium* using qPCR (IPZ 5c)

Examinations of samples from hop fields at various farms in the Hallertau region showed that mild *Verticillium* strains are now present only in a few areas. Of the 129 samples examined, qPCR analysis detected just three mild strains but 79 lethal strains. *Verticillium* was not detected in the remaining 47 samples.

Work Package 6: Rhizobiome in Hops

For the Hop Rhizobiome subproject, 64 bine, root, and soil samples were collected from Hallertauer Tradition in the "Gebrontshausen" experimental garden on three occasions. The samples were submitted to IPZ 5c for qPCR analysis. A sufficient number of both positive and negative plants were identified. Sequencing and analysis at AL 1c took place during the winter of 2024/25. The results are expected to be available in mid-2025.

5.8 Evaluation of vegetation indices for the detection of *Verticillium* in hops using short-range remote sensing with UAV-supported hyperspectral sensors

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 Brauereien München e. V.
(Scientific Station for Munich Breweries)

Project Management: M. Stark[1], S. Euringer[2]

Team: F. Fleischer[1], M. Stark[1], K. Lutz[2], F. Weiß[2]

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(*Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)*

Duration: June 1, 2024 to June 30, 2025

Project Description

As part of the collaborative project "Evaluation of vegetation indices for the detection of *Verticillium* in hops using short-range remote sensing with UAV/drone-supported hyperspectral sensors" (UAV = “unmanned aerial vehicle”), the University of Eichstätt-Ingolstadt is responsible for the scientific processing and analysis of the hyperspectral data collected by the LfL. The aim of this study is to systematically process hyperspectral data from two hop gardens in the Hallertau (Jebertshausen and Berghausen) and compare them with terrestrial assessments to evaluate the suitability of hyperspectral vegetation indices (VIs) for the detection of *Verticillium*.

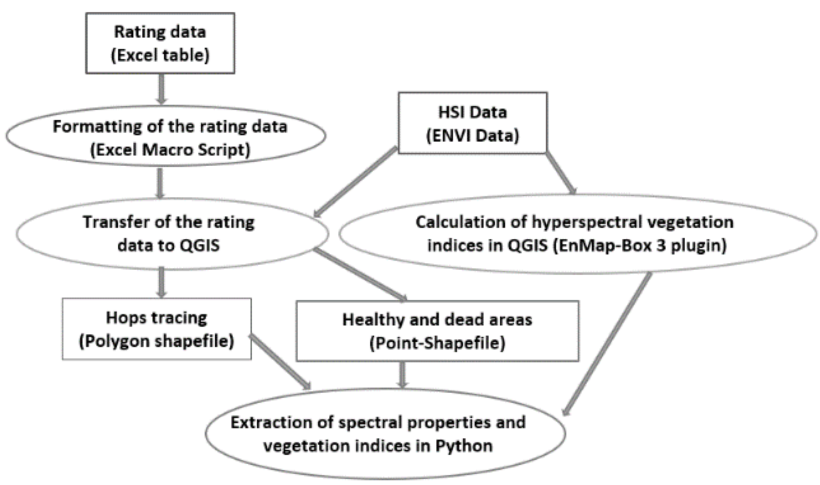

Figure 34: Schematic representation of data preparation

Data preparation and analysis are carried out in three coordinated work packages (data preparation, analysis of the VIs, derivation of recommendations for action). In the first step, the raw data are processed, relevant VIs are calculated, and the results of the terrestrial assessments are processed (Figure 34). The calculated VIs are then compared with the results of the traditional single-bine assessment to identify the most suitable indices for the precise detection of *Verticillium* infestation in hops. In the long term, the findings will be integrated into the working methods of the Hop Research Center and used as a basis for further research.

Materials and methods

The radiometrically calibrated and georeferenced datasets were available as contiguous flight strips. All subsequent analysis steps were scripted in Python and can be executed in the Jupyter Notebook environment. The terrestrially recorded assessments were re-sorted using a Visual Basic for Applications (VBA) script to ensure better orientation between the assessment table and the mapping base. Using the Vegetation Index Toolbox of the QGIS plugin EnMAP-Box 3 (DLR), 50 different hyperspectral VIs were calculated for each dataset. These exhibit different sensitivities to structural, biochemical, or biophysical properties of the vegetation. The automated extraction of spectral values and VIs was performed in two different ways: 1. object-based (polygon of a hop plant) and 2. pixel-based. In pixel-based analysis, the measured values are derived directly from the corresponding location of the hop plant, whereas in object-based analysis, various statistical parameters are calculated for the respective polygon (e.g., mean, standard deviation, median, minimum, maximum, interquartile range (IQR), mean absolute deviation (MAD)). The representation and analysis of the spectral signatures took place in several steps. The most important ones include the creation of smoothed spectrograms grouped by assessment and infestation classes and the analysis of significant differences in the spectral signatures between the groups (Kruskal-Wallis test). The analysis of the VIs was carried out using various statistical methods (Spearman correlation analysis, point-biserial correlation, random forest analysis, feature importance within the random forest model) to investigate relationships between the VIs and the observed disease characteristics. Hyperspectral image analysis can be performed using a variety of classification methods. For the present study, surveillance-based classification using a random forest model was selected.

Results

Figure 35 shows an uneven distribution of hop bines across the various assessment classes, with especially class 3 exhibiting a significantly disproportionate frequency. In contrast, other classes (4, 5, 7, and 8) are significantly underrepresented. Mapping the infestation classes (healthy and dead) reveals a significantly more homogeneous distribution of the samples.

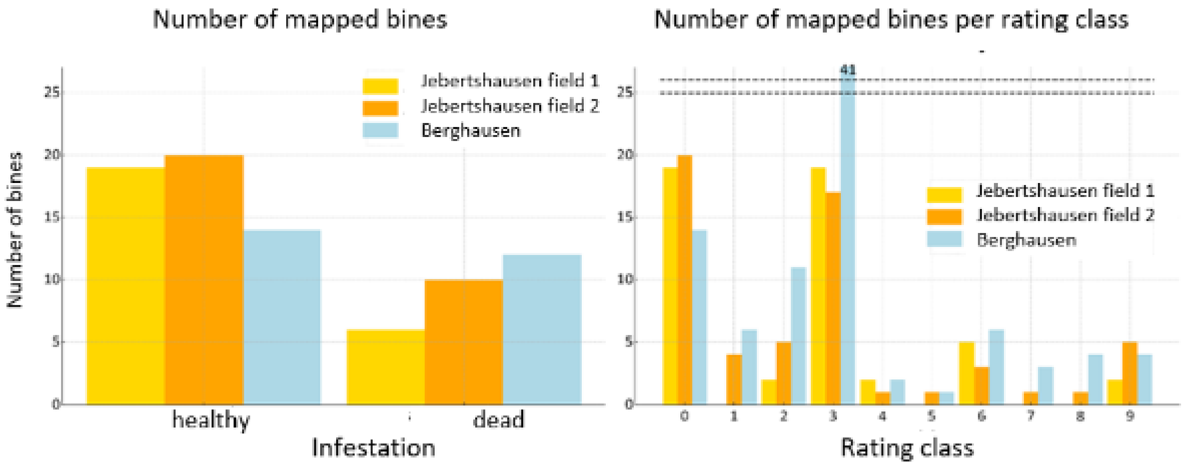

Figure 35: Number of mapped hop bines differentiated by assessment class, field and survey date (left) and number of mapped points for the infestation class (healthy and dead) that were used for further analysis

<u>Spectral signatures</u>

Analysis of the spectrograms reveals a consistent pattern (Figure 36). Particularly striking is the flutter near-infrared reflectance curve of the infested plant parts and the higher assessment classes at Jebertshausen at the second time point compared to the first time point, indicating a progressive loss of structural integrity of the dead plant parts. This pattern becomes even more pronounced with increasing assessment classes. The Kruskal-Wallis test supports these observations by revealing significant differences in the near-infrared spectral signatures of the dead plant parts between the recording times, while the healthy plant parts show no significant changes.

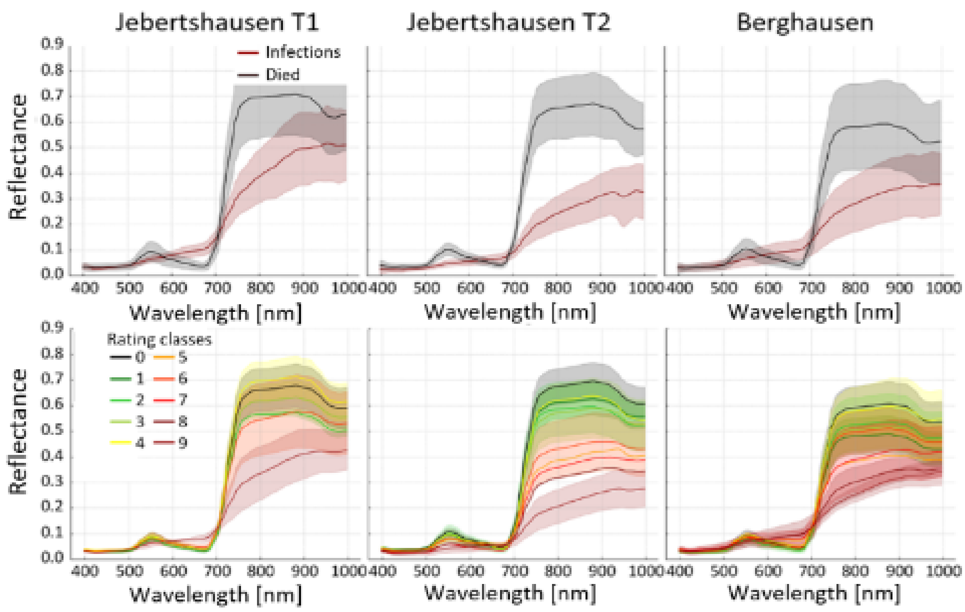

Figure 36: Smoothed spectrograms of the infestation classes (top) and the assessment classes (bottom). The figures show both the mean (line) and the scatter (shaded area) to clearly illustrate the variability of the data.

The following results demonstrate the diagnostic suitability of various VIs in the context of *Verticillium* infestation in hop plants. The focus is on the statistical correlations of the indices with different infestation and assessment classes (Figure 37 and Figure 38).

Of particular note are the indices SRb2, RGI, and SIPI. These show a significantly strong positive association in the correlation analyses, indicating great potential for monitoring disease progression. In contrast, the indices MCARI2, MSAVI, and G show strongly negative correlations. The highly significant correlations illustrate the potential of the VIs to be implemented as early warning systems in agricultural practice. However, Figure 39 (left) also shows that, in the case of assessment classes, significant differences often only become apparent from class 4 onwards.

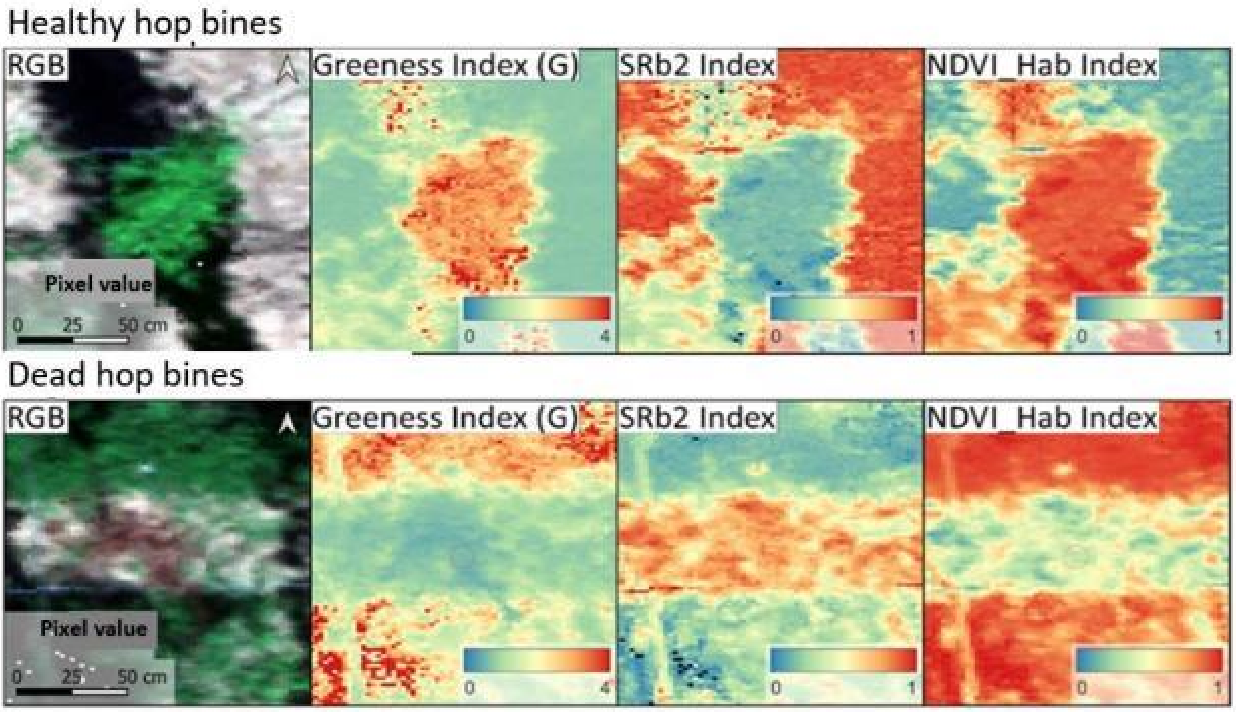

Figure 37: Graphical representation of a selection of calculated VIs for one healthy and one infected hop plant (rating class 9).

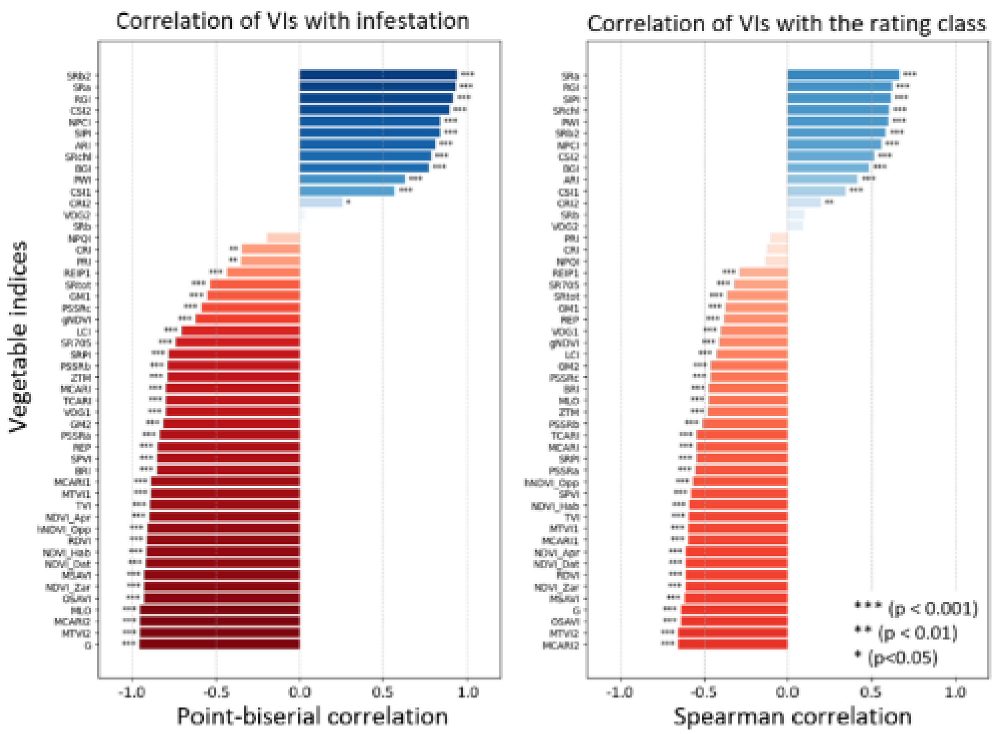

Figure 38: Illustration of the point-biserial correlation of the VIs with the binary infestation class (left) and the Spearman correlation with the ordinal assessment class in the context of Verticillium *infestation in hops. Positive correlations are shown in blue, negative correlations in red. The significance levels are indicated by the number of asterisks (* p < 0.05; ** p < 0.01; *** p < 0.001).*

However, the combination of several indices appears particularly promising to better reflect the variability of disease symptoms and thus increase classification accuracy, which, in turn, allows for the development of robust and practice-relevant approaches for the early diagnosis and monitoring of disease progression in an agricultural context. Overall, the correlations between the VIs and the binary infestation classes tend to be stronger than the correlation with the ordinal assessment class. The analysis of the Random Forest model shows that both models, the one trained with all available VIs and the one with the five most important VIs (NDVI_Hab, SRchl, NDVI_Apr, SRb2, G), accurately determine the infestation class of the hop plants and distinguish between healthy and dead plant parts (Figure 39, right).

However, these results refer exclusively to the reference dataset used, from which the training and test datasets were generated. Currently, the model is not yet capable of performing an automatic digital assessment for random fields. To ensure the transferability of the model to other growing regions, additional measures are required. First, the amount of training data must be expanded to create a more robust foundation for the model. Furthermore, precise differentiation between the hop plants and other components of the scene, as well as explicit segmentation of individual hop plants, is essential to enable more precise and generalizable classifications.

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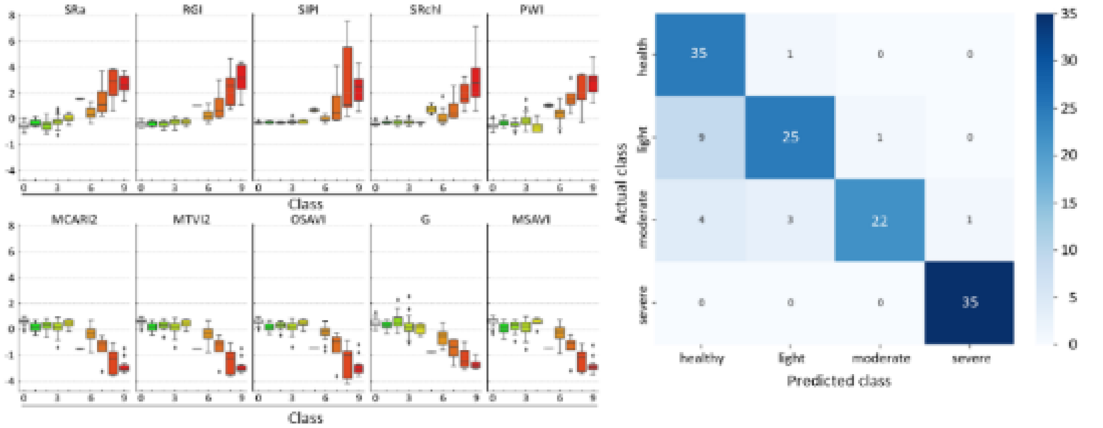


Figure 39: Left - Boxplots of the VIs with the strongest correlations to the ordinal rating class in the context of Verticillium *infestation in hops (standardized). Right - Confusion matrices for the optimized RF model. The matrix shows the actual classes (y-axis) versus the predicted classes (x-axis). Since some rating classes had a very small number of values, they were regrouped for the present analysis (rating classes 1-3 = "mild", 4-6 = "medium", 7-9 = "severe"), and a possible imbalance between majority and minority classes in the data sets was compensated using the Synthetic Minority Oversampling Technique (SMOTE).)*

The application of hyperspectral data in hop cultivation opens up a wide range of possibilities for future research and development projects beyond the analysis of *Verticillium* infestation (e.g., hyperspectral signatures of various disease stages, investigations of plant stress caused by drought and nutrient deficiencies, or pest infestation). Of particular interest here is the correlation of spectral signatures with compounds such as alpha acids or essential oils. The implementation of such applications in agricultural practice requires close collaboration between farmers, scientists, and technology providers. Only through interdisciplinary cooperation can practical solutions be developed and implemented that ensure the sustainable and efficient use of hyperspectral technologies in hop cultivation. In summary, these approaches demonstrate the enormous potential of hyperspectral remote sensing not only in the detection of disease infestations, but also in the optimization of yields and resource utilization in hop cultivation. The ongoing development of these technologies opens up promising prospects for future-oriented agriculture.

6 Hop Breeding Research

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

Many thanks go to J. Kneidl, D. Ismann, B. Brummer, A. Hartung, K. Merkl, S. Ostermeier, U. Pflügl, J. Redl, A. Roßmeier, M. Schleibinger, M. Siglhofer, A. Zimmermann, M. Nieder, B. Haugg, B. Forster, and P. Hager, as well as to our colleagues in Hüll, Wolnzach, and Freising, for their active support in the 2024 trial year. Plant breeding—especially for a perennial, vegetatively propagated crop like hops—is a laborious but exciting task that can only be successful as a team effort.

In Bavaria, hops, a specialty crop, are an economically and culturally important agricultural crop, with almost 17,000 hectares of cultivation area. The independent development and broad availability of agronomically efficient and brewing-relevant hop varieties are crucial to ensuring an internationally competitive hop industry in Bavaria in the future. As a vegetatively propagated perennial crop with separate male and female plants, variety breeding is a complex but essential task given the rapidly changing growing conditions.

In the breeding work at the Hüll Hop Research Center, hop strains are developed through classic cross-breeding and selection. New strains are then brought to the regulatory variety approval stage in cooperation with partners such as the Society for Hop Research e.V. and the HVG e.G. and made available to German hop growers through commercial partners. Breeding work within the LfL is characterized by the following objectives:

- Strengthening the climate resilience of hop production through continuously adapted varieties and the utilization of natural genetic diversity
- Improving the resource efficiency of new hop varieties by taking advantage of natural resistances in wild hops
- Development of classic aroma varieties with hop-typical, finely spicy aroma characteristics
- Development of agronomically high-performing, high-alpha varieties with very pleasant bitterness characteristics

Biotechnological and genome analysis techniques accompany the classical breeding process. Especially meristem culture has a firm place among biotechnological methods in the development of varieties to eliminate pathogens. This allows healthy plant material to be produced and made available for in-house cultivation trials and propagation. Furthermore, molecular techniques are used to research the genetic material of hops and accelerate the breeding process.

6.1 Crossbreeding 2024 and the further development of promising breeding lines

In 2024, 94 crosses were successfully conducted in Hüll. Of these, 48 were aroma hops and 46 were bitter hops.

After the harvest, 11 promising breeding lines from two locations each were presented to the advisory board of the Society for Hop Research (GfH). The advisory board is comprised of representatives from all stakeholders in the hop and brewing industries (research, brewers, hop trade, and experimental farmers). A detailed aroma profile was jointly created for all breeding lines under consideration, followed by a discussion of the next steps. Trial beers from one of these breeding lines were also tasted and evaluated. Substitution series were used to examine how the aroma expression and quality differed from the classic Hallertauer Mfr. landrace. Following the presentation to the advisory board, further variety developments are under way in close coordination with the GfH and the entire hop and brewing industry.

6.2 Development and validation of sex-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 Brauereien München e. V. *(Scientific Station for Munich Breweries)*
Team:	Dr. T. Albrecht, Dr. B. Büttner, Dr. R. Seidenberger, B. Forster, P. Hager, B. Haugg, J. Kneidl, A. Lutz, Dr. S. Gresset
Collaborators:	IPZ 1d, IPZ 1a, HudsonAlpha Institute for Biotechnology, Huntsville, AL 35806, USA
Duration:	January 1, 2024 to August 31, 2024

Humulus lupulus L. is a perennial dioecious crop. After flowering, so-called hop cones develop on the female hop plants, the compounds of which are used in the beer and food industries. Accordingly, only female hop plants are cultivated for cone production. If female hop flowers are fertilized by wind-dispersed pollen, seeds form in the cones, which can negatively impact brewing quality. To prevent this and to evaluate only female hop plants in complex yield tests, sex determination is one of the first challenges of any hop breeding program. Since female (XX) and male hop plants (XY) can only be visually distinguished during or after flowering, and since flower formation usually only occurs in the second year in our climate, it usually takes two years before the selection of the highest-yielding and highest-quality hop offspring can begin. A method for determining sex based on the genetic information of the seedling shortly after germination would significantly increase the efficiency of hop breeding programs. Therefore, there is a high need for the development of genotypic markers for sex determination. Sex-specific genomic markers developed by international research groups in recent years have proven to be of little use thus far in predicting sex in Central European hops due to incomplete linkages.

Recent sequence analyses have expanded our knowledge of the structure and diversity of sex chromosomes in hops, and genomic markers recently developed in the USA also show promising applications for the German hop breeding program. To test the suitability of these genomic markers for variety development in Germany and, if necessary, to identify more suitable markers for the German hop breeding program, we analyzed a diverse spectrum of 190 hop varieties from around the world, as well as wild hops, and current breeding material. SNP (single nucleotide polymorphism) markers of the 190 genotypes were obtained by genotyping using sequencing. These were analyzed in a genome-wide association study. The genomic markers thus identified were tested together with previously published markers in two validation sets to examine their significance in different hop origins. We also identified the position of these genomic markers in the hop genome. Based on these analyses, we were able to validate two genomic markers located in the sex-determining region of the X and Y chromosomes. Both markers together were able to correctly assign the sex of all hop genotypes in both validation sets. Furthermore, it was shown that the newly developed genomic markers can also identify isolated monoecious hop genotypes, i.e., those that produce both male and female flowers. This will enable a more targeted allocation of limited resources in the hop breeding program in the future. This progress will lead to increased selection intensity and thus promote progress in the development of resilient hop varieties for a sustainable brewing industry.

The full publication of this study can be found in BrewingScience under "Independent validation of molecular markers for sex determination on diverse sex chromosomes in hops (Humulus lupulus L.). T. Albrecht, B. Büttner, S.B. Carey, R. Seidenberger, A. Lutz, A. Harkess, and S. Gresset. BrewingScience, 77 (November/December 2024), pp. 172-183.

6.3 Establishment of a phenotyping platform for the standardized assessment of the genetic tolerance of hops to infestations by the hop aphid (*Phorodon humuli*, Schrank).

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 Brauereien München e. V.
(Scientific Station for Munich Breweries)

Team: Dr. B. Büttner, Dr. R. Seidenberger, B. Forster, P. Hager, B. Haugg, J. Kneidl, A. Lutz, Dr. S. Gresset

Collaborators: IPZ 5b, IPZ 2b

Duration: June 6, 2024 to May 31, 2025

Background:

Next to the common spider mite, *Tetranychus urticae*, the hop aphid, *Phorodon humuli* (Schrank), is the most significant pest in hop cultivation in the Northern Hemisphere. The aphids' feeding activity in the phloem of hop plants results in both direct and secondary losses in both yield and quality of the hop harvest. This occurs, on the one hand, through the removal of assimilates and the blockage of vascular pathways in the hop plants, and, on the other hand, through the transmission of viruses and bacteria by the aphids. The aphids' highly sugary secretions act as a breeding ground for the secondary colonization of the hop plant with fungi. Due to the increasing occurrence of insecticide-resistant aphid populations and the sharp, ecologically mandated reduction in the use of approved insecticides in hop cultivation, this pest will become even more important in the future.

The hop aphid is one of the key host-shifting aphid species, which overwinter as eggs on at least four members of the genus *Prunus spp*. From the end of March, the first generation of aphids hatches on their winter hosts. After several generations of wingless aphids on the winter host, winged morphs appear starting around the end of April, depending on the temperature. These morphs leave the winter host and, from mid-May, attack hop crops specifically. During a single growing season, up to 10 generations of aphids can develop on hops as a host. In isolated cases, even the first generation developed on the hops can already produce winged individuals (Alatea), which attack new hop crops. On the hops, the wingless aphids form dense colonies on the undersides of leaves (Figure 40), with each individual producing an average of 21 offspring through parthenogenesis. From around the beginning of September, winged females and males emerge, which migrate to the winter hosts and mate there. The females lay 6 to 12 eggs, preferably in the leaf scars on the winter host, thus creating the basis for the new spring generation.

Figure 40: Phorodon humuli *(Schrank) on hop leaves, left original image, right contrast-optimized image*

The huge damage potential of this pest is the result of its highly dynamic population on its summer host and its rapid spread via winged individuals. In the past, insecticides were generally used to prevent their mass reproduction on hops. However, because of recent revocations of the approval of the active ingredient spirotetramat in Germany by the Federal Office of Consumer Protection and Food Safety, only one insecticidal active ingredient (flonicamid) will be available in German hop cultivation in the future. Spirotetramat is a broad-spectrum, systemic insecticide used to control sucking insects like aphids, mealybugs, whiteflies, and scales. It inhibits lipid biosynthesis, thus preventing growth and reproduction in immature insects. This reduces their overall population. Without the option to switch back and forth between active ingredients, a widespread resistance of the aphid population to the remaining active ingredient is to be expected.

Since no effective biological control methods are currently available for hop aphid control, the only remaining option for sustainably securing yields is the breeding of varieties with resistance or tolerance to the hop aphid.

Due to massive aphid damage in hop cultivation, a special breeding program for aphid tolerance was initiated in the United Kingdom (Wye College, Kent) in the 1980s. A Japanese wild hop was discovered that passed on strong aphid tolerance to its offspring. This source of tolerance was extensively used in the United Kingdom for dwarf hop breeding (hop cultivation on low trellises), and Boadicea, a dwarf general-purpose hop variety with aphid tolerance and medium brewing suitability received regulatory approval. It was derived from an open pollination of a second-generation female from the wild Japanese hop. At the beginning of the 20th century, another wild hop breeding line was discovered in the German hop breeding program. Its offspring also showed tolerance to aphid infestations. This was used, for instance, in the development of the current aroma hop variety Spalter Select, which also exhibits above-average aphid tolerance. Currently, the Hüll breeding program includes several breeding lines with varying degrees of aphid tolerance, which argues against monogenic inheritance. Knowledge of the mode of inheritance (monogenic or quantitative) and, if necessary, the development of suitable molecular markers for selection would significantly accelerate the development of additional hop varieties with pronounced aphid tolerance, especially in the currently highly susceptible high-alpha variety segment.

To date, no quantitative genetic studies focusing on aphid tolerances in hops have been conducted. Such studies require observations across a variety of hop genotypes with consistent infestation pressure. Since hop aphids usually occur in nests in the field and pathogen pressure is subject to strong annual fluctuations, reliable data cannot be collected across many genotypes in the field. Therefore, the development of a phenotyping platform is necessary to enable a standardized, repeatable quantification of tolerance expression across a variety of hop genotypes.

Building on the research of Dr. Weihrauch from the Hüll Hop Research Center, the project aims to:

- Establish a standardized test for assessing aphid tolerance in genotypes during the breeding process
- Develop a method for the automated quantification of aphids on hop leaves using AI-assisted image analysis
- Develop a method for the molecular quantification of aphid infestation using quantitative PCR (qPCR)
- Compare the methods for assessing aphid infestation in terms of accuracy, throughput, and cost-effectiveness

Implementation:

At the beginning of March, 2024, pot samples from 15 hop strains in eight replicates were prepared for aphid tests. Based on long-term field observations, seven of these 15 hop strains had known aphid susceptibility, while eight were crosses that presumably inherited aphid tolerances from parental breeding lines. The pot samples were transplanted individually into micro-greenhouses at the beginning of June. Two wingless and healthy aphids of equal age were placed on each plant. The micro-greenhouses were closed with a fine-mesh net and placed in a climate chamber in a completely randomized block experiment. The climate conditions were 24.5°C for 14 hours with light and 20.5°C for 8 hours without light. The relative humidity was maintained at >37% throughout. After 10 days, the micro-greenhouses were opened one at a time and visually scored on a scale of 0–5 (0, no viable aphids detected, 5, all leaves and stems infested with aphids) (Score 1). Following the scoring, the micro-greenhouses were watered, resealed, and returned to the original experimental design (Figure 41).

Figure 41: Micro-greenhouses of the aphid test in the climate chamber & development of plants in a micro-greenhouse after 18 days

After another 13 days, the experiment was terminated, and the visual assessment was repeated as described above (assessment 2). The plants were then individually transferred from the micro-greenhouses into transparent bags. The number of live aphids was determined for each plant under the binocular microscope (aphid count per plant). Furthermore, a representative leaf was selected from each plant, representing the overall infestation, and the number of viable aphids was determined under the binocular microscope (aphid count per leaf). These leaves were individually digitally photographed and frozen in the bag together with the corresponding entire plant.

Using the "RootPainter" software (Smith et al. 2022), a statistical model was trained to detect and count aphids in two cycles using 30 images from the aphid experiment. The trained model was then used to estimate the number of aphids for all photographed leaves (n = 120) (estimated aphid count).

Preliminary Results:

Significant differences between the hop strains were observed for all traits assessed. The repeatability of observations was highest for the visual assessments (Table 17). Overall, the trait "estimated aphids" showed the lowest repeatability.

Table 17: Variance components and repeatability of the traits measured on the whole plants in the aphid test

Feature	Genotypic variance	Residual variance	Repeatability [%]
Assessment 1	2.38	0.75	76
Assessment 2	2.44	0.75	76
Aphids Whole Plant	49.34	55.40	47

Regarding the agreement of the different observations, the statistical analysis revealed significant correlations between all traits recorded on the whole plants (Table 18).

Table 18: Phenotypic correlations between all traits recorded on the whole plant during the aphid test (, significant at $p<0.05$)*

Phenotypic correlations	Assessment 2	Aphids whole plant	Aphids single leave
Assessment 1	0.88*	0.68*	0.61*
Assessment 2		0.87*	0.80*
Aphids Whole Plant			0.84*

For the hop varieties with long-term observations of aphid susceptibility in the field, the results from the aphid tests in the climate chamber confirmed the respective classifications. The varieties Spalter Select, Boadicea, and 3W showed no to very low aphid infestation, while the varieties Hallertauer Magnum, Herkules, and Tango showed a strong aphid proliferation during the trial.

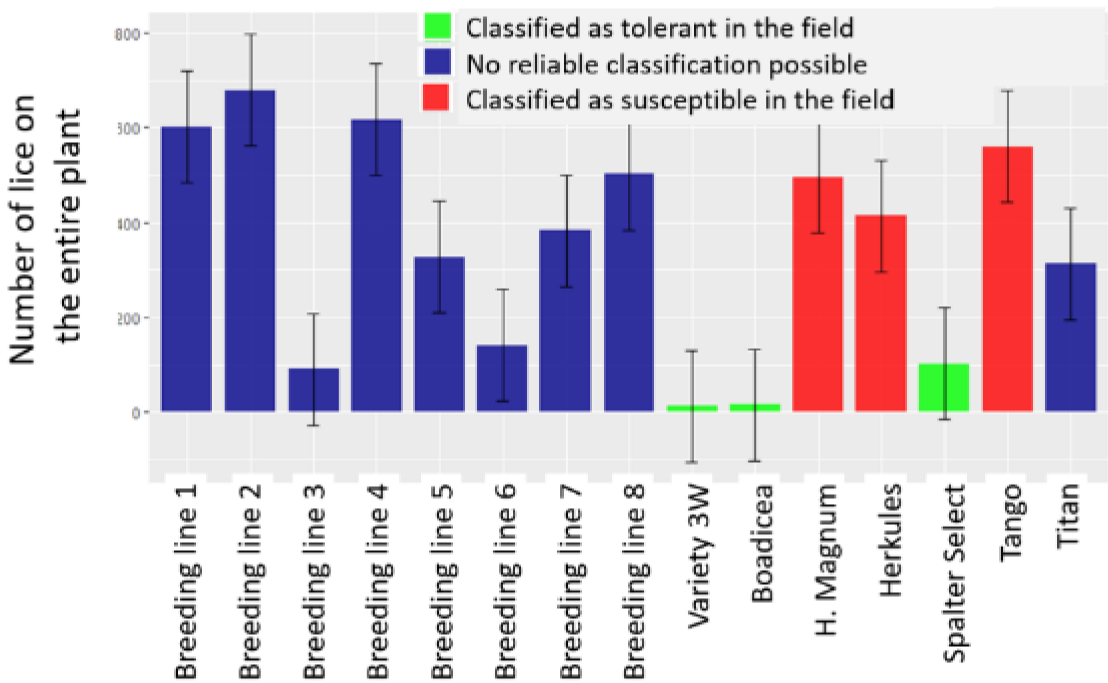


Figure 42: Number of aphids counted on the entire plant for the 15 tested hop strains

The feature “estimated aphids”, which was determined by the previously trained statistical model, showed a significant correlation with the number of aphids counted under the binocular microscope on the respective single leaf.

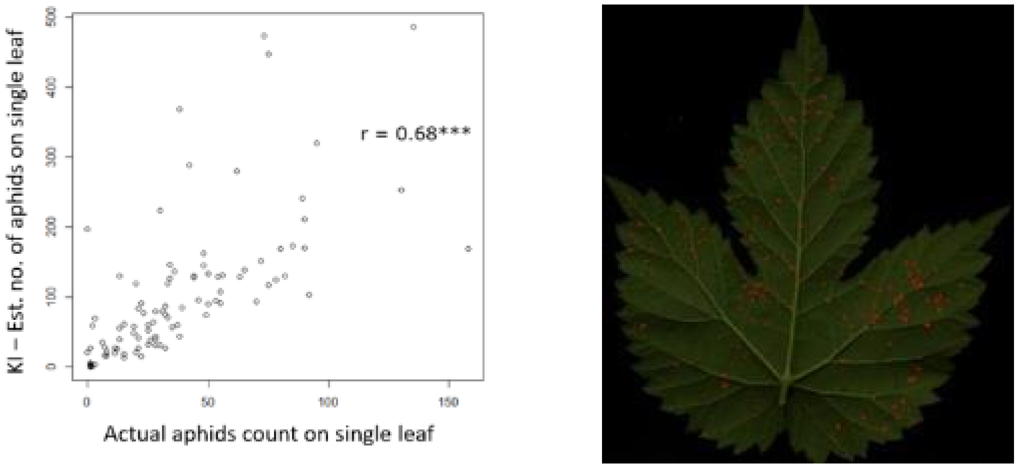


*Figure 43: Left - Statistical correlation between the number of aphids counted under the binocular microscope per leaf and the statistically estimated number of aphids per leaf (r; correlation coefficient, ***; p<0.01).*
Right - Aphids detected by the statistical model on a leaf (red).

Summary and outlook:

Based on the results available so far, we can summarize:

- The differences in aphid susceptibility between hop strains found in the climate chamber are consistent with field observations.
- The high repeatability found in the various aphid susceptibility traits allow for halving the required replications and doubling the strains. Since the experiment can be performed several times a year, the throughput threshold required for quantitative genetic analyses is achievable.
- Visual assessment proved to be the fastest and most repeatable method for assessing aphid susceptibility and is therefore preferable for selecting candidates in the breeding process.
- Quantitative assessment of aphid susceptibility is necessary to detect the genetic structures underlying the different aphid susceptibilities and to use them in the development of new aphid-tolerant hop varieties. The developed statistical model can detect aphids on hop leaves and count them with sufficient accuracy. This method will therefore be available in the future instead of the expensive and time-consuming binocular counting.

To potentially enable even more meaningful and rapid quantification of aphid infestation on hops, we are currently attempting to quantify aphids using their DNA.

To do this, a DNA isolation method must be established that can simultaneously extract DNA from the aphid and the hop plant. In the next step, the aphid DNA will be quantified in relation to the hop DNA using qPCR, and conclusions about the infestation will be drawn from this.

One challenge with DNA isolation is the amount of material that must be processed. Since the aphids are not evenly distributed across the plant, the entire plant (approximately 30 cm including leaves and stems) must be processed. For this purpose, the plant was dried whole, and from five tested methods, we were able to establish a method for grinding the plant and subsequent DNA isolation. The next step is to test whether we can also use this method to digest the aphids and isolate their DNA.

In parallel with establishing DNA isolation, we are working on developing qPCR, which will detect hop and aphid DNA in a single run. In the first step, primer pairs for aphids described in the literature were tested. None of the seven primer pairs tested are specific for the hop aphid, but two pairs were able to amplify DNA from the hop aphid. The next step is the establishment of duplex PCR for the simultaneous detection of hop and aphid DNA.

Literature:

Smith A.G., Han E., Petersen J., Olsen N.A.F., Giese C., Athmann M., Dresboll D.B., Thorup-Kristensen K. (2022) RootPainter: deep learning segmentation of biological images with corrective annotation. New Phytol, 236:774–791

6.4 Establishment of a hop garden under cultivation conditions defined by an organic association

Sponsors:	Bayerische Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung *(Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)*
Financing:	BarthHaas, Nürnberg
Team:	D. Ismann, J. Kneidl, A. Lutz, Dr. S. Gresset, Dr. K. Kammhuber, Dr. F. Weihrauch
Collaborators:	GfH, IPZ 5d, 5e
Duration:	From 2024

Despite the noticeable trend toward more organic farming in Germany, organic hop cultivation can still be described as a "niche within a niche" and, globally, is not an economically important factor within the specialty crop of hops. Political demands to increase the share of organic hop production to 30% by the end of the decade will not be feasible in hop cultivation, although a clear trend has been observed in recent years, albeit starting from a very low level: While only 76 hectares of organically farmed hops were cultivated in Germany in 2010, by 2024, 261 hectares of organic hops were already being cultivated in Germany. In addition, there are currently 41 hectares in conversion. If the trend of the last 10 years continues, there could be around 400 to 500 hectares (2 to 2.5% of the total area) under organic hop cultivation in Germany by 2030.

For scientists, however, organic hops are an important playground for developing new, environmentally friendly methods, particularly in plant protection. In intensive exchange between innovative researchers and open-minded practitioners, a wide variety of approaches are being investigated using thermal, mechanical, and biological applications. Due to the challenges of the future (resistance development, regulatory elimination of pesticides, etc.), the methods developed for organic cultivation to maintain plant health are also attracting the attention of conventional hop growers, enriching their portfolio of possibilities. For instance, the mechanical application of predatory mites to control the common spider mite is now practical and economical. In 2024, almost 100 hectares of farmland at 19 farms were successfully protected in this way.

In addition to these technical solutions, hop breeding has long focused on sustainability, environmental protection, and resource conservation. The aim is to develop varieties that are also optimally adapted to organic cultivation. The current breeding program is based on the motto "Low Input – High Output." In the breeding gardens, the breeding lines and varieties are tested taking future conditions into account:

- Reduction of nitrogen fertilization by at least 50 kg/ha compared to the recommended standard fertilizer application
- Minimal use of pesticides
- Elimination of irrigation

Great importance is also placed on a favorable cone-to-remaining plant ratio (harvest index). By reducing total biomass while maintaining or increasing yield, the need for fertilizers, pesticides, and water can be further reduced. Furthermore, the CO2 footprint shrinks significantly.

Since 2007, varieties, breeding lines, and wild hops have been tested for their resistance to diseases and pests in a small, isolated breeding garden without any pesticides. Combined with experience from breeding gardens, greenhouses, and laboratory tests, a meaningful overall picture emerges.

The testing of particularly promising breeding lines is rounded out by row and large-plot cultivation trials in German hop-growing regions under normal commercial agronomic conditions.

In 2024, an organic farm of long standing in the Hallertau region was included in this trial program. Currently, two new aroma breeding lines and one high-alpha breeding line are being cultivated and compared with the well-established Spalter Select and Tango varieties. Meaningful results are expected from the 2025 harvest onwards. This will ensure that organic farms can be provided with appropriate information regarding the suitability of new varieties for cultivation.

7 Hop Quality and Analysis

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

7.1 General

The IPZ 5d working group performs all analytical work in the IPZ 5 Hops working area, thus playing a central role. All other working groups rely on this analytical data to support their experimental research. Hop breeding is not possible without hop analysis.

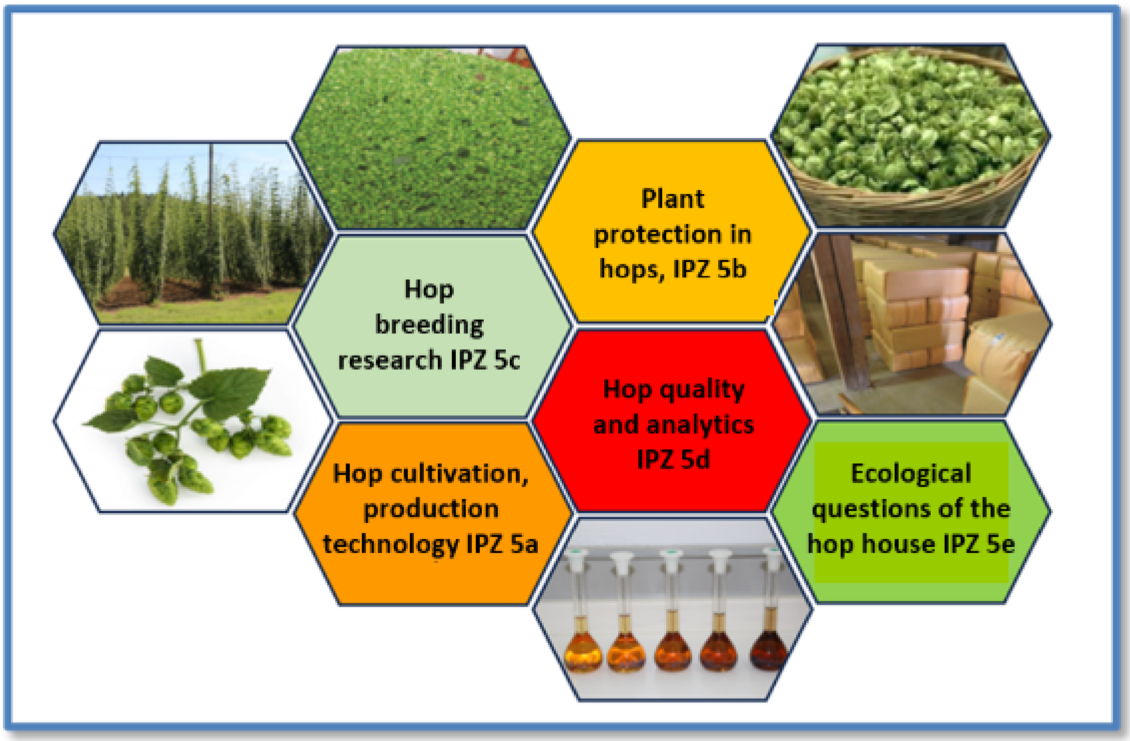


Figure 44: The central importance of the IPZ 5d working group

Hops are cultivated for their valuable ingredients. Hops contain three groups of valuable ingredients. These are, in order of importance, bitter compounds, essential oils, and polyphenols.

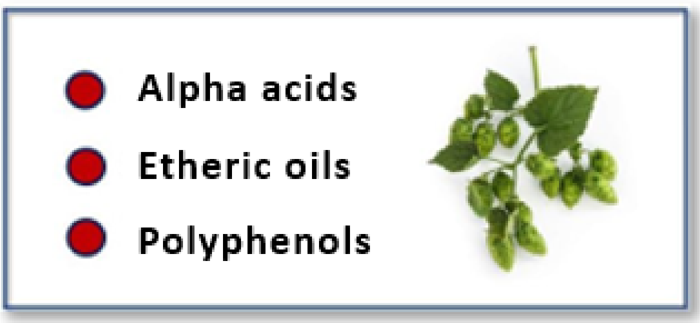


Figure 45: The valuable ingredients of hops

Alpha acids are considered the primary quality characteristic of hops, as they are a measure of bittering potential, and hops are added to beer based on their alpha acid content (currently, internationally, approximately 4.5–5.0 g of alpha acids per 100 liters of beer). Alpha acids are also becoming increasingly important in the way farmers are paid for their hops. Payment is either made directly based on the weight of alpha acids (kg of alpha acids) or hop supply contracts contain additional agreements for surcharges and discounts if a neutral range is exceeded or not met.

Hops were originally discovered in the Middle Ages as a raw material for brewing beer to improve its shelf life because of its antimicrobial properties. Today, hops' primary function is to impart their typical subtle bitterness and pleasant aroma to beer. Hops also possess many other beneficial properties.

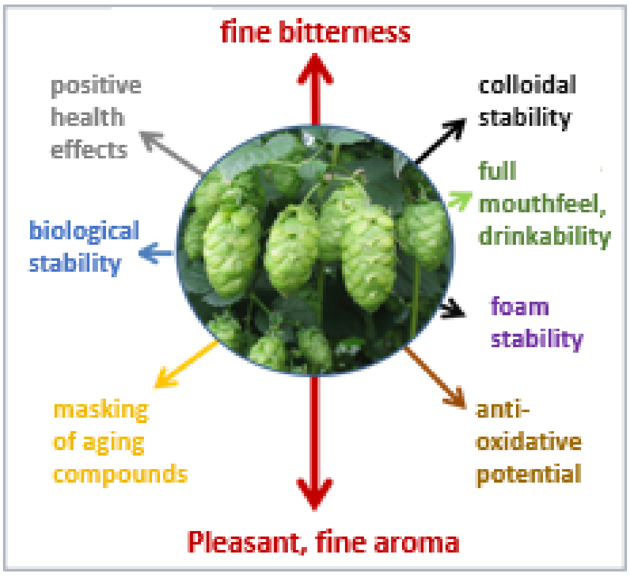


Figure 46: The many functions of hops in beer

7.2 What requirements regarding its ingredients should hops meet in the future?

Hops are grown almost exclusively for brewing beer. 95% of the hop production is used in breweries, and only 5% is used for alternative applications, although efforts are underway to expand this area.

Figure 47: Uses for hops

7.2.1 Requirements of the brewing industry

There are very different philosophies regarding the use of hops in the brewing industry. Some are only interested in cheap alpha acid, others select hops very carefully based on variety and growing region, and there are fluid transitions in between.

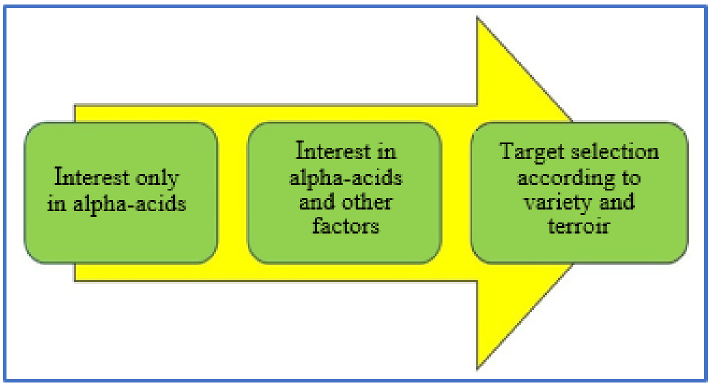


Figure 48: Different philosophies regarding the use of hops

However, there is agreement that hop varieties should be bred with the highest possible α-acid content and high α-acid stability with regard to vintage fluctuations. Climate change will also be the biggest future challenge for hop cultivation. A low cohumulone content as a quality parameter no longer plays such a significant role. For so-called downstream products and products for Beyond Brewing, even high-alpha varieties with high cohumulone contents are desirable. However, a low cohumulone content is beneficial for greater foam stability.

The oils should correspond to the classic aroma profile. Polyphenols have not yet played a major role in the brewing industry, although they certainly contribute to sensory properties (mouthfeel) and have many positive health effects (see 7.2.2).

7.2.1.1 The special requirements of craft brewers

The craft brewing movement has been a huge success in the US. Craft breweries account for approximately 13% of total beer sales. Worldwide, 2.5% of craft brewers consume 20% of the global hop harvest. However, in Germany, where traditional beer styles are preferred, the craft brewing scene has not been as successful.

Craft brewers want hops with fruity and floral aromas that differ from traditional hop flavors. These hops are collectively referred to as "aroma varieties with special characteristics."

7.2.1.2 The technique of dry hopping is experiencing a renaissance

In craft brewing, the technique of dry hopping has been rediscovered. This process was already known in the nineteenth century and is now experiencing a renaissance. This method corresponds to the principle of cold extraction. Hops are added to the finished beer in the lager tank, usually based on the oil content. Beer is a polar solvent, consisting of 92% water and 5% ethanol, which is why it extracts primarily polar compounds from hops.

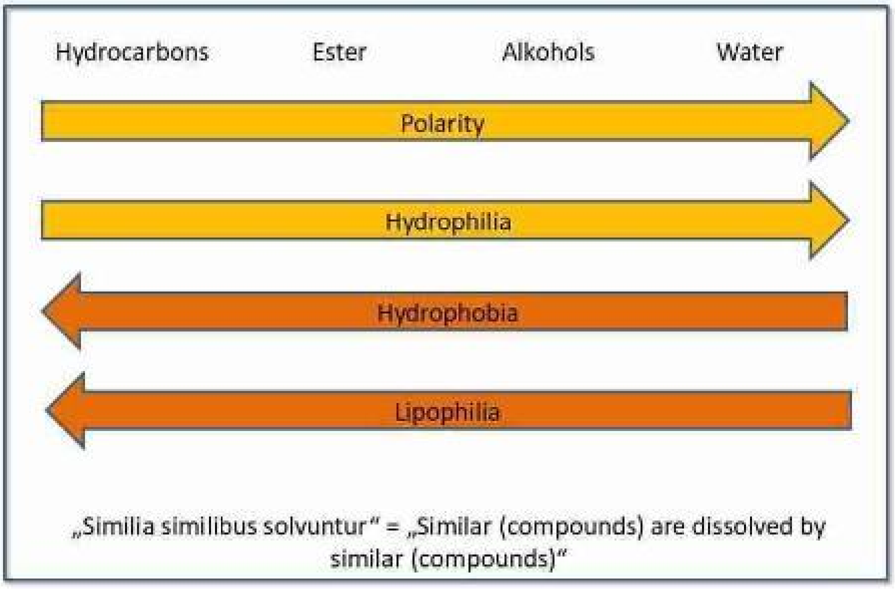


Figure 49: The solubility behavior of hop compounds is based on polarity

Low-molecular-weight esters are reasonably soluble, and alcohols such as linalool or geraniol are readily soluble. This is the reason why cold-hopped beers develop fruity and floral aromas. Non-polar substances such as myrcene dissolve in trace amounts (maximum 1 mg/L).

The group of polyphenols is also highly soluble due to their polarity. Unfortunately, undesirable substances such as nitrate also migrate completely into the beer. The average nitrate content of hops is around 0.7%. However, the nitrate limit of 50 mg/L, which is used by many jurisdictions for drinking water does generally not apply to beer.

Pesticides are usually larger organic molecules and therefore non-polar. However, there are also some inorganic active ingredients. The chemical properties of pesticides are well represented, for example, in the GESTIS substance database (Hazardous Substances Information System of the German Social Accident Insurance) https://gestis.dguv.de . A great deal of information can also be found in the "Pesticide Properties DataBase" of the University of Hertfordshire: https://sitem.herts.ac.uk/aeru/ppdb/en/ .

Most of the pesticides approved for use in hops are not readily soluble, with two exceptions. Fosethyl-Al is readily soluble in water at 120 g/l but decomposes immediately to phosphonic acid. Metalaxyl-M is also readily soluble at 8.4 g/l, but the maximum permitted level is very low at 15 ppm.

7.2.2 Alternative Applications

Both the cones and the remaining plant material from the hop plant can be used for alternative applications. A project on the extraction and suitability testing of fibers for nonwoven fabric production was carried out by the IPZ 5a working group. This is reported in detail on pages 32-42 of the 2023 Annual Report. However, the shives, the detached inner woody parts of the hop bine, can also be used. Due to their good insulating properties and high mechanical strength, these are suitable as a material for loose-fill insulation and, when bound, for insulating mats. They can also be processed into fibers for molded parts such as automotive door panels. However, there are currently no significant technical applications.

In the case of cones, it is primarily the antimicrobial properties of the bitter compounds that make hops useful for alternative applications. The bitter substances show both antimicrobial and preservative effects even in catalytic amounts (0.001-0.1 wt.%), in the ascending order of iso-β-acids, β-acids and β-acids.

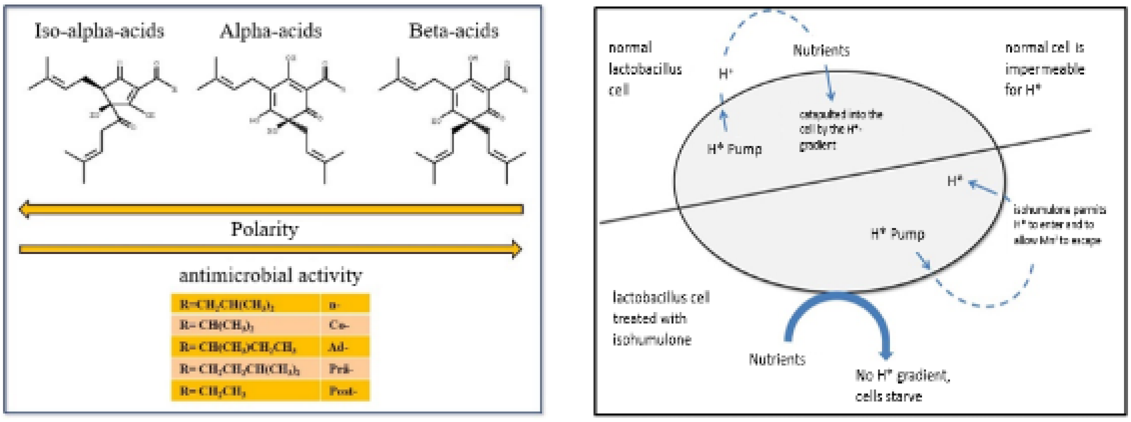


Figure 50: Sequence of antimicrobial activity of iso-alpha acids, alpha acids, and beta acids, as well as their effectiveness

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 19: 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 for these applications is certainly conceivable in the future. Therefore, one of the breeding goals in Hüll is to increase the beta-acid content. The current record value is around 20%. There is even a breeding strain that produces only beta acids and no β-acids. This variety (Relax) is used to make tea.

Because of their numerous polyphenolic substances, hops are also of interest in the health, wellness, dietary supplements, and functional food sectors. Polyphenols are secondary plant compounds synthesized by the plant as defenses against diseases and pests, as growth regulators, and as pigments for UV protection. Their antioxidant properties and their ability to capture free radicals have numerous positive health effects.

Diseases based on oxidative processes include cancer, atherosclerosis, Alzheimer's disease, and Parkinson's disease. As a result of their polarity, polyphenols are readily absorbed into beer, and their significance for sensory perception is certainly still underestimated, but could become more significant in the future. They contribute, for example, to the body and mouthfeel of beer. Higher molecular weight polyphenols bond with proteins via hydrogen bonds, resulting in turbidity. Therefore, higher molecular weight polyphenols tend to be problematic and are removed with filter aids such as PVPP (polyvinylpolypyrrolidone).

The literature on polyphenols and health is virtually inexhaustible. Here is a summary of a few of these:

Table 20: 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 have anti-inflammatory properties
Polyphenols protect the immune system
Polyphenols protect neurogenerative diseases such as Alzheimer’s

There is a clear consensus that one should eat a diet rich in polyphenol. This means eating plenty of fruit and vegetables. Hops are very rich in polyphenols even compared to fruits.

Of all the hop polyphenols, however, xanthohumol has received the most public attention in recent years, and scientific research on It has exploded. The health-promoting effects of xanthohumol have now also been scientifically proven. In 2016, the US Food and Drug Administration (FDA) granted "health claim" status for the "DNA protection" of the XAN extract from T.A. XAN Development S.A.M. Extensive information on the history of xanthohumol and its effects can be found on the company's website https://www.xan.com/.

A request for "health claim" status has been made to the European Food Safety Authority (EFSA) but has not yet been granted. Xanthohumol is effective against almost everything (Figure 52) but its anticarcinogenic effect is considered most significant.

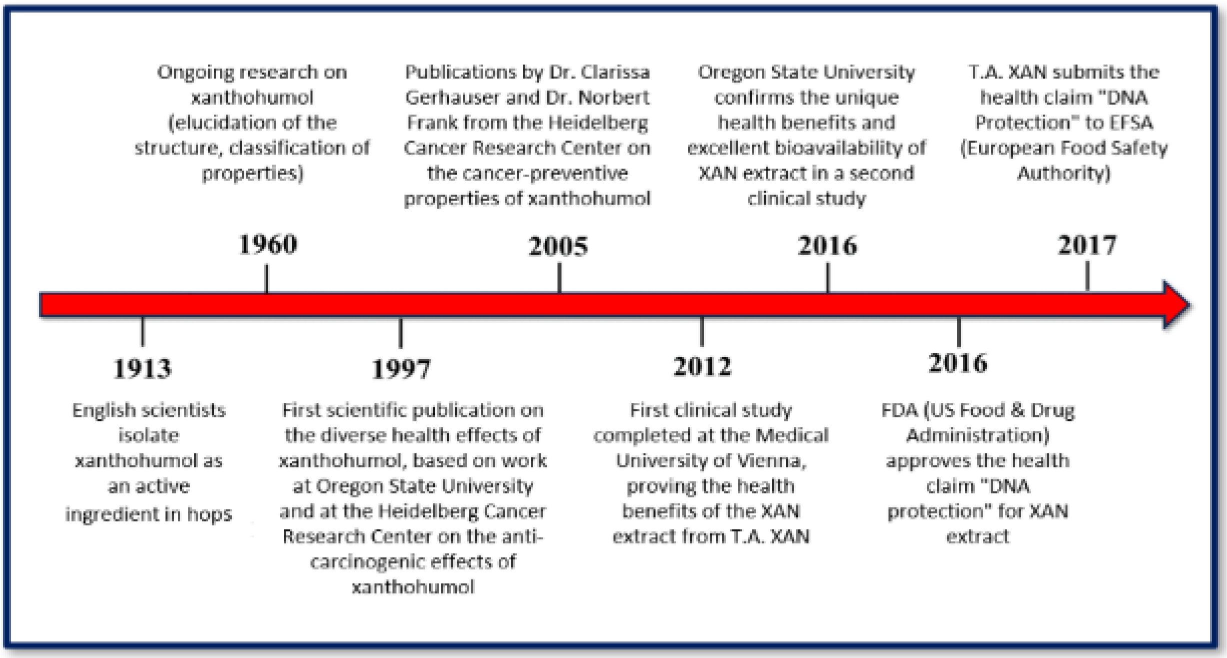


Figure 51: History of Xanthohumol Research

During the brewing process, a constant conversion of the prenylated flavonoids takes place (Figure 52). Xanthohumol is isomerized to iso-xanthohumol during wort boiling, and desmethylxanthohumol is isomerized to 8- and 6-prenylnaringenin. Therefore, desmethylxanthohumol is not found in beer, and the concentrations of prenylated naringenins are significantly higher in beer than in hops.

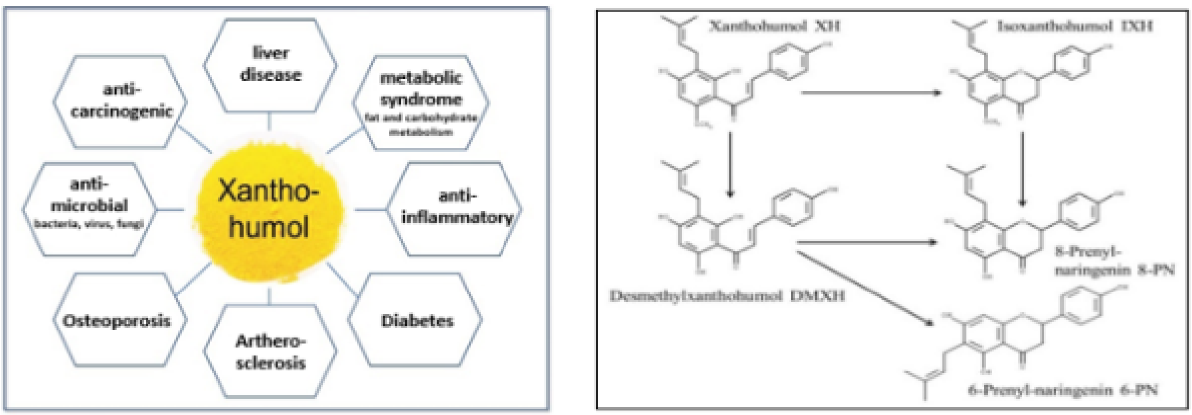


Figure 52: Effects of xanthohumol and transformations in the brewing process

8-Prenylnaringenin is one of the most potent phytoestrogens in the plant kingdom. Its estrogenic effect is based on its structural similarity to the female sex hormone 17-ß-estradiol.

Another group of substances in hops up to 0.2% are multifidols (see figure below). These compounds were already extensively reported on in the 2021 and 2022 annual reports. Due to their polarity, multifidol glucosides are fully absorbed into beer.

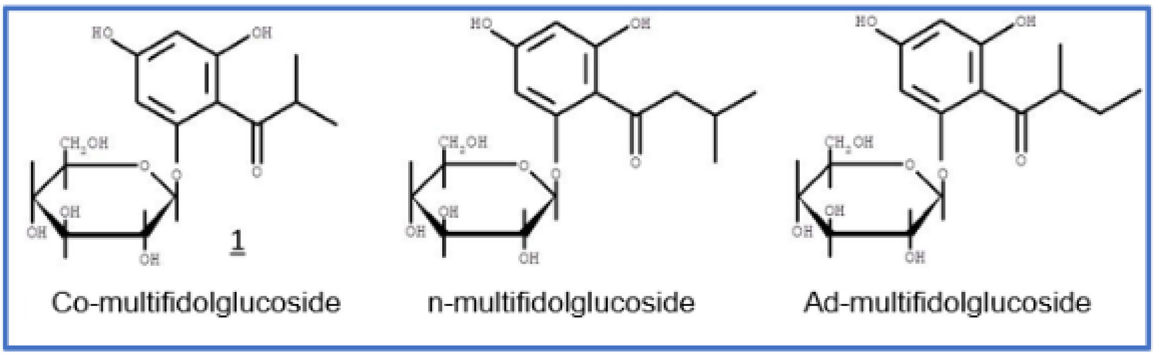


Figure 53: Chemical structures of multifidols

The main compound in hops is co-multifidol glucoside. Multifidol glucosides have anti-inflammatory properties because they can inhibit the enzyme cyclooxygenase, a key enzyme in the development of inflammation. Well-known painkillers such as aspirin (acetylsalicylic acid), ibuprofen, naproxen, and Voltaren (diclofenac) work according to the same principle.

7.3 The essential oils of hops

Hops' essential oils are responsible for their aroma. The literature usually mentions 200-300 individual substances (Eri, S., Khoo, B., K., Lech, J., Hartman, T., G., Direct thermal desorption – gas chromatography and gas chromatography – mass spectrometry profiling of hop (*Humulus lupulus L.*) essential oils in support of varietal characterization, J. Agric. Food Chem. 2000, 48, 1140-1149). The total oil content is determined by steam distillation, and individual components are determined by gas chromatography – mass spectroscopy. The Hüll laboratory can qualitatively identify 120 substances and quantitatively measure those for which standards are available. The Hüll laboratory is interested in the following three questions regarding essential oils:

- Which oil components are important for distinguishing varieties?
- Which substances determine the aroma of hops?
- Which substances are transferred into the beer?

Hops must be delivered in pure varietal form, with only two percent foreign matter permitted. The laboratory in Hüll is also responsible for verifying varietal purity.

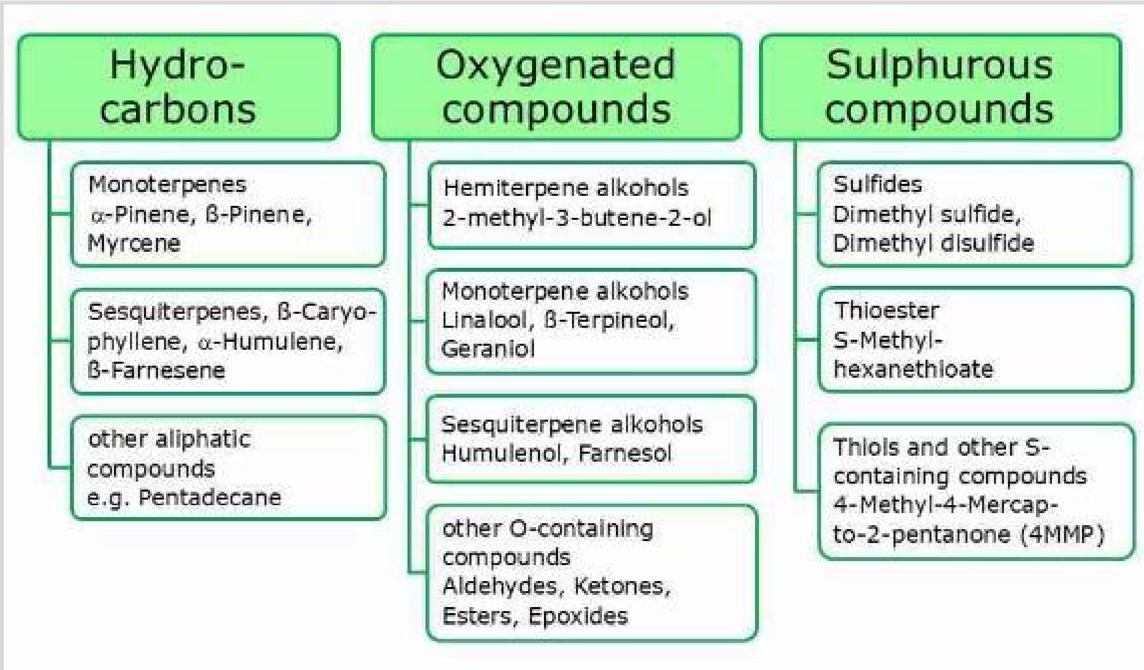


Figure 54: Systematic classification of essential hop oils

Sesquiterpenes such as ß-caryophyllene, humulene, ß-farnesene, ß- and ß-selinene are well-suited for varietal differentiation. ß-Farnesene is the typical characteristic of the Saaz variety. However, these compounds are poorly absorbed into beer and are not aroma-active. According to S. Brendel et al. (Brendel, S., Hofmann, T., Granvogl, M., Characterization of Key Aroma Compounds in Pellets of Different Hop Varieties (*Humulus lupulus L.*) by Means of the Sensomics Approach, J. Agric. Food Chem. 2019, 67, 12044-12053), the hop aroma is primarily characterized by myrcene and linalool. Myrcene imparts an earthy, sweet odor similar to cloves. The solubility of myrcene in water is low at 1 mg/l. However, since myrcene is the main component of hop oil, myrcene is also found in beer. Linalool is considered the indicator substance for a pleasant hop aroma. It is highly soluble and has fresh, floral notes. Sulfur compounds such as 4-mercapto-4-methyl-2-pentanone (4-MMP) also play a role in aroma varieties with special properties. 4-MMP is one of the most odorous compounds of all. In concentrated form, 4-MMP smells almost unbearable; in very diluted form, it has the blackcurrant scent that craft brewers love so much. The odor impression is created by the interaction of many individual substances. Some substances neutralize each other, while others intensify their effects. During fermentation, yeasts can also alter aroma compounds. Esters are transesterified to ethyl esters, geraniol can be reduced to citronellol, and glycosidically bound aroma compounds such as linalool or geraniol can be released. These biotransformations are described in detail in an article by Dr. Kiyoshi Takoi (Sapporo Breweries) in Brauwelt International, 2019/II, pages 130 - 136.

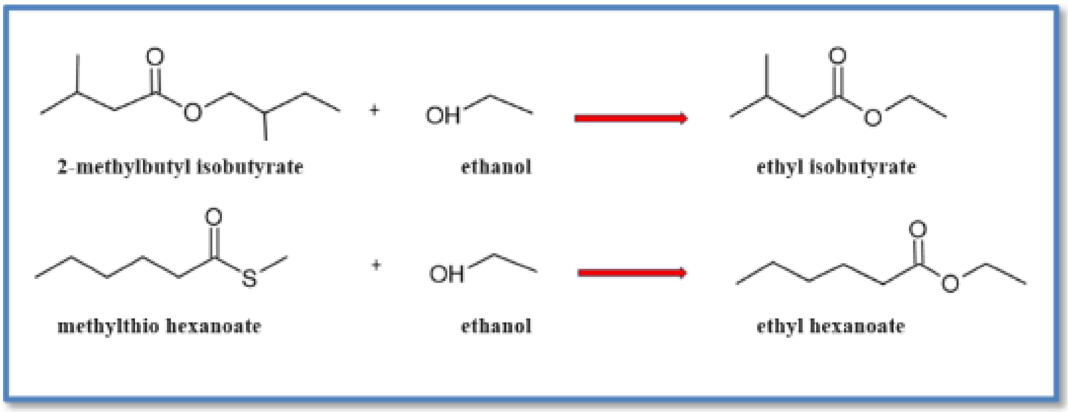


Figure. 55: Transesterification of esters and thioesters to ethyl esters

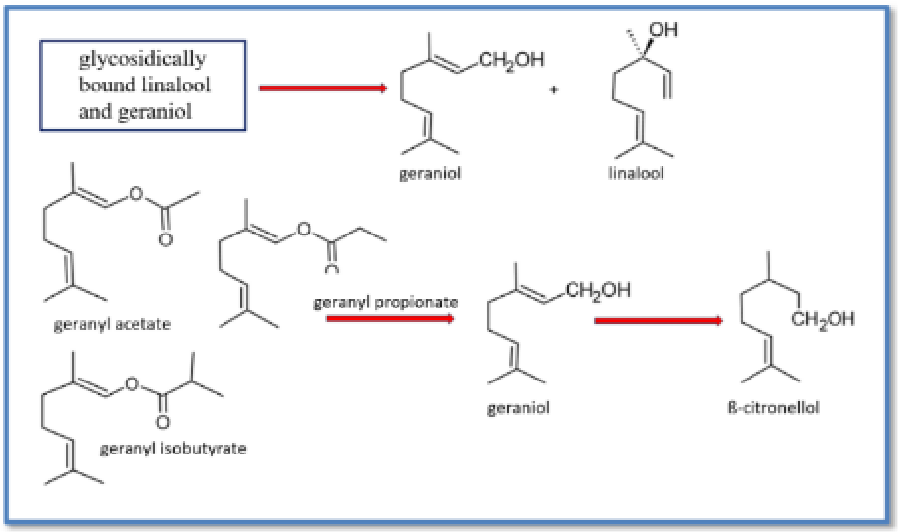


Figure. 56: Release of glycosidically bound linalool and geraniol, release of geraniol from geranyl esters, reduction of geraniol to ß-citronellol

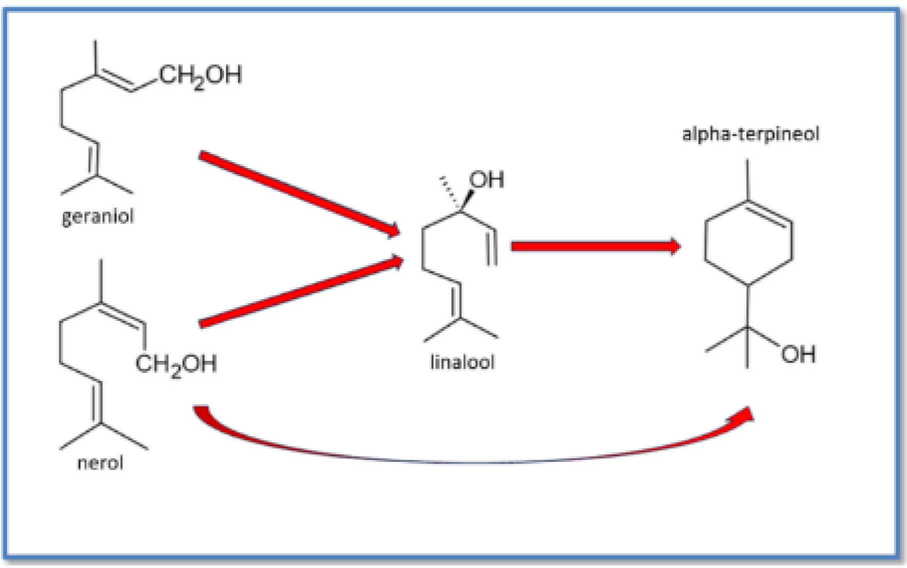


Figure 57: Biotransformation of geraniol and nerol to linalool and alpha-terpineol

7.4 World hop portfolio (2023 harvest)

Every year, the essential oils of the world's hop varieties are analyzed using headspace gas chromatography, and the bittering compounds are analyzed using HPLC. Table 21 shows the results for the 2023 harvest year. It can be used as a tool to classify unknown hop varieties into a specific variety type.

The components of hops are determined by DNA, which is specific to each variety, although many external factors, known as exogenous factors, play a role in the development of both the morphological appearance and the components (metabolome).

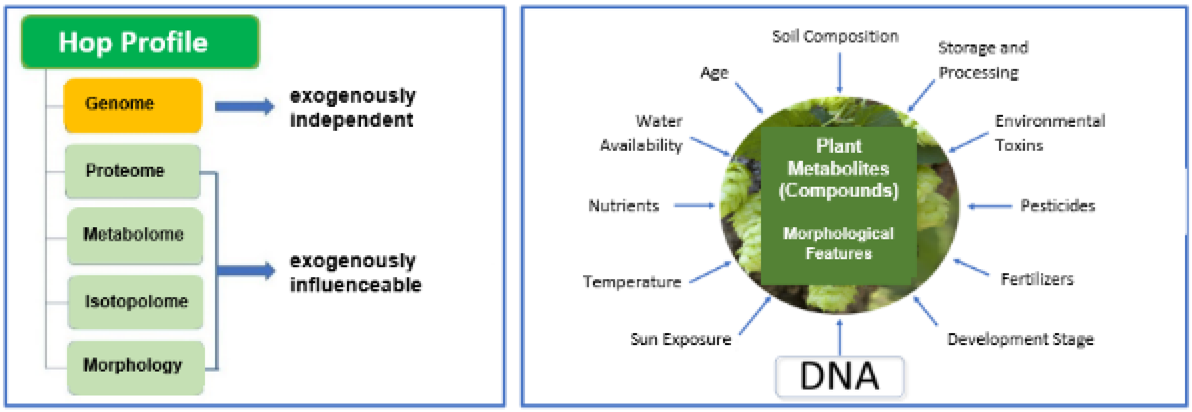


Figure 58: Hop morphology and metabolome are determined by many exogenous factors

Table 21: World hop portfolio (Fall 2023)

Variety	Myrcene	2-Metyl-butyl-isobutyrate	Methyl-isoheptanoate	ß-Ocimene	Linalool	Aromadendrene	Undecanon	Humulene	ß-Farnesene	γ-Muurolene	ß-Selinene	α-Selinene	ß/γ-Cadinene	3.7-Selinadien	Geraniol	α-acids	ß-acids	ß/α	Cohumulone	Colupulone
Admiral	1939	557	0	173	91	0	11	354	10	19	2	4	45	0	0	12.2	5.8	0.48	37.8	66.5
Agnus	1029	98	4	30	21	0	5	174	0	18	4	7	36	0	3	7.8	5.1	0.65	35.9	58.9
Ahil	2170	381	69	30	55	0	25	244	130	15	5	9	37	0	13	6.8	4.9	0.72	27.5	5w9.4
Alliance	670	152	0	9	43	0	9	222	5	18	2	3	44	0	0	4.5	4.4	0.98	26.9	47.4
Ariana	2148	472	184	358	51	0	37	392	0	19	17	32	44	0	4	7.4	5.4	0.73	34.1	56.9
Atlas	2076	437	78	98	43	0	3	246	149	14	6	11	33	0	14	6.3	4.9	0.78	31.1	60.9
Backa	1433	391	1	141	68	0	11	266	35	20	2	3	41	0	1	4.8	4.7	0.98	36.6	69.7
Belgisch Spalter	964	188	0	87	46	2	8	207	0	21	19	37	38	56	0	3.5	4.3	1.23	25.7	51.0
Blisk	1391	212	85	42	61	0	3	200	145	16	4	7	34	0	13	7.2	4.8	0.67	29.4	61.5
Bobek	3098	324	14	260	102	0	25	359	50	14	2	3	35	0	3	3.3	4.4	1.33	28.5	50.6
Bor	1000	128	2	198	21	0	16	263	0	14	2	4	37	0	4	7.1	5.1	0.72	24.2	50.0
Bramling Cross	1646	364	2	121	71	0	22	329	0	12	8	16	28	8	2	2.3	3.9	1.70	27.1	66.2
Braustern	727	132	2	157	18	0	9	195	0	18	2	3	40	0	0	6.4	5.5	0.86	27.8	49.9
Brewers Gold	1932	349	36	143	33	0	2	265	0	17	6	10	40	0	14	6.1	3.3	0.54	35.7	64.1
Callista	3497	434	136	112	113	0	22	517	0	21	27	52	48	0	1	4.6	6.1	1.33	18.9	39.1
Cascade	3478	318	88	135	43	0	8	381	59	18	8	15	42	2	5	7.9	5.8	0.73	32.8	50.8
Challenger	2179	420	10	168	49	0	28	395	7	17	27	54	40	0	1	4.8	3.6	0.75	27.6	47.3
Chang bei 1	1409	90	11	23	74	0	37	257	40	21	14	27	45	46	1	4.7	4.9	1.04	22.6	39.4
Chang bei 2	1441	6	10	19	76	0	40	284	41	20	12	24	41	45	0	4.4	4.7	1.07	21.4	37.6
Chinook	1326	360	34	35	20	0	5	270	0	55	11	17	115	32	10	10.6	3.2	0.30	29.9	54.5
Columbus	1740	266	67	70	25	0	3	260	0	41	7	12	82	22	4	16.2	4.8	0.30	31.0	56.4
Comet	914	107	14	199	29	0	5	14	0	4	26	50	8	27	5	8.6	5.0	0.58	33.6	65.5
Crystal	945	99	1	90	51	16	4	228	0	23	21	41	33	67	1	1.9	5.4	2.84	15.2	44.5
Density	1652	296	0	47	80	0	16	406	0	14	3	6	35	0	0	2.0	4.0	2.00	28.9	63.6
Dr. Rudi (Super Alpha)	1833	421	52	171	102	0	35	348	0	18	3	5	38	0	1	7.6	5.0	0.66	37.4	69.8

Variety	Myr-cene	2-Metyl-butyl-isobutyrate	Methyl-isohep-tanoate	ß-Oci-mene	Lina-lool	Aroma-dend-rene	Unde-canon	Hu-mulene	ß-Far-nesene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß/γ-Ca-dinene	3.7-Seli-nadien	Gera-niol	α-acids	ß-acids	ß/α	Cohu-mulone	Co-lupulone
Early Choice	1273	273	1	142	18	0	8	325	0	13	33	65	32	0	0	3.2	3.6	1.13	35.8	91.7
Emerald	882	153	9	149	21	0	27	263	0	17	4	7	43	0	2	6.2	4.9	0.79	28.6	52.1
Galena	2729	770	101	681	39	0	25	372	4	15	5	9	31	1	4	5.0	4.1	0.82	41.9	67.1
Ging Dao Do Hua	2039	575	0	34	62	0	18	296	1	42	25	48	86	1	8	5.0	4.6	0.92	40.0	73.4
Golden Star	2098	622	0	28	64	0	20	333	1	53	30	54	113	0	7	5.2	4.6	0.88	42.9	75.7
Granit	1168	158	13	126	22	0	32	217	0	13	7	13	32	0	3	7.8	5.1	0.65	25.2	42.8
Hallertau Blanc	8514	1144	391	61	107	0	24	405	1	21	247	475	55	0	7	9.2	5.6	0.61	20.7	37.8
Hall. Magnum	2026	196	126	108	20	0	10	368	0	15	2	4	38	0	1	10.6	5.5	0.52	22.5	40.6
Hall. Merkur	1579	275	61	37	44	0	11	351	0	19	2	3	46	0	1	12.7	6.6	0.52	15.0	38.2
Hallertauer Mfr.	1001	152	4	25	41	0	14	312	0	24	2	3	48	0	0	3.3	4.5	1.36	19.4	37.8
Hall. Taurus	3095	236	61	159	105	0	27	408	0	18	41	79	46	0	2	12.0	3.9	0.33	19.1	43.1
Hall. Tradition	2106	325	23	78	79	0	12	433	0	18	2	3	38	0	0	4.1	3.7	0.90	25.5	48.0
Harmony	1323	162	12	89	68	0	20	273	0	17	42	82	40	0	2	4.7	5.6	1.19	23.1	47.2
Herkules	2520	489	188	440	28	0	19	435	0	16	2	3	41	0	6	14.0	5.6	0.40	32.3	52.7
Hersbrucker Pure	2411	326	0	84	71	1	10	392	0	22	21	43	41	80	1	4.3	1.7	0.40	24.3	46.6
Hersbrucker Spät	1771	173	16	124	54	27	1	312	0	25	22	43	44	69	2	4.7	4.7	1.00	21.4	37.0
Huell Melon	7309	1887	3	514	64	1	56	125	203	49	215	398	103	168	17	7.0	7.3	1.04	29.2	49.7
Hüller Anfang	651	151	20	3	44	0	12	222	0	23	2	3	42	0	0	2.0	5.1	2.55	24.8	45.9
Hüller Aroma	873	170	3	3	68	0	17	273	0	22	2	3	48	0	0	3.0	4.8	1.60	31.1	54.9
Hüller Fortschritt	1050	126	28	9	74	0	18	297	0	20	2	3	42	0	0	2.5	5.0	2.00	27.1	48.9
Hüller Start	907	113	2	32	28	0	18	291	0	21	2	3	41	0	0	2.0	4.3	2.15	34.3	58.6
Jap. C 730	1126	109	32	271	33	0	21	212	126	10	6	10	23	0	4	4.0	4.1	1.03	30.5	49.7
Jap. C 845	986	90	42	171	20	0	11	189	37	20	2	4	44	0	3	11.0	5.4	0.49	24.0	41.9
Kirin 1	1846	499	1	36	54	0	17	306	3	37	23	18	84	0	6	5.3	4.9	0.92	42.1	67.6
Kirin 2	1960	528	0	21	56	0	19	306	0	52	31	59	104	0	6	4.7	4.4	0.94	43.8	78.2
Kitamidori	895	91	32	160	16	0	9	189	24	21	2	3	46	0	3	9.8	5.2	0.53	23.2	39.9
Kumir	1142	202	2	168	70	0	18	280	0	17	2	3	40	0	2	7.1	5.2	0.73	25.0	44.6

Variety	Myr-cene	2-Metyl-butyl-isobutyrate	Methyl-isohep-tanoate	ß-Oci-mene	Lina-lool	Aroma-dend-rene	Unde-canon	Hu-mulene	ß-Far-nesene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß/γ-Ca-dinene	3.7-Seli-nadien	Gera-niol	α-acids	ß-acids	ß/α	Cohu-mulone	Co-lupulone
Lubelski	1943	71	2	57	69	0	31	421	103	17	15	30	37	0	1	3.2	4.9	1.53	30.6	48.8
Mandarina Bavaria	5433	1112	20	185	74	0	32	613	15	30	69	20	66	0	31	10.5	5.9	0.56	37.3	57.3
Mt. Hood	1238	114	32	21	46	0	10	303	0	25	7	12	51	0	2	3.9	4.9	1.26	20.2	41.4
Neoplanta	651	136	0	143	10	0	6	144	20	17	2	3	40	0	0	4.2	4.7	1.12	31.2	62.8
Neptun	1112	190	106	27	44	0	4	214	0	20	2	2	45	0	1	9.9	4.5	0.45	22.5	44.8
Northdown	877	153	2	99	44	0	6	204	0	18	2	2	41	0	1	6.1	5.2	0.85	26.4	50.1
Northern Brewer	1609	259	1	217	19	0	10	342	0	15	1	2	38	0	1	6.4	4.1	0.64	25.5	47.9
Nugget	1863	296	5	151	54	0	11	307	0	13	6	10	33	0	1	12.6	3.9	0.31	25.1	50.6
Olympic	1105	169	10	133	55	0	17	196	0	13	9	17	32	0	1	13.1	5.2	0.40	26.0	48.5
Opal	1605	129	35	209	57	0	10	285	0	18	2	0	35	0	4	6.4	5.5	0.86	11.9	29.6
Orion	606	155	10	71	44	0	17	171	0	22	2	3	47	0	1	6.0	4.9	0.82	28.8	53.2
Perle	899	139	2	157	13	0	7	255	0	17	2	3	40	0	1	5.1	3.6	0.71	29.6	51.5
Polaris	1315	180	86	178	12	0	10	251	0	18	2	3	46	0	2	18.4	5.4	0.29	20.7	41.9
Premiant	1364	159	4	99	45	0	16	330	0	17	2	4	42	0	1	6.1	3.7	0.61	19.9	41.8
Pride of Ringwood	809	126	0	3	15	0	23	50	0	20	46	89	39	0	1	6.9	5.3	0.77	28.9	50.9
Record	1673	51	1	6	71	0	18	473	0	17	2	4	36	0	0	3.3	5.0	1.52	34.3	51.8
Relax	1689	134	10	37	14	0	19	422	0	22	4	6	39	0	4	0.4	9.3	23.25	36.7	27.0
Rottenburger	1189	144	1	11	58	0	28	308	0	20	2	3	46	0	0	4.2	5.6	1.33	26.5	42.3
Rubin	1338	247	84	102	38	0	8	271	0	21	42	81	46	0	8	9.3	4.7	0.51	28.8	58.3
Rubin	2313	241	88	117	32	0	7	345	0	21	43	82	47	0	10	10.8	3.6	0.33	31.8	54.2
Saazer	3561	26	3	65	77	0	35	611	123	20	2	3	39	1	1	2.4	3.7	1.54	24.3	41.7
Saphir	1738	121	13	259	67	1	21	278	0	18	11	21	35	34	2	2.3	4.3	1.87	13.1	39.6
Serebrianker	984	168	1	38	58	0	7	227	6	28	24	40	45	0	2	1.7	4.9	2.88	30.8	48.4
Sladek	966	139	3	109	56	0	17	254	7	17	2	3	43	0	2	6.6	5.3	0.80	18.1	40.1
Smaragd	2380	41	32	182	70	0	15	406	7	16	3	1	38	0	4	5.3	3.3	0.62	15.6	34.4
Sorachi Ace	1168	119	0	160	27	0	18	174	18	20	2	4	43	0	5	8.2	5.8	0.71	26.5	48.8
Southern Promise	522	178	14	64	2	0	39	243	0	23	12	23	42	44	0	7.1	4.5	0.63	28.2	50.5

Variety	Myr-cene	2-Metyl-butyl-isobutyrate	Methyl-isohep-tanoate	ß-Oci-mene	Lina-lool	Aroma-dend-rene	Unde-canon	Hu-mulene	ß-Far-nesene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß/γ-Ca-dinene	3.7-Seli-nadien	Gera-niol	α-acids	ß-acids	ß/α	Cohu-mulone	Co-lupulone
Southern Star	771	215	8	14	12	0	22	207	28	25	2	4	51	0	2	9.6	4.9	0.51	28.9	54.4
Spalter	4657	15	4	74	100	0	34	639	172	17	2	2	35	0	3	1.7	4.6	2.71	24.8	42.4
Spalter Select	5293	340	61	99	186	1	33	485	206	21	21	42	37	74	1	5.5	3.6	0.65	22.2	43.4
Sterling	1288	303	14	171	59	0	12	225	0	14	6	11	34	0	1	11.4	5.1	0.45	25.6	47.2
Strisselspalter	1955	137	6	86	64	27	1	331	0	25	24	46	40	70	1	3.1	5.7	1.84	17.4	33.5
Südafrika	670	74	1	7	8	0	17	264	0	27	41	77	48	0	2	5.7	4.4	0.77	28.0	58.1
Tango	6026	177	9	50	126	8	15	209	245	30	72	131	43	123	11	5.3	6.0	1.13	27.6	45.5
Target	2534	541	1	174	69	0	34	326	2	25	6	11	60	14	1	9.4	4.4	0.47	36.3	60.4
Tettnanger	3323	32	2	52	63	0	24	528	137	17	1	3	36	0	2	1.5	3.6	2.40	26.3	42.9
Titan	1696	136	183	322	28	0	16	361	0	14	2	3	37	0	1	10.1	4.6	0.46	23.9	40.4
USDA 21055	993	282	6	313	19	0	5	141	46	15	8	16	37	0	2	10.5	5.3	0.50	39.9	69.6
Viking	2119	380	9	379	51	0	37	335	107	16	25	45	38	0	1	6.0	4.6	0.77	26.7	51.7
Vital	1858	129	18	133	92	0	84	54	18	9	48	87	23	0	4	12.3	6.2	0.50	23.5	46.5
Vojvodina	1273	214	1	195	23	0	18	252	4	14	2	3	36	0	2	5.7	4.9	0.86	27.0	50.7
WFG	2638	38	3	33	76	0	31	524	126	16	2	3	37	0	1	2.3	4.5	1.96	21.8	44.0
Willamette	805	133	4	52	40	0	6	160	17	19	3	5	44	0	1	3.3	2.4	0.73	30.7	51.5
Xantia	2303	324	46	349	32	0	21	298	155	15	17	32	35	0	4	13.9	3.7	0.27	23.8	41.7
Yeoman	677	164	38	90	21	0	9	180	0	17	27	52	46	0	4	9.4	5.4	0.57	26.0	46.0
Zenith	1051	179	11	168	63	0	21	245	0	16	45	88	43	0	3	7.7	4.7	0.61	25.7	50.4
Zeus	1684	296	69	42	24	0	2	266	0	44	7	13	86	24	3	15.0	4.2	0.28	30.6	56.2
Zitic	1023	3	2	97	26	0	18	287	0	17	2	3	44	0	5	5.0	5.0	1.00	26.2	46.8

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 2024 harvest

Starting in 2000 hop supply contracts also have included an agreement specifying that the α-acid content of a delivery batch should be considered and can modify the agreed-upon price 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 2024, once again, the working group had the task of organizing and evaluating chain analyses to ensure the quality of α-acid analyses. That year, the following laboratories participated in the interlaboratory comparison (listed alphabetically).

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

The analytical tests began on September 10, 2024, and ended on November 8, by which time most of the hop batches had been analyzed by the laboratories. The analyses were conducted nine times in 9 weeks. The sample material was kindly provided by the Hallertau Hop Ring. Each sample was taken from a single bale only to ensure maximum homogeneity. Every Monday, the samples were ground up in Hüll using a hammer mill. Then, they were divided (Figure 59), vacuum-packed, and transported to the individual laboratories. Subsequently, one sample was analyzed per day. The analysis results were returned to Hüll one week later and evaluated there. A total of 34 samples were analyzed in 2024.

Figure 59: Sample divider and hammer mill

The evaluations were forwarded to the individual laboratories as quickly as possible. The following figure shows an example of what an ideal round-robin test should look like. The numbering of the laboratories (1-7) does not correspond to the above list.

Nr. 10: SGD (September 25, 2024)

Laboratory	Measured Value		Mean	s	cvr	z-score
1	5.53	5.56	5.55	0.021	0.4	-0.639
2	5.49	5.52	5.51	0.021	0.4	-1.326
3	5.63	5.58	5.61	0.035	0.6	0.393
4	5.64	5.63	5.64	0.007	0.1	0.909
5	5.55	5.51	5.53	0.028	0.5	-0.896
6	5.60	5.60	5.60	0.000	0.0	0.307
7	5.66	5.65	5.66	0.007	0.1	1.253

mean	5.58
sr	0.021
sL	0.054
sR	0.058
Vkr	0.37
vkR	1.04
r	0.06
R	0.16
Min	5.49
Max	5.66

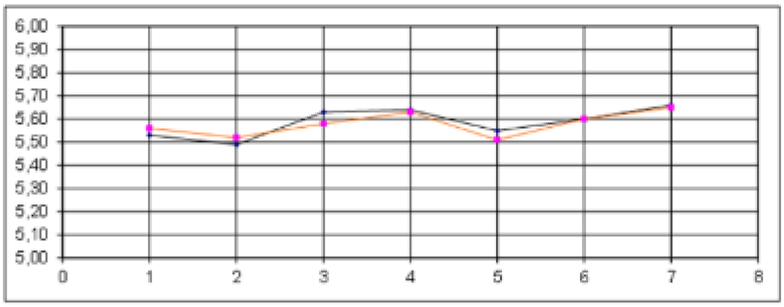


Figure 60: Evaluation of a set of chain analyses as an example

Since 2023, the z-score has also been included in the evaluation. The z-score is calculated using the following formula:

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

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

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

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

Formula 7.3

For eight laboratories and one duplicate determination, the value must be less than **2.274** for β = 1% G and less than **2.126** for β = 5% G, otherwise an outlier is detected. However, the z-score can also be used to detect laboratory outliers. If the z-score is less than -2 or greater than 2, these are outliers. In 2024, there were no outliers at all.

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

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

Formula 7.4

$$r = s_r * 2{,}8 \rightarrow R = s_R * 2{,}8$$

Formula 7.5

Since 2013, there have been five alpha classes and new tolerance limits. Table 22 shows the new classification and the exceedances for 2024.

Table 22: Updated alpha acid classes and tolerance limits as well as their exceedances in 2024

	< 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 2024	0	0	0	0	0

In 2024, there were no violations of the permitted tolerance limits.

Figure 61 shows all analysis results for each laboratory as relative deviations from the mean (= 100%), differentiated by α-acid contents <5%, >=5%, <10%, and >=10%. From this graphic one can clearly determine if a laboratory has a tendency to produce values that are too high or too low.

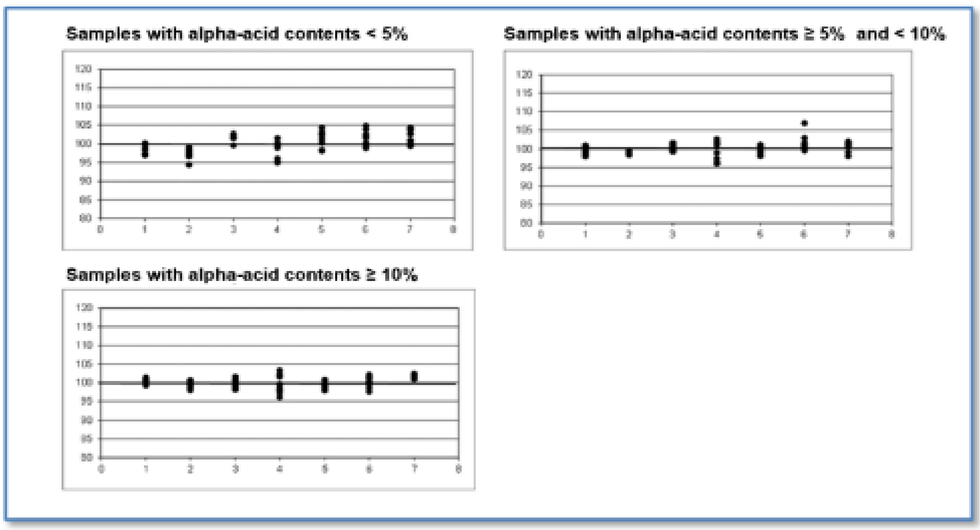


Figure 61: Laboratory analysis results relative to the mean

The Hüll laboratory is the number 5. In 2024, the α-acid levels were very low, so there were again more samples with 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 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 22). Table 23 shows the results for 2024. 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 23: Control evaluation in 2024

Sample name	Initial test laboratory	Initial test value	Follow-up tests			Average	Results confirmed
			1	2	3		
55397 NBR	AGROLAB	7.6	7.4	7.5	7.7	7.53	yes
55424 SSE	AGROLAB	3.7	3.5	3.6	3.6	3.57	yes
54626 HTR	AGROLAB	5.0	4.8	4.8	4.9	4.83	yes
Batch. 184 TET	BayWa	3.2	3.0	3.0	3.1	3.03	yes
Batch. 169 OPL	BayWa	7.9	7.8	7.8	7.9	7.83	yes
Batch. 115 PLA	BayWa	21.5	20.6	21.0	21.6	21.07	yes
DEH-TTN, 54375	HVG Mainburg	18.2	18.1	18.5	18.7	18.43	yes
DEH-TTN, 55726	HVG Mainburg	19.1	19.0	19.3	19.7	19.33	yes
DEH-HMG, 55722	HVG Mainburg	14.0	14.0	14.1	14.6	14.23	yes
Nr. 62562, HKS	HV St. Johann	13.7	13.7	13.7	13.9	13.77	yes
Nr. 62527, PER	HV St. Johann	5.5	5.2	5.3	5.4	5.30	yes
Nr. 62160, HMG	HV St. Johann	12.8	12.3	12.5	12.7	12.50	yes
KW41-HMG	HHV Au	11.9	11.8	11.9	12.1	11.93	yes
KW41-HKS1	HHV Au	18.7	18.5	18.5	18.6	18.53	yes
KW41-HKS2	HHV Au	17.0	16.6	16.6	17.0	16.73	yes
KW42-67650, MBA	AGROLAB	9.5	9.4	9.5	9.5	9.47	yes
KW42-67213, HKS	AGROLAB	15.3	15.4	15.7	15.8	15.63	yes
KW42-67368, HAL	AGROLAB	4.4	4.3	4.3	4.4	4.33	yes
KW43, Batch. 187, HBC	BayWa	11.2	11.2	11.2	11.3	11.23	yes
KW43, Batch. 205, HKS	BayWa	17.0	16.5	16.6	16.7	16.60	yes
KW43, Batch. 222, HTR	BayWa	5.6	5.6	5.8	5.8	5.73	yes

Sample name	Initial test laboratory	Initial test value	Follow-up tests			Average	Results confirmed
			1	2	3		
DEH-TTN, KW44, 65107	HVG Mainburg	16.3	16.4	16.7	17.0	16.70	yes
DEH-PLA, KW44, 64932	HVG Mainburg	18.8	18.4	19.0	19.1	18.83	yes
DEH-HKS, KW44, 64839	HVG Mainburg	17.3	17.6	17.7	17.7	17.67	yes
DEH-PER-Agrolab Nr. 60006	HV St. Johann	6.1	5.7	5.7	5.9	5.77	yes
DEH-NUG-Agrolab Nr. 67911	HV St. Johann	12.2	11.7	11.8	12.3	11.93	yes
DEH-HKS-Agrolab Nr. 67917	HV St. Johann	16.6	16.2	16.5	16.5	16.40	yes
KW46-PER	HHV Au	7.6	7.6	7.7	7.8	7.70	yes
KW46-HKS1	HHV Au	14.5	14.4	14.5	14.7	14.53	yes
KW46-HKS2	HHV Au	15.1	15.0	15.0	15.3	15.10	yes

7.5.3 Follow-up examinations for the 2024 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 24: 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 test is submitted as an LfL follow-up test report within three working days of receipt of the follow-up test results to the initial testing laboratory, which then immediately forwards the results to the client who commissioned the follow-up test. In 2024, a total of 38 follow-up tests were conducted. In three cases, the initial test result was not confirmed (marked in yellow). Table 25 shows the follow-up test results in ascending chronological order. 14 follow-up tests were conducted on behalf of HV St. Johann, 10 by HVG Mainburg, and 7 each by AGROLAB GmbH and HHV Au. Of the varieties, Herkules led the way with 30 follow-up tests, followed by Perle with 4, Hall. Tradition with two, Titan and Hall. Magnum with one each.

Table 25: Follow-up examinations in 2024

Sample name	Initial test laboratory	Initial test results	Follow-up tests			Mean	Results confirme d
			1	2	3		
HTR, Agrolab Nr. 56098	AGROLAB	5.6	5.3	5.5	5.5	5.43	yes
DEH-TTN, Analyses Nr. Agrolab 58090	HVG Mainburg	12.9	12.9	12.9	13.3	13.03	yes
DEH-HKS, Analyses Nr. Agrolab 60930	HVG Mainburg	14.9	14.8	14.9	15.0	14.90	yes
DEH-PER Nr. Agrolab 57255	HV St. Johann	8.0	8.0	8.0	8.1	8.03	yes
PER Agrolab Nr. 58750	AGROLAB	4.8	4.5	4.6	4.6	4.57	yes
PER Agrolab Nr 59013	AGROLAB	7.5	7.1	7.1	7.1	7.10	yes
HHKS, Nr. 60160	HV St. Johann	15.4	15.4	15.6	15.9	15.63	yes
Perle AN 58030	AGROLAB	8.3	7.7	7.8	8.0	7.83	yes
HKS, AN 61727	AGROLAB	11.4	11.0	11.2	11.3	11.17	yes
DEH-HKS, Analyses Nr. Agrolab 62579	HVG Mainburg	15.7	16.8	17.0	17.1	16.97	no
Agrolab-Analyses Nr. 62288, Batch number, 2339216, Variety	HHV Au	14.6	14.4	14.6	14.7	14.57	yes
Nr. 61089 - HKS	HV St. Johann	16.6	16.3	16.6	16.8	16.57	yes
Nr. 55085 - HKS	HV St. Johann	15.9	15.7	15.8	16.1	15.87	yes
Nr. 56263 - HTR	HV St. Johann	5.1	5.1	5.2	5.2	5.17	yes
DEH-HKS, Analyses Nr. Agrolab 62289, HVG Nr. 3423	HVG Mainburg	14.6	14.7	14.8	14.9	14.80	yes
Agrolab-Analyses nr. 62288, Variety HKS	HHV Au	14.6	14.4	14.6	14.7	14.57	yes
Agrolab-Analyses Nr. 62632, Batch number 23999416, Variety	HHV Au	13.7	13.6	13.6	13.7	13.63	yes
DEH-HKS, Analyses Nr. Agrolab 60988	HVG Mainburg	13.0	12.7	12.8	13.2	12.90	yes
DEH-HKS, Analyses Nr. Agrolab 60589	HVG Mainburg	13.4	13.1	13.2	13.8	13.37	yes
Agrolab-Analyses nr. 64927, Batch nr. 2010016, Variety	HHV Au	15.9	15.9	15.9	16.4	16.07	yes
Agrolab-Analyses nr. 63815, Batch number 2032743, Variety	HHV Au	14.4	14.2	14.2	14.5	14.30	yes

Sample name	Initial test laboratory	Initial test results	Follow-up tests			Mean	Results confirmed
			1	2	3		
Agrolab Nr. 63098, Variety DEH HKS	HV St. Johann	14.9	14.4	14.4	14.8	14.53	yes
Agrolab Nr. 61230, Variety DEH HKS	HV St. Johann	14.2	14.1	14.1	14.5	14.23	yes
Agrolab Nr. 61845, Variety DEH HKS	HV St. Johann	14.2	13.0	13.4	13.7	13.37	no
Agrolab Nr. 63861, Variety DEH HKS	HV St. Johann	15.5	14.9	15.0	15.2	15.03	yes
Agrolab Nr. 65715, Variety DEH HKS	HV St. Johann	14.8	14.8	15.5	15.6	15.30	yes
Agrolab Nr. 65982, Variety DEH HKS	HV St. Johann	15.1	15.2	15.5	15.9	15.53	yes
DET-HKS, Analyses Nr. Agrolab 66786	HVG Mainburg	17.1	16.8	17.2	17.4	17.13	yes
Batch number 2916911, Variety HMG	HHV Au	13.0	12.8	12.8	13.0	12.87	yes
Agrolab Nr. 66651, Variety HKS	AGROLAB	11.6	12.2	12.3	12.5	12.33	no
DEH-HKS, Analyses Nr. Agrolab 62478	HVG Mainburg	13.1	13.1	13.3	13.4	13.27	yes
DEH-HKS, Analyses Nr. Agrolab 66649	HVG Mainburg	15.4	15.3	15.6	15.7	15.53	ja
Agrolab Analyses Nr. 62591, Variety HKS	HHV Au	13.6	13.3	13.4	13.4	13.37	ja
DEH-HKS, Analyses Nr. Agrolab 62829	HV St. Johann	14.3	14.2	14.4	14.4	14.33	ja
DEH-HKS, Analyses Nr. Agrolab 66517	HV St. Johann	12.4	12.4	12.8	12.8	12.67	ja
DEH-HKS, Analyses Nr. Agrolab 67250	HVG Mainburg	15.8	16.2	16.2	16.4	16.27	ja
HKS, Analyses Nr. Agrolab 65315	AGROLAB	12.0	12.3	12.4	12.7	12.47	ja
DE-HKS, Analyses Nr. Agrolab 68223	HV St. Johann	11.5	11.2	11.2	11.3	11.23	ja

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

Table 26: Number of follow-up examinations and complaints from 2019 - 2024

Follow-up exams	Number	Complaints		Follow-up exams	Number	Complaints
2019	47	1		2022	42	1
2020	42	1		2023	36	3
2021	33	0		2024	38	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 yearly on essential oils and bitter substances to determine the optimum time for harvesting them. Table 27 shows the best harvest dates, although slight date shifts are possible for different years.

Table 27: Harvest dates derived from biogenesis experiments

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

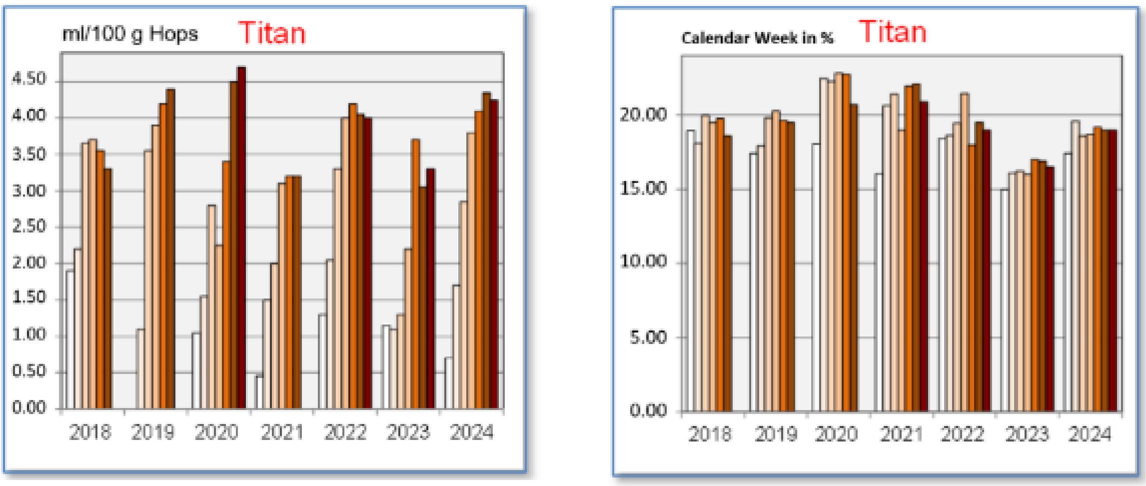


Figure 62: Biogenesis of oils and bitter substances in Titan at the Stadelhof location

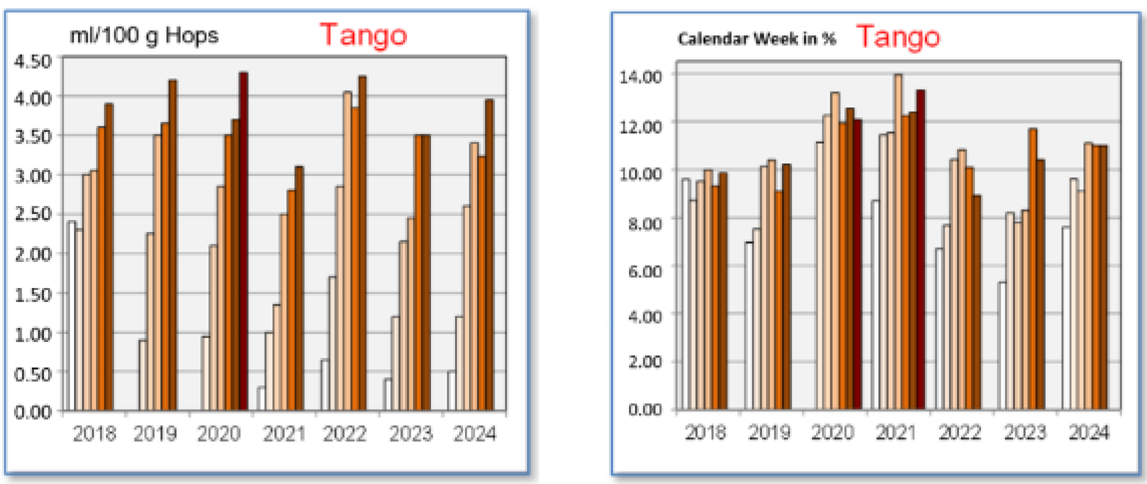


Figure 63: Biogenesis of oils and bitter substances in Tango at the Stadelhof location

The graphs (Figure 62 and Figure 63) clearly show that the oil content is much more dependent on the harvest time than is the bitterness content. At later harvest times, the oil content increases significantly primarily because of an increase in myrcene.

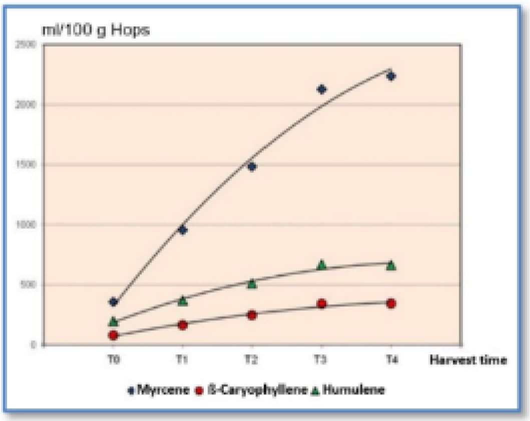


Figure 64: Increase in myrcene during biogenesis

Sulfur compounds are also formed later in the development cycle. The new Tango variety has a very high oil content (2.4–4.0 ml/100g) relative to its alpha acid content (7.5–11.0%). Climatic conditions appear to have different effects on different hop compounds. In dry and hot years, the oil concentration even increases over time, while 2021 was ideal for α-acids, which increased a record levels, but oil contents were lower. 2023, on the other hand, was the worst year for alpha acids but oil contents were average. In 2024, both alpha acid and oil contents were average.

Auch Schwefelverbindungen werden erst später gebildet. Die neue Sorte Tango hat relativ zu ihrem alpha-Säurengehalt (7,5 – 11,0 %) einen sehr hohen Ölgehalt (2,4 – 4,0 ml/100 g Hopfen). Auch scheinen sich die klimatischen Bedingungen unterschiedlich auf die Inhaltsstoffe auszuwirken. In trockenen und heißen Jahren steigt die Ölkonzentration sogar noch an. Das Jahr 2021 war ideal für die α-Säuren. In diesem Jahr gab es Rekord-α-Säurenergebnisse, aber die Ölgehalte waren geringer. Das Jahr 2023 war das schlechteste alpha-Säurenjahr, die Ölgehalte waren aber durchschnittlich. Im Jahr 2024 waren die alpha-Säurengehalte durchschnittlich und auch die Ölgehalte lagen im durchschnittlichen Bereich.

7.7 Development of NIRS calibrations based on conductometer and HPLC data generated by a new near-infrared reflection spectroscopy device

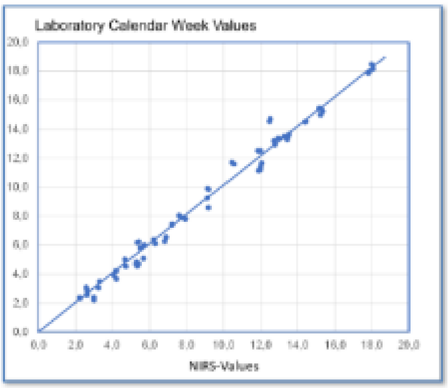
Since the spring of 2017, the laboratory in Hüll has owned a new NIRS device, which was fully financed by the Society for Hop Research (Figure 65).

Figure 65: NIRS device from Unity Scientific

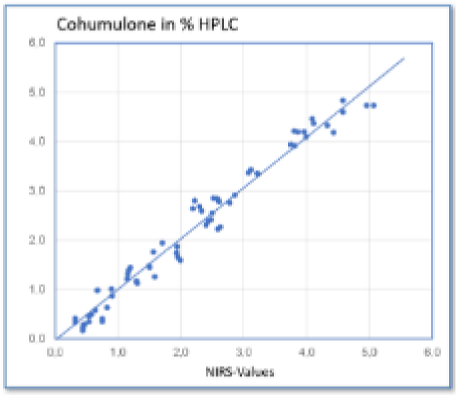
The device is compatible with the devices at AQU in Freising. The old calibration from the Foss device was adapted to the new device using a mathematical transformation.

However, we have also begun to develop our own calibrations based on conductometer and HPLC data from this device. These calibrations are expanded and validated annually using samples from the round robin test. The following figures show the correlations of the individual parameters between laboratory values and NIRS values (as of the 2024 harvest).

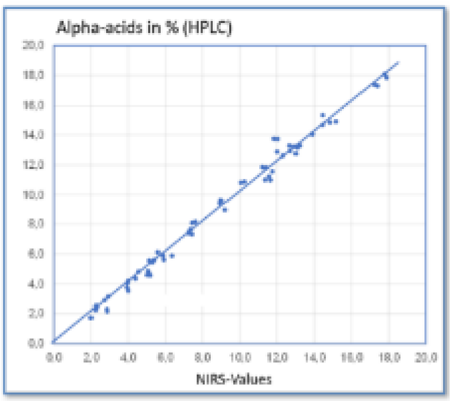
Conductometer values in %



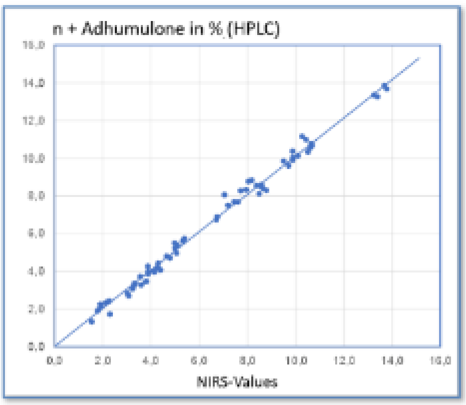
Cohumulone in %



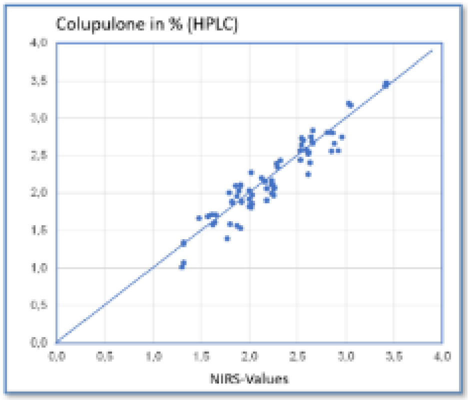
n+Adhumulone in %



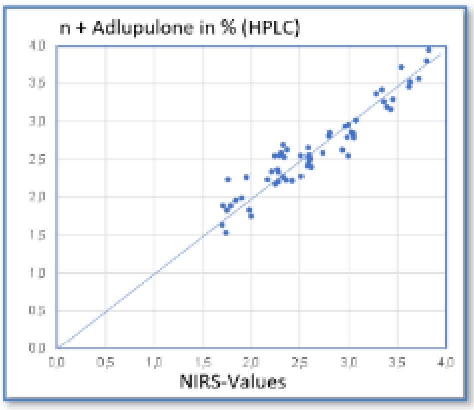
alpha-acids in %



Colupulone in %



n + Adlupulone in %



beta acids in %

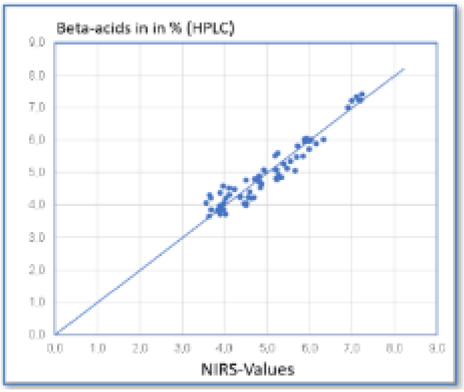


Figure 66: Correlations between laboratory values and NIRS values (2024)

Table 28 lists the statistical parameters for evaluating calibration precision. The Bias value represents the systematic deviation between the NIRS values and the laboratory values. SEP stands for Standard Error of Prediction, which is the standard error between the NIRS values and the values of the validation samples. SEP is calculated using Formula 7.6. The so-called random error SEP(C) is obtained using Formula 7.7. R^2 is the coefficient of determination between the NIRS values and the laboratory values. The higher R^2, the better the correlation.

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

Formula 7.6

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

Formula 7.7

Table 28: Statistical parameters for the precision assessment of the NIRS methods (2024)

Method	Bias	SEP	SEP(C)	R^2
Conductometer values	-0.108	0.580	0.570	0.986
Cohumulone (HPLC)	-0.027	0.238	0.237	0.973
n + Adhumulone (HPLC)	-0.080	0.330	0.320	0.992
Alpha-acids (HPLC)	-0.151	0.501	0.478	0.990
Colupulone (HPLC)	0.044	0.175	0.169	0.893

n + Adlupulone (HPLC)	0.037	0.186	0.182	0.934
Beta-acids (HPLC)	0.036	0.290	0.288	0.916

It is noteworthy that the conductometer values and the HPLC alpha-acid values are already quite well correlated with the NIRS values. The NIRS method is somewhat less effective for determining beta-acids. Calibrations are continuously improving because of the annual addition of new data sets. Near-infrared spectroscopy is a very valuable method for hop breeding, as it allows for the measurement of many samples per day and eliminates the need for solvents that are expensive to dispose of. However, NIRS is still too imprecise as a method for hop supply contracts, so conductometric titration is used there.

7.8 Alpha acid stability of the new Hüll cultivars against year-to-year fluctuations

Alpha acid data from 2012 to 2024 are now available for the new Hüll cultivars and can be nicely visualized using box plots. Figure 67 briefly explains the representation of a box plot analysis.

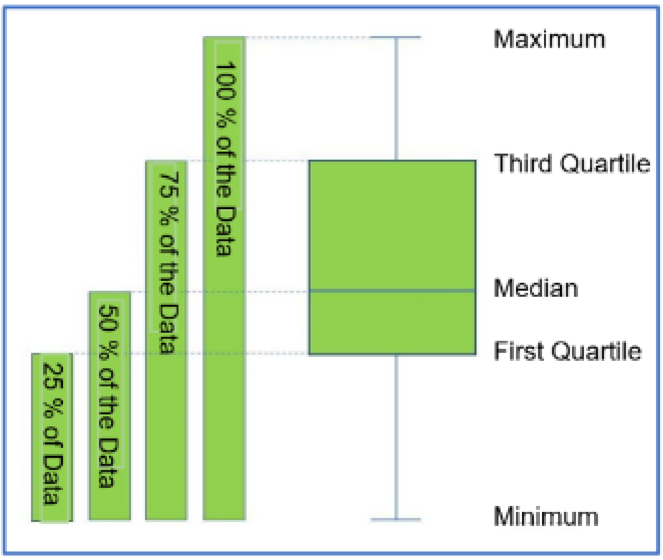


Figure 67: Explanation of a box plot representation

Figures 68 and 69 show box plot analyses of the official AHA results. These figures clearly demonstrate that the new Hüll cultivars are significantly more stable against vintage fluctuations than, for example, the Perle and Northern Brewer varieties.

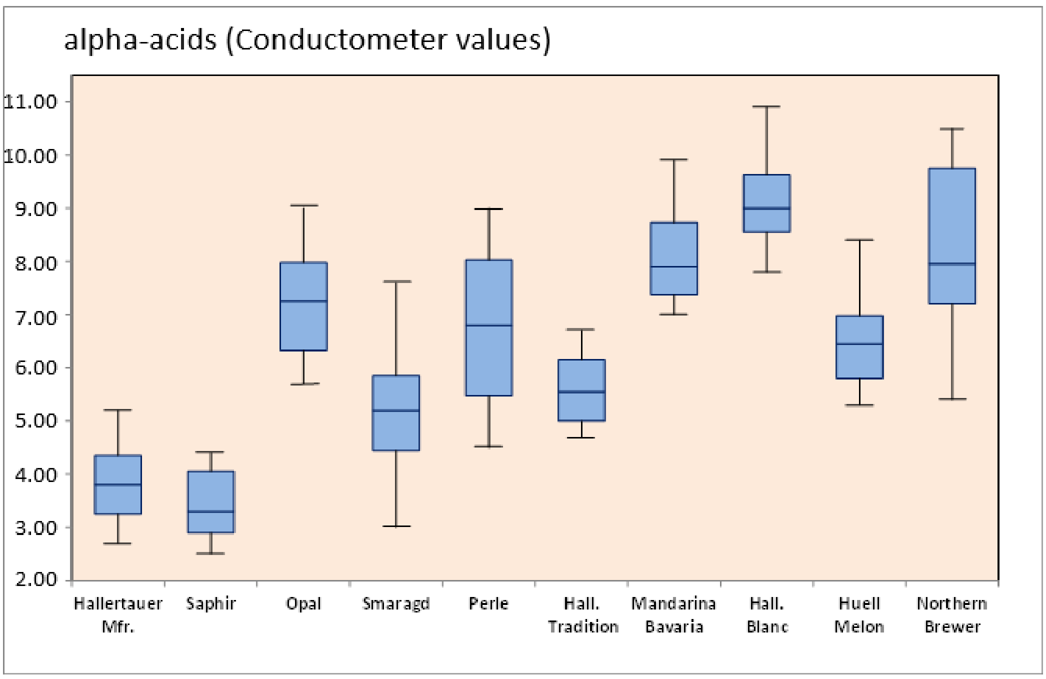


Figure. 68: Box-Plot evaluation of aroma varieties (2012 - 2024)

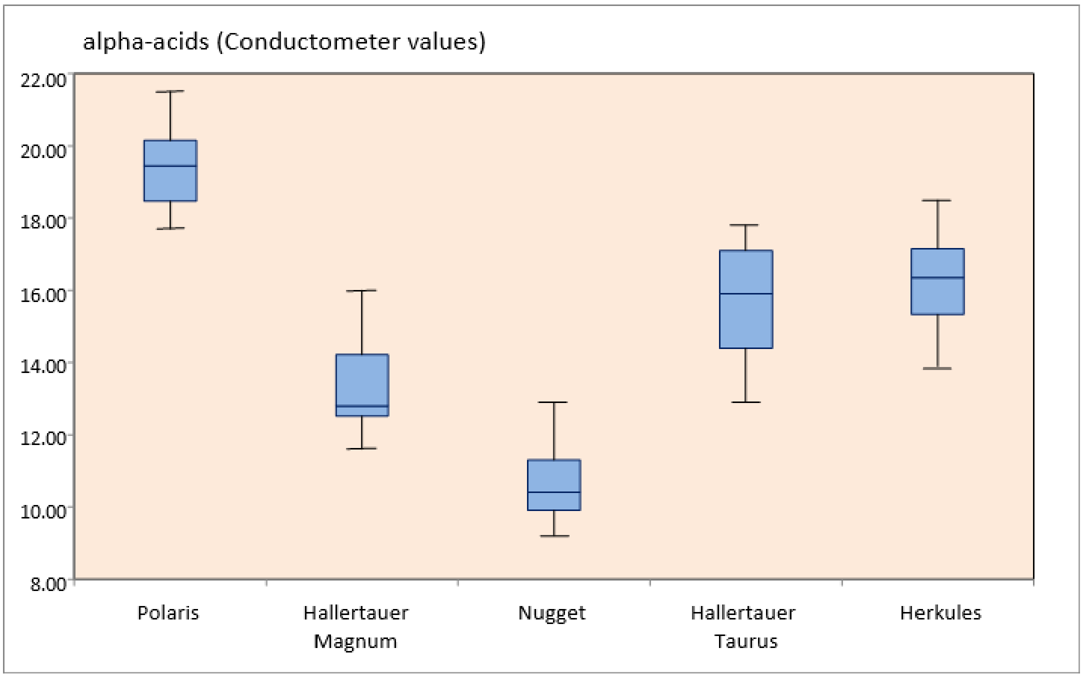


Figure 69: Box-Plot evaluation of bitter varieties (2012 - 2024)

7.9 Establishing an analysis of alkaloids in lupins

A new project for the analysis of alkaloids in lupins was created for Günther Schweizer's IPZ 1b research group. First was the development of a suitable sample preparation method; then of a GC method for analysis.

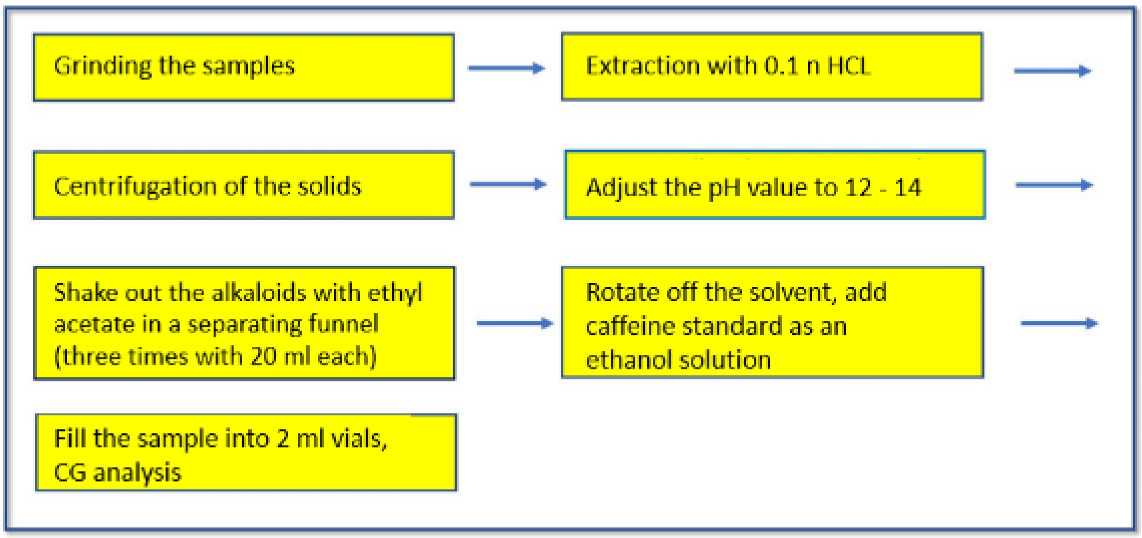


Figure 70: Sample preparation alkaloid analysis

Figure 71 illustrates the GC analysis.

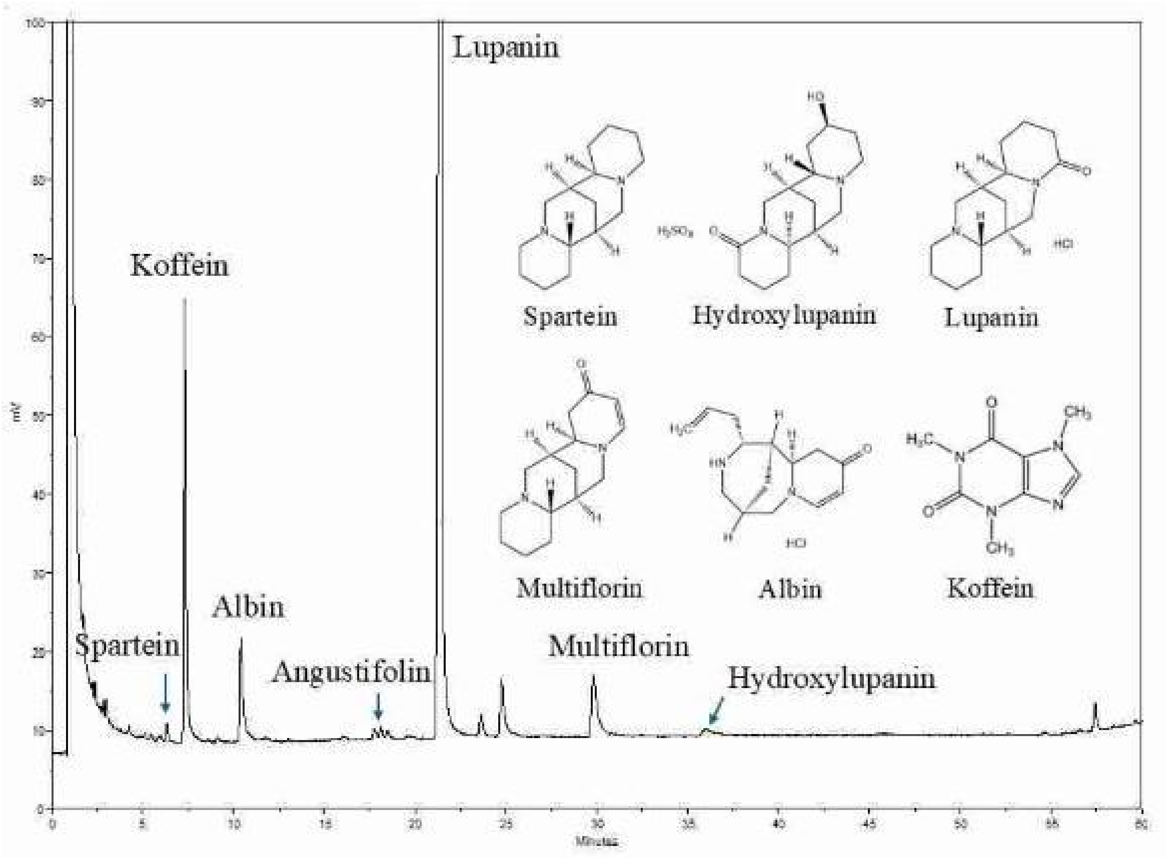


Figure 71: Gas chromatogram of alkaloids in lupins

The main compound is lupanine. Sparteine, hydroxylupanine, multiflorine, and albine were also identified. Quantitative analysis is performed using caffeine as an internal standard. There are still a few unknown peaks that need to be checked using standards. A total of 100 samples were measured in 2024. In Germany, the total alkaloid content for animal feed may not exceed 0.05%, and for food, it may not exceed 0.02%.

7.10 Control of variety authenticity in 2024

The verification of varietal authenticity for the food control authorities as administrative assistance is a mandatory task of the IPZ 5d working group.

In 2024, IPZ 5d performed 7 variety checks for the food inspection authorities (district offices), for which there were zero complaints.

8 Ecological Issues in Hop Production

Dr. Florian Weihrauch, Dipl.-Biol.

The task of this working group is fundamentally to update the state of knowledge and conduct applied research on environmentally friendly and ecological hop production. This includes diagnosis, observation, and monitoring of the occurrence of hop pests and their antagonists. This is done particularly with a view to advancing climate change and the resulting changes in biocenoses, as well as the development and evaluation of biological and other ecologically compatible plant protection methods, especially as essential building blocks for practical integrated plant protection. The working group is primarily funded to conduct research on ecological issues in hop cultivation.

8.1 Development of a catalogue of measures to promote biodiversity in hop cultivation

Sponsor:	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:	Erzeugerorganisation Hopfen HVG e.G. (*HVG Hop Producer Group)*
Project Management:	Dr. F. Weihrauch
Team:	Dr. F. Weihrauch, Dr. I. Lusebrink, M. Kremer
Collaborators:	Interessengemeinschaft Niederlauterbach (IGN) e.V. *(IGN Interest Community for Quality Hops Niederlauterbach)* AELF Ingolstadt-Pfaffenhofen, FZ Agrarökologie *(Centre of Expertise for Agroecology)* Landesbund für Vogelschutz, KG Pfaffenhofen *(The State Association for Bird Protection in Bavaria eV)* uNB, Landkreis Pfaffenhofen *(Lower Nature Conservation Authority UNB)*
Duration:	March 1, 2018 to February 28, 2026 (Project extension)

Purpose and background

After the Bavarian State Government declared 2019 and 2020 'Years of Biodiversity,' the term biodiversity continues to be on everyone's lips. As early as the beginning of 2018, the EG HVG, together with the LfL, began initiating measures to prevent species loss and promote biodiversity in hop cultivation. These included the evaluation of measures to promote biodiversity in and around hop gardens, the development of a work plan, the exploration of individual topics, and the moderation of sessions about their implementation in practice. Fundamentally, the aim of the project is to not interfere with the productivity of valuable arable or hop acreage, but to discourage the use or repurpose of marginal, unproductive, or critical areas just because they are there.

Procedure

The most important step was to establish a cooperative network of as many affected associations, organizations, and institutions as possible to jointly develop a constructive approach and solutions. In addition to the LfL and the TUM, the AELF Ingolstadt-Pfaffenhofen (Center for Agroecology), the LBV (Lenzinger Land Association), the UNB (University of Applied Sciences) at the Pfaffenhofen District Office, the IGN Niederlauterbach, and all organizations at the House of Hops have been involved to date.

Concept of the 'Eichelberg Biodiversity Scenic Area'

The first decisive step was the intensive collaboration with the IGN Niederlauterbach. In the fields of the traditional hop-growing village of Eichelberg, on the edge of the Ilm Valley, there is a virtually closed 85-hectare parcel of land, the majority of which is owned and managed by three IGN farms. This land is divided into 34 hectares (40%) are hop gardens, 28 hectares (33%) of arable land, as well as wooded areas, grasslands, wild flower areas, and otherwise unused areas. Thanks to a small number of committed and interested landowners and farmers, this 'Eichelberg Biodiversity Scenic Area' offers exceptional opportunities to develop a model for demonstrating that hop cultivation and biodiversity are not necessarily mutually exclusive, but can easily coexist. In the fall of 2020, an action plan was developed outlining the measures to be implemented.

Implementation began in the spring of 2021. The initial work focused on creating and establishing new habitats and overwintering areas for beneficial insects such as predatory mites. These structures were then "inoculated" with predatory mites from viticulture in the spring 2022. To evaluate the extent to which beneficial insect promotion can contribute to biological spider mite control, four hop gardens in the Eichelberg area were each divided approximately in half. One section managed conventionally with acaricide applications and one without them, but instead with beneficial insect promotion (Figure 72), followed by annual monitoring of spider mite infestations. In addition, the yield and quality of the harvests in both halves were analyzed (Figure 73).

Figure 72: The left hop garden in Eichelberg (variety HKS) was not treated with acaricides for four years, just with introduced beneficial insects (photo from August 3, 2023).

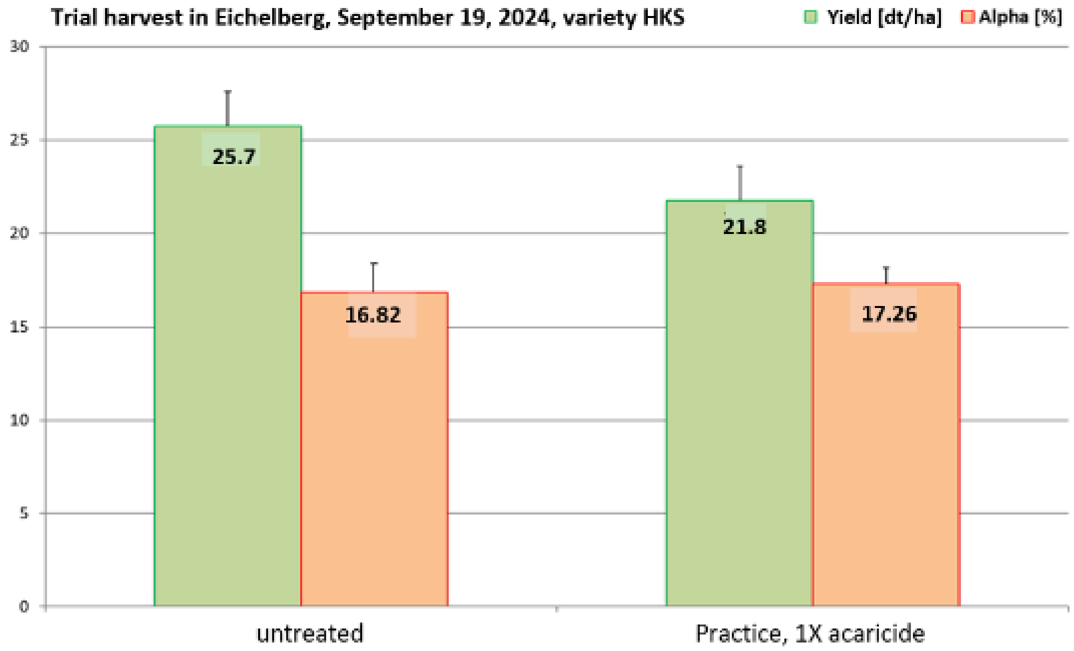


Figure 73: Trial harvest 2024 in this hop garden in Eichelberg (variety HKS) Comparison of the area that was treated annually with acaricide with the directly adjacent area in which only measures to promote beneficial insects were carried out.

Another important part of the project concerns public relations. This included a 2.5 km circular walking trail with 16 information panels themed “Hops and Biodiversity,” opened in July 2023. The panel design and content were created by the IPZ 5e working group in collaboration with the AELF IN-PAF, the unBNB at the district office, and the LBV (Local Association of Hop Growers). The panel topics included “The Woodlark” (Figure 75), “Untreated soil areas”, “Spider mite control with beneficial insects” and “Antlions”. To raise public awareness, nine two-hour guided tours, attended by a wide variety of visitor groups, from hop organizations, such as the 'Ring of Young Hop Growers' to interested politicians, were organized in 2024 (Figure 74).

Figure 74: In the summer of 2024, nine two-hour guided tours were organized for visitor groups of the “Hops and Biodiversity” trail in Eichelberg

Figure 75: Information board "The Woodlark" on the "Hops and Biodiversity" trail in Eichelberg

8.2 Development of a technical possibility for predatory mite application

Sponsor:	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. Kremer, A. Baumgartner, M. Felsl
Collaborators:	Blüml GbR, (Hop Farm) Dürnwind Kürzinger, (Hop Farm) Eichelberg Koppert Biological Systems
Duration:	May 2021 to October 2025

Background, approach and objective

Europe's largest producer of beneficial insects, Koppert Biological Systems from the Netherlands, plans to test and improve the potential of a technical solution for dispersing predatory mites (*Phytoseiulus persimilis*) in hops in a pilot project in the Hallertau. The goal is to use these mites to control the common spider mite (*Tetranychus urticae*). However, the technology must also be competitive in terms of cost and personnel requirements with conventional acaricide applications. Initial trials were conducted in 2021 using a specially designed device mounted on the rear of a tractor. It distributed predatory mites throughout the crop via six discharge pipes at three height levels. After a large proportion of beneficial insects landed in the furrows between the rows of hops rather than directly on the hops, a modified approach was tested in 2022. Very early in the growing season, at the beginning of May, only the newly emerging hop plants were treated once at ground level, using only two discharge pipes. Because this method proved potentially practical, a similar technical solution was tested in trials in 2023 and 2024, on May 15 and 16, respectively (Figure 76). The predatory mites were again applied on the hop rows via conveyors with the sawdust carrier, thus avoiding damaging the new plants (Figure 77).

Figure 76: Predatory mite application in the Dürnwind experimental garden, directly after the first tillage on 15 May 2024 along a row of freshly trained plants

Based on experiences gained from these long-term trials at the Hop Research Center, a mixture of the two predatory mites, *Neoseiulus californicus* and *Phytoseiulus persimilis* was used, which proved effective at a rate of 100,000 mites per hectare. The trial was conducted in Dürnwind with Herkules. The test included a comparison with an untreated control, a sprayed plot (one application of spirotetramat), and an application on bean leaves (application on June 13, 2024), which has been particularly effective in all trials over the years.

Figure 77: Using sawdust as a carrier substance, the predatory mites are gently blown onto the young hop bines during application

Results 2024

At the beginning of the season, spider mite infestation was virtually zero; and by harvest time it had increased to an average of just two insects per leaf. As in most of the Hallertau and Tettnang regions, no spider mite pressure was observed at either trial site in 2024. A significant difference in spider mite numbers between the treatments was not evident in any case.

Trial harvests were carried out at both sites on September 19, 2024. The lack of differences in spider mite infestation between the treatments is also reflected in the yield or alpha acid data (Figure 78, Figure 79). All predatory mite plots and the untreated control showed no losses compared to conventional crop protection. At the Dürnwind site, the plot with the acaricide application showed by harvest lower yields (Figure 78). As in previous years, any damage because of lack of acaricide use can be ruled out.

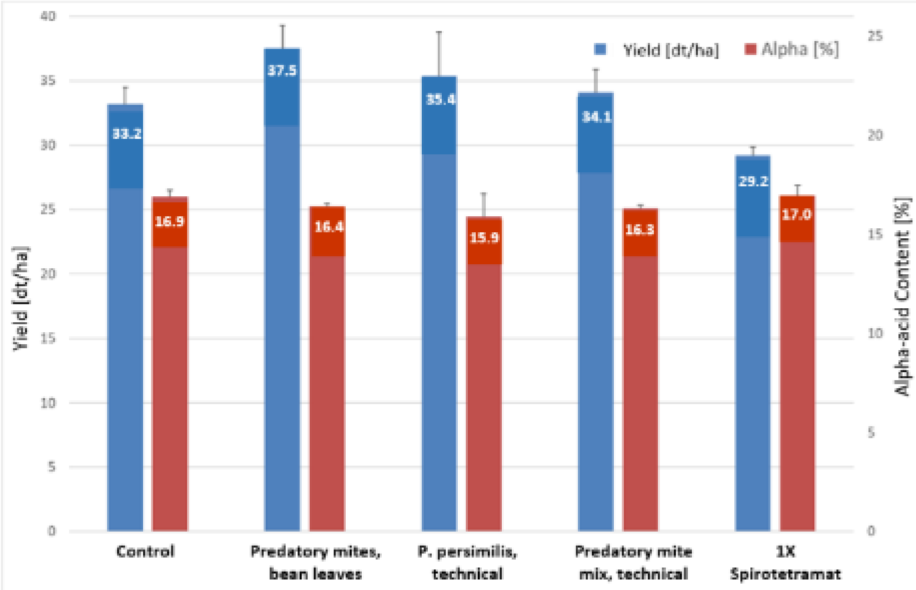


Figure 78: Results of the trial harvest on September 19, 2024, using predatory mites in Dürnwind (variety HKS), compared with untreated control and acaricide use

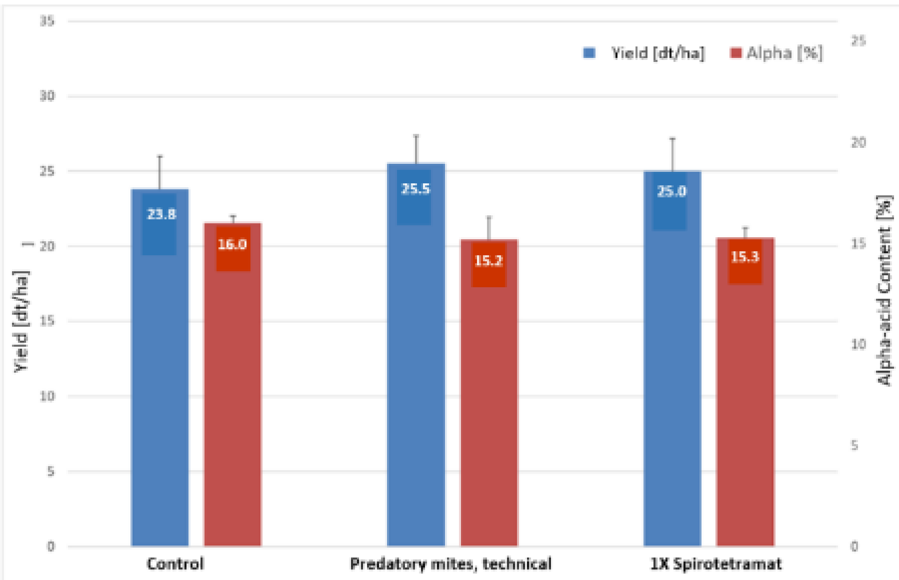


Figure 79: Results of the trial harvest on September 19, 2024, using predatory mites in Eichelberg (variety HKS), compared with untreated control and acaricide use.

Outlook

For a technical predatory mite application that is competitive with the use of chemical-synthetic acaricides against spider mites, only a few minor adjustments remain. For example, the optimal timing for application is still being worked out, and the question of whether a second predatory mite application makes sense and, if so, when, remains to be clarified. After the method has already been tested with the support of the Hopfenring on 19 farms covering almost 100 hectares (hop ring), further applications on commercial farms are planned for 2025, as well as another large-scale trial. However, as in the previous year, the low spider mite infestations in 2024 unfortunately prevented any reliable conclusions.

8.3 Induced resistance to spider mites in hops

Sponsor:	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 Environmental Foundation (DBU), funding initiative 'Avoidance and Reduction of Pesticides in the Environment', funding reference: AZ 35937/01-34/0*
Project Management:	Dr. F. Weihrauch
Team:	Dr. I. Lusebrink, M. Kremer, A. Baumgartner, M. Felsl, J. Klepmair
Collaborators:	20 practical farms from integrated hop cultivation Working Group IPZ 5d, Hop Analysis
Duration:	June 2021 to May 2026

Background and objective

The common spider mite can build up very large populations in short periods of time during dry, hot summers, causing, in some years, enormous losses in hop quality and yield. In recent decades, various plant protection trials conducted by the Hop Research Center have discovered that hop plants, after surviving severe spider mite infestations, are able to defend themselves independently against new, excessive spider mite infestations in subsequent years. The InduResi project is now investigating if and to which extent one- or two-year heavy infestations with this pest can reduces the susceptibility of hops to spider mites in subsequent years through "induced resistance."

Procedure

Field trials are being conducted in the Hallertau in Bavaria and in Tettnang in Baden-Württemberg. In the Hallertau, ten trial gardens each with the Hallertauer 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 trial gardens with the classic Tettnanger (TET).

Each trial garden contains a control plot and a test plot of 550 m² each. The spider mite population is allowed to develop freely in the control plot. The other plot should be treated at least once with acaricide, which is standard practice. Thus, it should be free of spider mites as much as possible. For the spider mite assessment, leaves are taken from the lower, middle, and upper sections of the bines in the middle of each of the two plots. The corresponding infestation index (BI) is calculated based on the number of spider mites and their eggs. Beneficial organisms, that is, insects and mites that feed on spider mites and their eggs, are also counted.

At the end of the season, a trial harvest of both plots is conducted in one to three of the most interesting gardens of each variety. Yields per hectare, alpha acid contents, weights, and cone qualities are determined. The data obtained are then statistically evaluated and examined for possible differences between the controls and the other plots.

Results

Due to the humid weather with few hot days, there was only a low level of spider mite infestation in the trial gardens in the first project in 2021. In six of the ten HKS gardens, there were significantly more spider mites in the control plot than in the other plot. However, in the HKS garden, both plots did not reach the control threshold (BI = 0.5). In the HTR gardens, seven gardens exceeded the control threshold and had a higher BI than the control plots, and in the SSE gardens, there was only one location where this was the case. In Tettnang, the BI differed significantly in one trial garden, although the BI was higher in the field plot. One trial harvest was conducted for each variety. No yield loss was observed; only the harvested HTR garden experienced a loss of cone quality.

The second project year, 2022, was ideal for spider mites. Because of the persistent drought and heat, the pests were able to multiply rapidly, and the infestation pressure was high. Only three HKS gardens showed no significant difference in the BI between the two plots, although even in there, the control threshold was exceeded towards the end of the season. In the HTR gardens, only two trial plots were spared from major spider mite infestations. In the SSE gardens, there were no significant differences between the plots in one garden, although both plots exceeded the control threshold there. The situation in Tettnang was similar, with only one yard largely spared from spider mites. At the end of the season, two gardens per variety were harvested in the Hallertau and one in Tettnang. The two harvested HTR yards and one of the SSE yards suffered yield losses. The subsequent cone assessment showed that even the regular commercial plots were not completely free of spider mites, which is why the cone quality in all harvested trial gardens suffered from the strong spider mite pressure of the year, both in the control and the commercial plots.

Spider mite pressure was very low in 2023. For our project, this meant that the control threshold, as well as a significant difference between the control and field plots were reached only in one HKS garden, two HTR gardens, and one SSE and one TET garden. The decision as to which garden would be retired was made in previous years at the penultimate assessment date, taking into account the extent to which there were differences in infestation between the two plots. This year, we primarily selected trial gardens that had a severe infestation the previous year and had already been harvested in 2022. The only exception was Tettnang, where the garden that had been harvested in previous years showed no spider mite infestation at all. No yield loss due to spider mites was detected in any of the trial harvests.

Similar to the previous year, 2024 was characterized by extremely low spider mite pressure until late summer. Only in the late varieties, especially HKS, did a certain infestation develop in some areas in September. Accordingly, the 2024 assessments failed to produce any meaningful results, and the trial harvests did not show any significant losses in the untreated control, either in yield or alpha acids. In one case (HTR, Einthal site), there was even a significant increase in yield in the control plot (Figure 80).

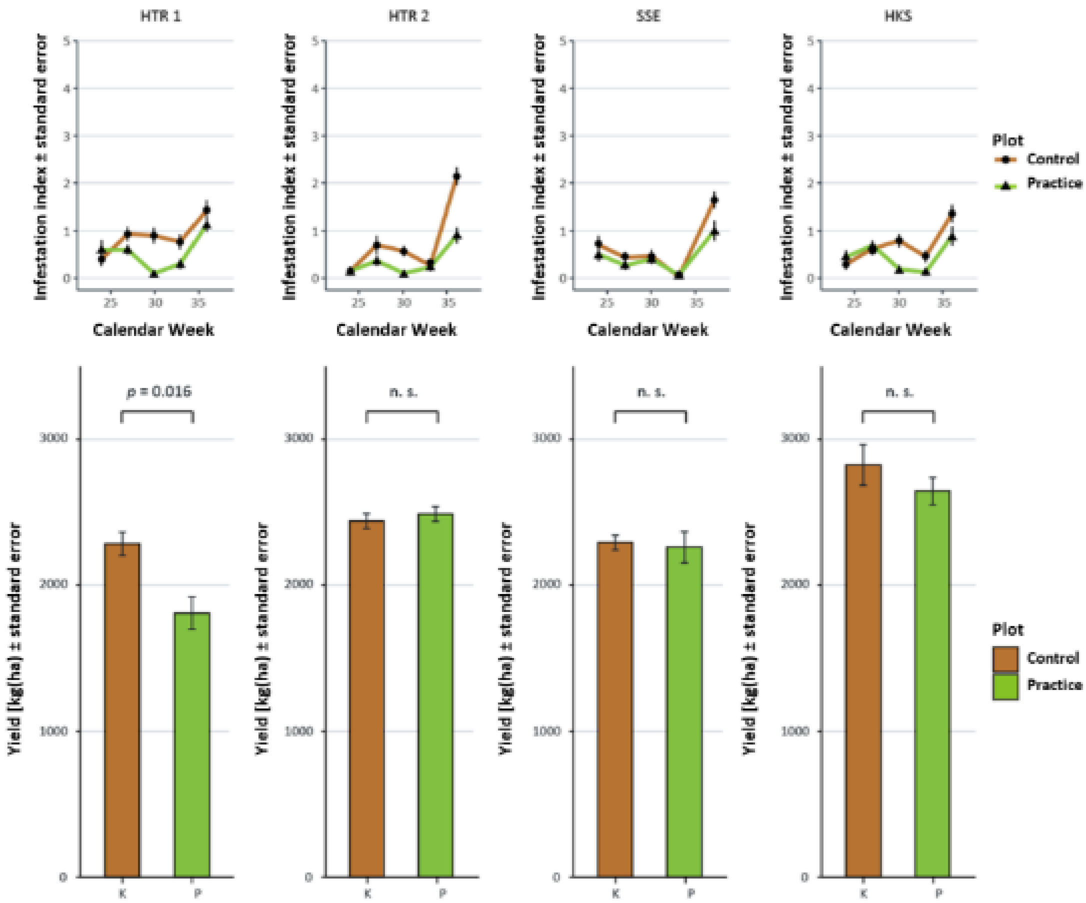


Figure 80: Results of the 2024 trial harvests for the varieties HTR (2), HKS, and SSE. The development of the infestation index over the 2024 growing season is shown above. Green represents the field plots (treated with acaricide), brown represents the untreated control plot.

Because the trial harvests in one of the experimental gardens (Oberulrain, HTR) in all four project years to date showed relatively high spider mite counts in the control plot, a reliable comparison is possible with the spider mite development without the use of acaricides. The data clearly show that an increased spider mite infestation in a crop in one year does not mean that a high initial infestation by spider mites should be expected in the following year (Figure 81).

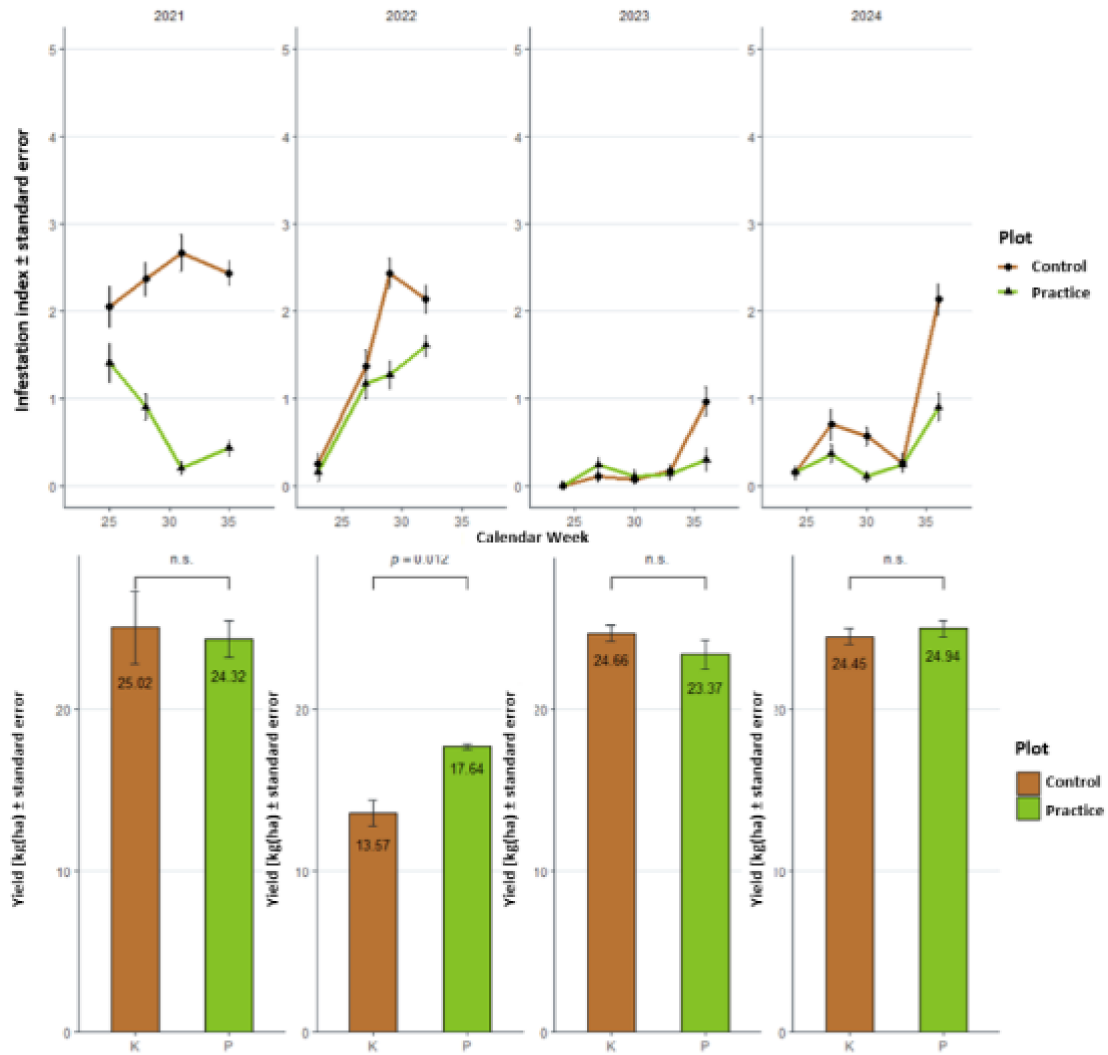


Figure 81: Results of the trial harvests and the course of the infestation index over four years (2021-2024) in the same trial garden (Oberulrain, HTR 2). Green represents the field plot (treated with acaricide), brown represents the untreated control plot.

9 Publications and Technical Information

9.1 Public relations overview

	Number		Number
Internet contributions	1	Memberships	43
Internships	7	Lectures	76
Guided tours, excursions	31	Publications	35
Expert assessments and opinions	4		

9.2 Publications

9.2.1 Guided tours, excursions

Date	Name	Subject/Title	Guest(s)	No.
July 24, 2024	Head of the Hop Research Center Hüll	Guided tour of the Hop Research Center	Field trip QE 3+4	40
September 23, 2024	Head of the Hop Research Center Hüll	Guided tour of the Hop Research Center	CDU/CSU Agriculture Spokespersons of the Federal States	30
October 11, 2024	Dr. Gresset, A.; Lutz, A.; Dr. Kammhuber, K.	Guided tour of the Hop Research Center	Technical University of Munich (TUM) Agricultural Systems Engineering	20
September 27, 2024	Dr. Gresset, S.	Guided tour of the Hop Research Center	BayWa, Hops	10
September 19, 2024	Dr. Gresset, S.	Guided tour of the Hop Research Center	HVG Polar Brewery	5
July 18, 2024	Dr. Gresset, S.	Guided tour of the Hop Research Center	New employees from HVG	12
October 1, 2024	Dr. Gresset, S.	Guided tour of the Hop Research Center	Kirin	4
August 20, 2024	Dr. Gresset, S.	Guided tour of the Hop Research Center	Media representatives RTL, SAT 1	3
July 26, 2024	Dr. Gresset, S.	Guided tour of the Hop Research Center	US Team Steiner	4
June 10, 2024	Dr. Gresset, S.; Dr. Kammhuber, K.	Guided tour of the Hop Research Center	Beer Guides	2
July 10, 2024	Dr. Gresset, S.; Dr. Kammhuber, K.; Lutz, A.	Guided tour of the Hop Research Center	Brewing Students, Technical University of Munich (TUM)	30
July 26, 2024	Dr. Gresset, S.; Dr. Weihrauch, F.	Guided tour of the Hop Research Center	HVG, Visitors from Japan	6

Date	Name	Subject/Title	Guest(s)	No.
July 25, 2024	Dr. Gresset, S.; Fuß, S.	Guided tour of the Hop Research Center	LWS PAF	20
September 20, 2024	Dr. Gresset, S.; Lutz, A.; Portner, J.; Münsterer, J.; Stampfl, R.; Dr. Weihrauch, F.; Dr. Kammhuber, K."	Guided tour of the Hop Research Center	AB InBev Brewmaster	44
September 23, 2024	Dr. Gresset, S.; Lutz, A.; Portner, J.; Stampfl, R.; Dr. Weihrauch, F.; Dr. Kammhuber, K.	Guided tour of the Hop Research Center	CDU/CSU Agricultural spokespersons' meeting	30
July 24, 2024	Dr. Gresset, S.; Lutz, A.; Stampfl, R.; Kaindl, K.	Guided tour of the Hop Research Center	LW Administrative trainees	40
July 23, 2024	Dr. Kammhuber, K.; Lutz A.	Guided tour of the Hop Research Center	Agricultural School	20
September 3, 2024	Dr. Kammhuber, K.; Lutz, A.	Guided tour of the Hop Research Center	Professors at Aarhus University	2
July 17, 2024	Dr. Weihrauch, F.; Lutz, A.	Guided tour of the Stadelhof breeding garden	AK Organic Hops	25
August 14, 2024	Lutz, A.	Everything about the 2024 hop harvest	QM hops	100
September 2, 2024	Lutz, A.	Hop aroma assessment	Beer sommeliers	20
October 14, 2024	Lutz, A.	New Hüll breeding lines	Dan Carey, New Glarus Brewery	1
June 25, 2024	Lutz, A.; Stampfl, R.	Guided tour of the Hop Research Center, presentation of research focuses	Bundesanstalt für Landwirtschaft und Ernährung *(Federal Office for Agriculture and Food)*	5
June 6. 2024	Lutz, A.; Kammhuber, K.	Guided tour of the Hop Research Center	Public Relations Working Group	10
July 16, 2024	Lutz, A.; Dr. Kammhuber, K.	Guided tour of the Hop Research Center m	HVG US Sales Partner	5
May 27, 2024	Lutz, A.; Dr. Kammhuber, K.	Guided tour of the Hop Research Center	Students from Missouri State University	15
May 7, 2024	Lutz, A.; Dr. Kammhuber, K.	Guided tour of the Hop Research Center and hop assessment	Brewing students from Doemens Academy	30

Date	Name	Subject/Title	Guest(s)	No.
January 25, 2024	Lutz, A.; König, W.; Dr. Kammhuber, K.	Hop breeding and hop assessment	Brewing Students, Technical University of Munich (TUM)	20
April 11, 2024	Münsterer, J.	Peronospora warning service	Agricultural Vocational School	21
September 17, 2024	Münsterer, J.	Developments and technical innovations in belt dryers for hops	Czech hop growers	30
September 17, 2024	Stampfl, R.; Euringer, S.	Follow-up work in hop cultivation	BASF OPEX Delegation	2

9.2.2 Internet contributions

Author	Title	Target Group
Fuß, S.	Dry matter and alpha acid monitoring of the most important hop varieties	Hop growers

9.2.3 Publications (Peer-reviewed)

Publications (Peer-reviewed)
Albrecht, T., Büttner B., Carey SB, Seidenberger R., Lutz A., Harkess A., Gresset S. (2024): Independent validation of molecular markers for sex determination on diverse sex chromosomes in hops (*Humulus lupulus* L.). BrewingScience, 77, 172 - 183
Hagemann, M. H., Treiber, C.; Sprich, E.; Born, U.; Lutz, K.; Stampfl, J.; Radišek, S. (2024): Composting and fermentation: mitigating hop latent viroid infection risk in hop residues. European Journal of Plant Pathology

9.2.4 Publications (Not peer-reviewed)

Publications (Not peer-reviewed)
Fuß, S. (2024): Pflanzenstandsbericht August 2024. Hopfen-Rundschau, 75, 09/2024, Edit.: Verband Deutscher Hopfenpflanzer e. V., 293
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Fuß, S., Arnold, S. (2024): Pflanzenstandsbericht April 2024. Hopfen-Rundschau, 75, 05/2024, Edit.: Verband Deutscher Hopfenpflanzer e. V., 151
Gresset S., Lutz A. (2024): Kreuzungen 2023 und Weiterentwicklung von erfolgversprechenden Zuchtstämmen. LfL-Information. Jahresbericht Sonderkultur

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Kammhuber, K. (2024): Ergebnisse von Kontroll- und Nachuntersuchungen für Alphaverträge der Ernte, Hopfen Rundschau, Ausgabe 08/2024, Edit.: Verband Deutscher Hopfenpflanzer e.V., 242 - 245
Kammhuber, K.: Welche Faktoren haben am meisten Einfluss auf das Hopfenaroma?, Hopfenrundschau International, 2024/2025, Edit.: Verband Deutscher Hopfenpflanzer e.V., 84 -89
Kammhuber, K.: 142. Treffen der Arbeitsgruppe für Hopfenanalytik (AHA), Hopfen-Rundschau, 75 09/2024, Edit.: Verband Deutscher Hopfenpflanzer e. V., 292-293
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Lutz K., Lutz A.; Gresset S. (2024): Kreuzungen 2023 und Weiterentwicklung von erfolgversprechenden Zuchtstämmen, Jahresbericht Sonderkultur Hopfen, Jahresbericht Sonderkultur Hopfen, Edit.: LfL, 72 - 74
Lutz, K. (2024): Sanieren lohnt sich, Hopfen-Rundschau, 75/2024, Edit.: Bayerische Landesanstalt für Landwirtschaft (LfL), 290 - 292
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Portner, J., Arnold, S. (2024): Modell- und Demonstrationsvorhaben "Humusaufbau im Hopfenanbau" - Demonstrationsbetriebe für die Modellregionen Hallertau, Spalt, Tettnang und Elbe-Saale gesucht, Hopfen-Rundschau, 75, 07/2024, Edit.: Verband Deutscher Hopfenpflanzer e. V., 202 - 206
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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 2024 (AG = Working Group)

IPZ 5

Coordinator: Director, LfL, Dr. Peter Doleschel

Alexandra Hertwig
Birgit Krenauer

IPZ 5a

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(*Hop Cultivation, Production Technology*)

Managing Director: LD Johann Portner

Elke Fischer
LAR Stefan Fuß
LR Jakob Münsterer
Andreas Schlagenhaufer B.Sc.

IPZ 5b

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

Head: Simon Euringer M.Sc.

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Florian Weiß M.Sc.

IPZ 5c

AG Züchtungsforschung Hopfen
(*Hop Breeding Research*)

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Brigitte Brummer
Brigitte Forster
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Brigitte Haugg
Daniel Ismann
Jutta Kneidl
LR Anton Lutz
Katja Merkl
Martina Nieder (3/18/24 to 7/31/24)
Sonja Ostermeier
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Maximilian Schleibinger

IPZ 5d

G Hopfenqualität und -analytik
(*Hop Quality and Analytics*)

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MTLA Magdalena Hainzlmaier
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(*Ecological Issues in Hop Cultivation*)

Head: Dipl.-Biol. Dr. Florian Weihrauch

Dr. Inka Lusebrink (until 10/31/24)
Maria Kremer M.Sc.