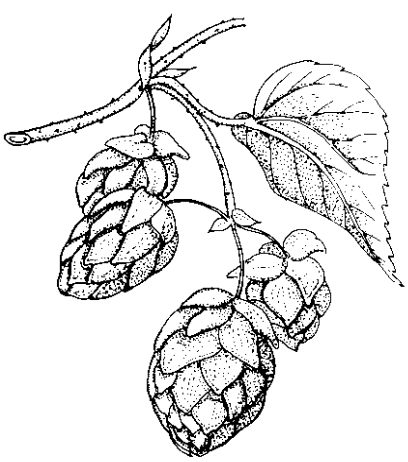
Bayerische Landesanstalt für Landwirtschaft

Wir forschen Hopfen

Gesellschaft für Hopfenforschung e.V.

Annual Report 2020

Special Crop: Hops



Bavarian State Research Center for Agriculture

- Institute for Crop Science and Plant Breeding -

and

Society for Hop Research e.V.

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Foreword

The crop year 2020 was strongly influenced by the corona pandemic. With the cancellation of folk festivals, including the Oktoberfest, beer output decreased by about 10%, which, of course, had a ripple effect on the demand for hops. This is likely to have an impact on hop markets around the world for years to come. Eventually, the corona crisis will surely be behind us, but the great challenges will remain. A current problem is undoubtedly the rapidly advancing climate change with significant effects on all facets of hop cultivation. Therefore, stress-tolerant varieties are an absolute prerequisite. They need to be able to cope equally well with heat, drought, and excess moisture, while also delivering high yields and stable acid contents, even in years when the weather slides into extremes. The new varieties that come out of Hüll excel in stability and sustainability even in the face of adverse, climate-induced factors. Importantly, they also come with favorable brewing-quality characteristics. Thus, they represent clear breeding successes.

The second major issue is the move towards more ecology and sustainability, a topic that has now reached society and politics at large. For some scientists, maintaining biodiversity has become even more important nowadays than fighting global warming. Either way, hop research is well positioned with answers in these areas.

The Working Group IPZ 5e is making major contributions to the development and promotion of biodiversity and ecology in hop cultivation.

During the past few years, the Working Group IPZ 5a has been working on a research project about fertigation as a way to use fertilizers in a more targeted, needs-based, and thus efficient manner. The goal is to supply nutrients more optimally. Another project investigates the nitrogen dynamics in hop soils and conducts experiments in composting and recycling of shredded hop bines. First results show that the application of such material in hop gardens in the fall does not result in an increase in nitrogen mineralization. The work on optimal hop kilning procedures is of immense importance for reducing the greenhouse gas CO_2. This work has the potential of substantial savings in heating oil and costs, while reducing greenhouse gas emissions.

To get a handle on the spread of the Citrus Bark Cracking Viroid (CBCVd) in Bavarian hop-growing regions, more than 2,300 samples were taken from 400 farms and tested in the laboratory in 2020. After three hop farms had been identified as CBCVd-infected in 2019, four additional farms needed to be added to the list in 2020. This research will be expanded; and monitoring will resume in 2021.

While the agronomic properties of hops are important, their compounds and their brewing quality are, of course, also significant. Thanks to the GfH, the laboratory in Hüll is a well-equipped facility to work efficiently on these issues.

In all future-oriented topics, the Hop Research Center in Hüll has the capabilities to shoulder the challenges and to develop solutions, both for the good of hop cultivation in Bavaria and for the good of Germany. The following annual report summarizes the activities of the Hop Research Center. Above all, successful hop research requires hard-working, dedicated, and creative staff. Therefore, may we take this opportunity to thank all of you for your commitment.

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

Dr. Peter Doleschel
Head of the Institute for
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 1.1: Number of hop farms and their acreages in Germany

Year	Number of Farms	Hop acreage per farm in ha	Year	Number of Farms	Hop acreage per farm in ha
1975	7,654	2.64	2010	1,435	12.81
1980	5,716	3.14	2015	1,172	15.23
1985	5,044	3.89	2016	1,154	16.12
1990	4,183	5.35	2017	1,132	17.26
1995	3,122	7.01	2018	1,121	17.97
2000	2,197	8.47	2019	1,097	18.61
2005	1,611	10.66	2020	1,087	19.05

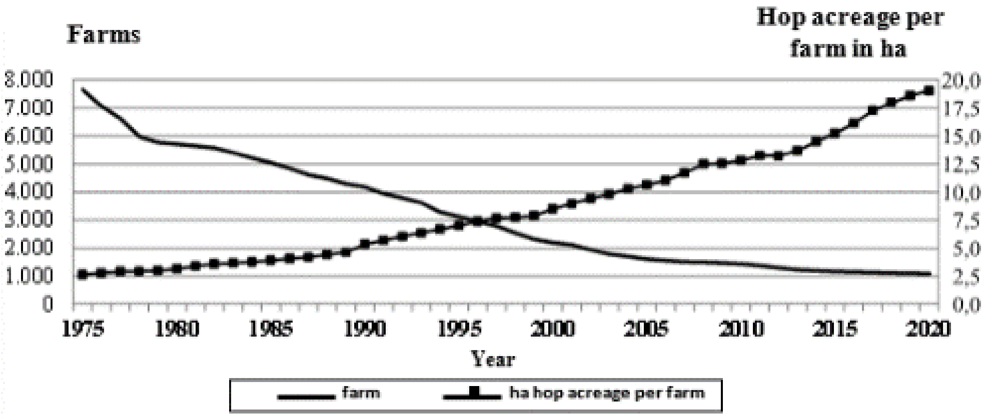

Figure 1.1: Number of hop farms and their acreages in Germany

Table 1.2: 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 2019	in ha 2020	Increase + / Decrease - 2020 to 2019 ha	%	2019	2020	Increase + / Decrease - 2020 to 2019 Farms	%	2019	2020
Hallertau	16,995	17,233	238	1.4	886	880	- 6	- 0.7	19.18	19.58
Spalt	415	408	- 7	- 1.7	52	51	- 1	- 1.9	7.98	7.99
Tettnang	1,438	1,479	42	2.9	128	125	- 3	- 2.9	11.23	11.84
Baden, Bitburg, Rhein-Palatinate	22	22	0	± 0	2	2	± 0	± 0	11.00	11.00
Elbe-Saale	1,547	1,564	17	1.1	29	29	± 0	± 0	53.35	53.93
Germany	**20,417**	**20,706**	**289**	**1,4**	**1,097**	**1,087**	**- 10**	**- 0.9**	**18.61**	**19.05**

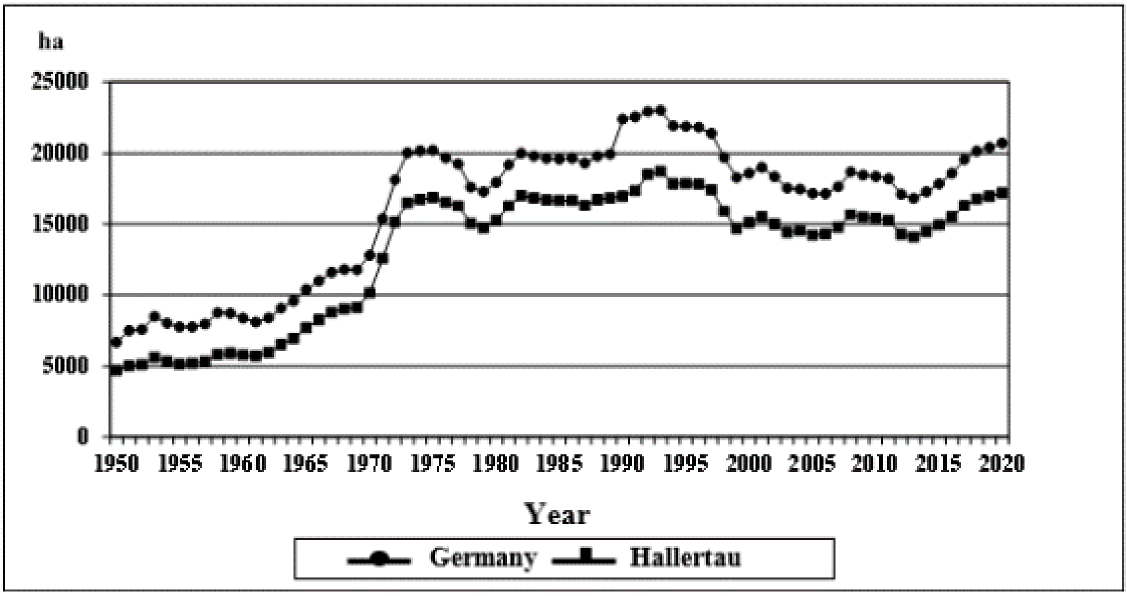

Figure 1.2: Hop acreage in Germany and in the Hallertau

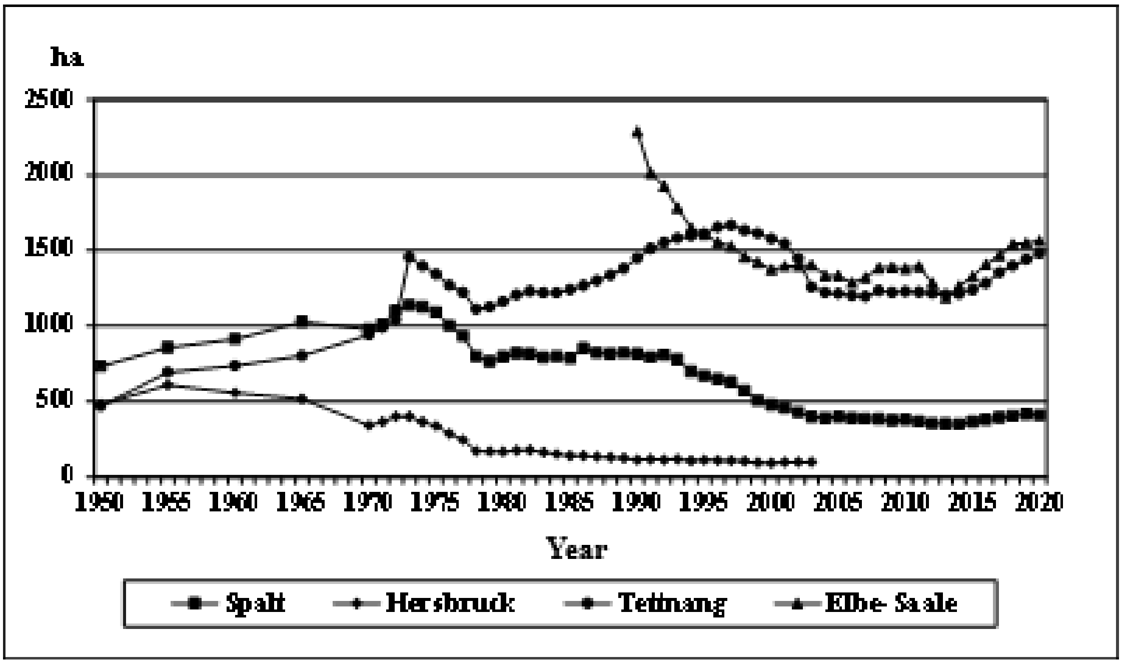

Figure 1.3: Hop acreage in Spalt, Hersbruck, Tettnang and Elbe-Saale

Since 2004, the Hersbruck region has been considered part of the Hallertau region.

1.1.2 Hop varieties

In 2020, the German hop acreage increased by 289 hectares (ha). This is the seventh annual increase in a row. The total acreage is acreage now 20,706 ha.

The proportion of **aroma varieties** remains unchanged at 55%. Akoya, Aurum, Diamant, and Solero have been added as new varieties. They amount to a total of 41 ha. Most of the newer aroma or flavor varieties of recent years, as well as a few older varieties and several old landraces, have lost area. The variety with the greatest decline in acreage was Saphir, losing 42 ha.

On the other hand, there were substantial acreage increases for the traditionally strong aroma varieties Perle (+ 149 ha) and Hallertauer Tradition (+ 100 ha).

Bitter hops cultivation has also increased and now accounts for 45%. Again, older bitter varieties, such as Hallertauer Magnum, Merkur, and Taurus have declined in acreage, whereas Herkules (+ 162 ha) and Polaris (+ 65 ha) gained acreage again. This has propelled Herkules to be by far the most plentiful hop variety in Germany (6,717 ha), or almost one-third of the total hop acreage.

Table 1.3: Hop varieties in German growing regions in hectares in 2020

Aroma Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Akoya	24			1	0	**26**	**0.1**	**26**
Amarillo	155		8	16		**178**	**0.9**	**-30**
Ariana	73	5	5			**83**	**0.4**	**7**
Aurum			1			**1**	**0.0**	**1**
Brewers Gold	19					**19**	**0.1**	**0**
Callista	48	1	8	4		**61**	**0.3**	**-5**
Cascade	61	4	4	9	1	**78**	**0.4**	**-9**
Comet	8		0			**8**	**0.0**	**0**
Diamant	9	2				**11**	**0.1**	**11**
Hallertau Blanc	140	3	13	12		**167**	**0.8**	**0**
Hallertauer Gold	4	2				**6**	**0.0**	**-1**
Hallertauer Mfr.	501	29	140		1	**671**	**3.2**	**-8**
Hallertauer Tradition	2,718	40	68	41	4	**2,870**	**13.9**	**100**
Hersbrucker Pure	1	2				**3**	**0.0**	**0**
Hersbrucker Spät	898	7	0			**904**	**4.4**	**-11**
Hüll Melon	82	5	10	10		**107**	**0.5**	**-17**
Mandarina Bavaria	245	3	12	17		**278**	**1.3**	**-20**
Monroe	20		3			**23**	**0.1**	**-3**
Northern Brewer	133			133		**266**	**1.3**	**-13**
Opal	142	1	1			**144**	**0.7**	**-2**
Perle	2,887	36	103	262	8	**3,297**	**15.9**	**149**
Relax	4					**4**	**0.0**	**0**
Saazer	7			150		**157**	**0.8**	**1**
Saphir	369	19	41	20		**449**	**2.2**	**-42**
Smaragd	64	1	17			**82**	**0.4**	**-1**
Solero	3					**3**	**0.0**	**3**
Spalter	0	113				**113**	**0.5**	**-5**
Spalter Select	491	90	22	4		**608**	**2.9**	**-3**
Tettnanger			718			**718**	**3.5**	**-14**
Total (ha)	**9,106**	**363**	**1.173**	**678**	**15**	**11,335**	**54.7**	**113**
Percentage (%)	**44.0**	**1.8**	**5.7**	**3.3**	**0.1**	**54.7**		**0.55**

Bitter Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Hallertauer Magnum	1,290	3		622	3	**1,918**	**9.3**	**-35**
Hallertauer Merkur	5	3				**8**	**0.0**	**-4**
Hallertauer Taurus	196	1	0	14		**211**	**1.0**	**-17**
Herkules	6,254	37	283	138	5	**6,717**	**32.4**	**162**
Nugget	117			6		**123**	**0.6**	**0**
Polaris	216		19	105		**340**	**1.6**	**65**
Record	1					**1**	**0.0**	**0**
Others	47	1	4	1		**52**	**0.3**	**4**
Total (ha)	**8,127**	**45**	**306**	**886**	**8**	**9, 371**	**45.3**	**176**
Percentage (%)	**39.2**	**0.2**	**1.5**	**4.3**	**0.0**	**45.3**		**0.85**

All Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Total (ha)	**17,233**	**408**	**1,479**	**1,564**	**22**	**20,706**	**100.0**	**289**
Percentage (%)	**83.2**	**2.0**	**7.1**	**7.6**	**0.1**	**100.0**		**1.4**

1.2 Harvest volumes, yields, and alpha acid contents

The **2020 hop harvest** in Germany amounted to 46,878,500 kg (= 937,570 German hundredweight), which was just below the previous year's record-breaking harvest of 48,472,220 kg (= 969,444 German hundredweight). Except for 2019, this was the second largest hop harvest in Germany. Considering that the total hop area had declined again, this yield amounted to an excellent average, which was not necessarily expected earlier in the year, when a drought in May and cool temperatures in May and June caused a lag in plant development of up to 14 days in the summer.

With an average yield of 2,264 kg/ha for the total area, the hectare yield this year is 110 kg/ha below that of the previous year.

In 2020, the **alpha acid content** of the most important hop varieties—except for the high alpha variety Hallertauer Taurus—was above the long-term average. At this writing, the overall amount of alpha acids produced in Germany in 2020 is now pegged at 5,460 metric tons (MT) in spite of the smaller harvest. This amounts to 200 MT more than in the previous year.

Table 1.4: Harvest volumes and yields per hectare of hops in Germany

	2015	2016	2017	2018	2019	2020
Yield kg/ha	1,587	2,299	2,126	2,075	2,374	2,264
Acreage in ha	17,855	18,598	19,543	20,144	20,417	20,706
Total harvest in kg	28,336,520	42,766,090	41,556,250	41,794,270	48,472,220	46,878,500

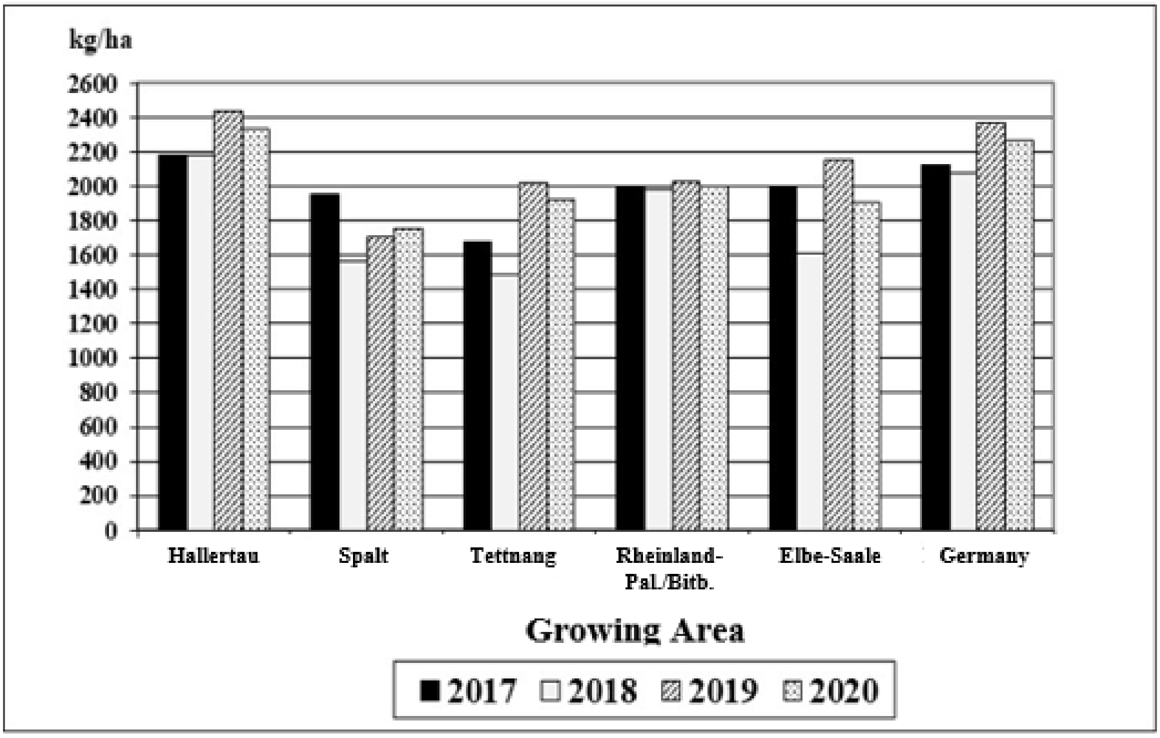

Figure 1.4: Average yields of the different growing regions in kg/ha

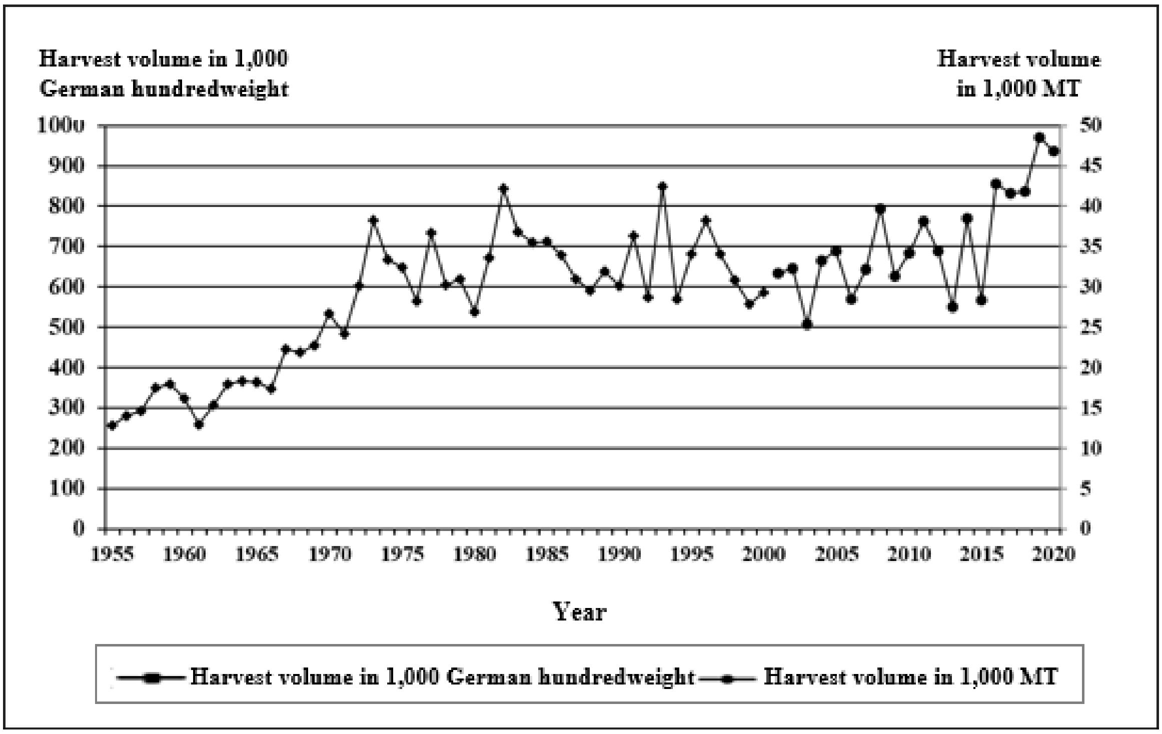

Figure 1.5: Total harvest volume in Germany

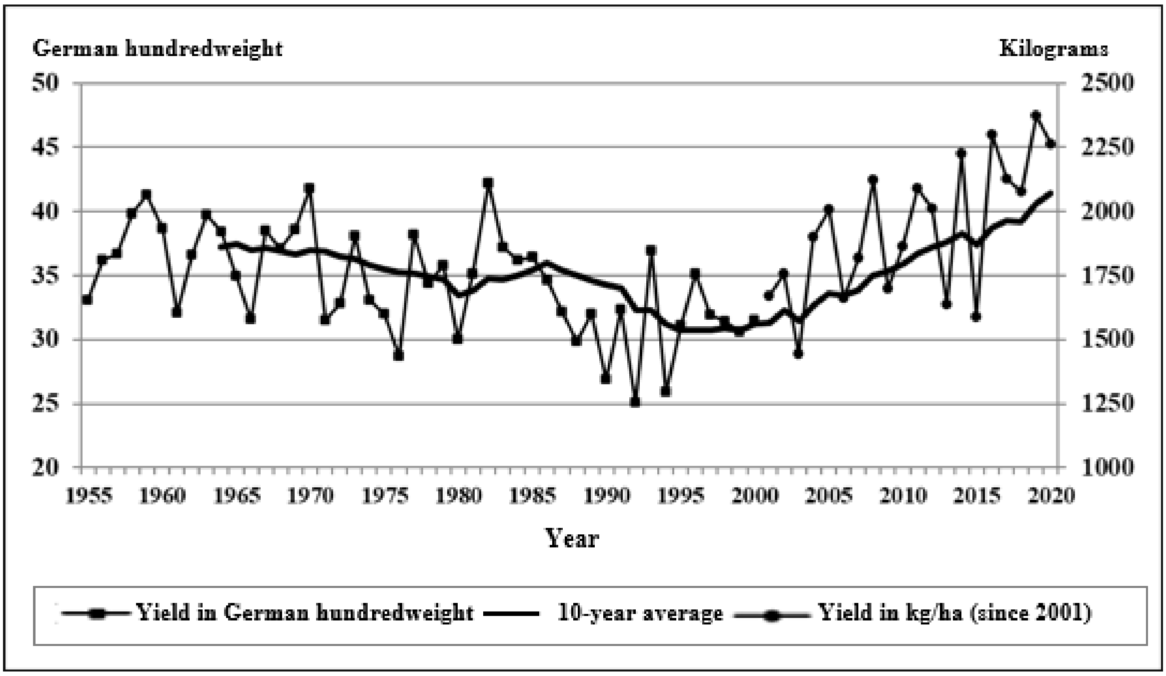

Figure 1.6: Average yield per hectare in Germany

Table 1.5: Yields per hectare in German cultivation areas

Growing area	Yield in kg/ha total area								
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Hallertau	2,090	1,638	2,293	1,601	2,383	2,179	2,178	2,441	2,338
Spalt	1,383	1,428	1,980	1,038	1,942	1,949	1,564	1,704	1,759
Tettnang	1,323	1,184	1,673	1,370	1,712	1,677	1,486	2,024	1,927
Baden/Rhine-land Palatinate Bitburg	2,353	1,953	2,421	1,815	1,957	1,990	1,985	2,030	2,003
Elbe-Saale	1,983	2,116	2,030	1,777	2,020	2,005	1,615	2,150	1,906
Æ Yield/ha Germany (kg)	**2,013**	**1,635**	**2,224**	**1,587**	**2,299**	**2,126**	**2,075**	**2,374**	**2,264**
Total harvest Germany (MT)	34,475	27,554	38,500	28,337	42,766	41,556	41,794	48,472	46,879
Acreage Germany (ha)	17,124	16,849	17,308	17,855	18,598	19,543	20,144	20,417	20,706

Table 1.6: Alpha acid values of individual hop varieties in Germany

Growing area/variety	2011	2012	2013	2014	2015	2016	2017	2018	2019	**2020**	**Ø 5 Years**	**Ø 10 Years**
Hallertau Hallertauer	5.0	4.6	3.3	4.0	2.7	4.3	3.5	3.6	4.1	**4.5**	**4.0**	**4.0**
Hallertau Hersbrucker	4.5	3.0	1.9	2.1	2.3	2.8	2.3	2.0	2.5	**3.3**	**2.6**	**2.7**
Hallertau Hall. Saphir	5.3	4.4	2.6	3.9	2.5	4.0	3.0	3.3	3.3	**4.2**	**3.6**	**3.7**
Hallertau Opal	9.7	9.0	5.7	7.3	5.9	7.8	7.2	6.4	7.3	**8.5**	**7.4**	**7.5**
Hallertau Smaragd	8.0	6.0	4.3	4.7	5.5	6.2	4.5	3.0	5.0	**5.8**	**4.9**	**5.3**
Hallertau Perle	9.6	8.1	5.4	8.0	4.5	8.2	6.9	5.5	6.7	**7.4**	**6.9**	**7.0**
Hallertau Spalter Select	6.4	5.1	3.3	4.7	3.2	5.2	4.6	3.5	4.4	**5.2**	**4.6**	**4.6**
Hallertau Hall. Tradition	7.1	6.7	5.0	5.8	4.7	6.4	5.7	5.0	5.4	**6.3**	**5.8**	**5.8**
Hallertau Mand. Bavaria		8.8	7.4	7.3	7.0	8.7	7.3	7.5	7.9	**9.0**	**8.1**	
Hallertau Hall. Blanc		9.6	7.8	9.0	7.8	9.7	9.0	8.8	9.0	**10.9**	**9.5**	
Hallertau Hüll Melon		7.3	5.3	5.4	5.8	6.8	6.2	5.8	6.6	**7.2**	**6.5**	
Hallertau North. Brewer	10.9	9.9	6.6	9.7	5.4	10.5	7.8	7.4	8.1	**9.1**	**8.6**	**8.5**
Hallertau Polaris		20.0	18.6	19.5	17.7	21.3	19.6	18.4	19.4	**20.6**	**19.9**	
Hallertau Hall. Magnum	14.9	14.3	12.6	13.0	12.6	14.3	12.6	11.6	12.3	**14.2**	**13.0**	**13.2**
Hallertau Nugget	13.0	12.2	9.3	9.9	9.2	12.9	10.8	10.1	10.6	**12.0**	**11.3**	**11.0**
Hallertau Hall. Taurus	17.4	17.0	15.9	17.4	12.9	17.6	15.9	13.6	16.1	**15.5**	**15.7**	**15.9**
Hallertau Herkules	17.2	17.1	16.5	17.5	15.1	17.3	15.5	14.6	16.2	**16.6**	**16.0**	**16.4**
Tettnang Tettnanger	5.1	4.3	2.6	4.1	2.1	3.8	3.6	3.0	3.8	**4.3**	**3.7**	**3.7**
Tettnang Hallertauer	5.1	4.7	3.3	4.6	2.9	4.4	4.3	3.8	4.3	**4.7**	**4.3**	**4.2**
Spalt Spalter	4.8	4.1	2.8	3.4	2.2	4.3	3.2	3.5	3.9	**4.7**	**3.9**	**3.7**
Spalt Spalter Select	6.4	4.6	3.3	4.5	2.5	5.5	5.2	2.9	4.1	**4.7**	**4.5**	**4.4**
Elbe-S. Hall. Magnum	13.7	14.1	12.6	11.6	10.4	13.7	12.6	9.3	11.9	**11.9**	**11.9**	**12.2**

Source: Arbeitsgruppe für Hopfenanalytik (AHA); *(Hop Analytics Working Group)*

2 Weather and Growth Development 2020

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

2.1 Weather and growth development

The hop growing season of 2020 started after the winter months that amounted to a winter in name only. Then came plenty of warm weather and an abundance of rainfall in February and March which largely replenished the lack of moisture in the dried-out soil. A warm April with little rainfall promoted early hop growth and allowed all planting work in dry fields to be completed on schedule. Training the bines around the wires started around April 22. Because of cooler temperatures at the beginning of May, the culling and training work took longer than usual and lasted until mid-May. Below-average temperatures in June exacerbated the delay in growth and development, resulting in some varieties flowering up to 14 days later than normal. Fortunately, another round of abundant rainfall in June once again compensated for potential moisture deficits that otherwise could have become severe in July. It then took a warm August with average rainfall for the crop to fully catch up; and the harvest started a few days late, in the last days of August. Finally, warm and dry harvest weather from September onwards accelerated the ripening process.

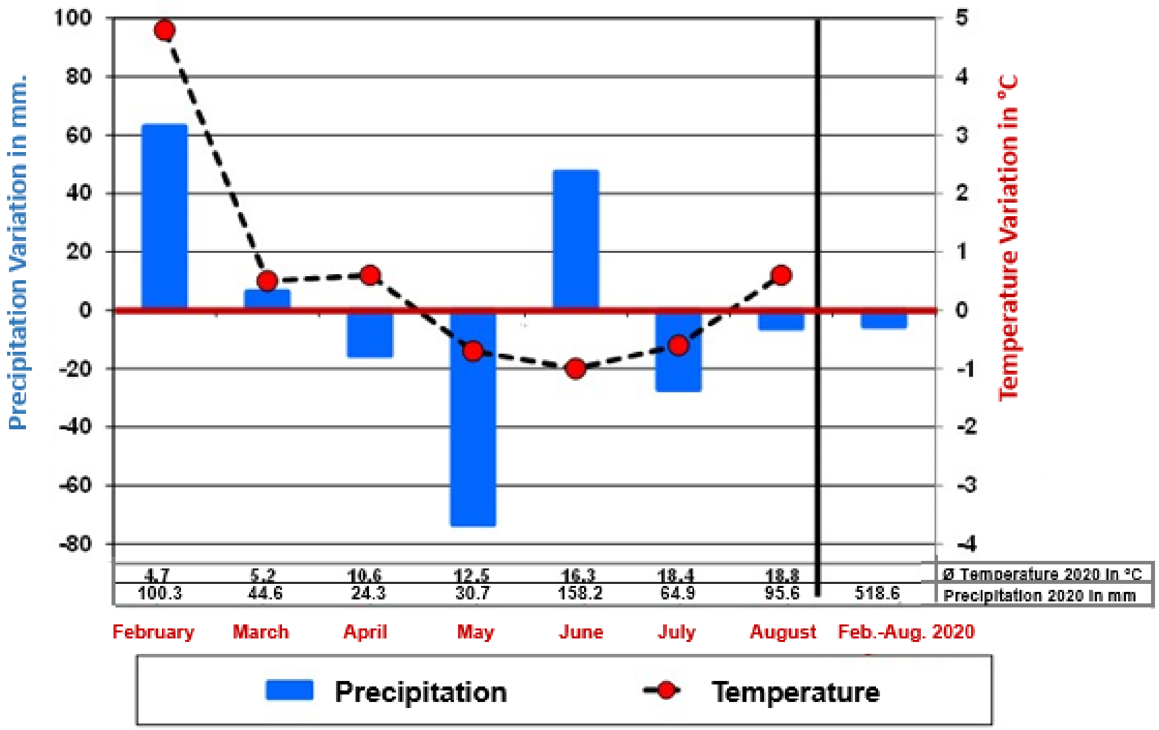

Figure 2.1: Weather patterns in Hüll during the 2020 vegetation period expressed as monthly deviations from the 10-year average

This year, violent thunderstorms with large amounts of precipitation were rare, short, and only localized. As a result, there was no major erosion damage to report. If the precipitation that occurred in February is considered part of the 2020 vegetation period, the Hüll reference location experienced sufficient rainfall. In sum, therefore, only a few locations reported drought stress in their hop gardens.

2.2 Problems resulting from disease and pest infestations

Alfalfa snout beetles (also knows a lovage weevils) appeared only locally this year and could be combated with Exirel insecticide, which was approved for short-term emergency use. Flea beetles feeding on hop plants, on the other hand, caused considerable damage in several growing areas.

Primary infections of downy mildew (*Peronospora*) increased this year right after training the bines. Especially after the onset of precipitation in June until July, clusters of stunted growth could be found on the lateral and horizontal shoots up to 5 m above the ground. Secondary infections of downy mildew were also correspondingly high. This was documented by the persistently high counts of zoosporangia in the spore traps. Thus, in fields with susceptible varieties, seven anti-*Peronospora* campaigns were necessary during the growing season; while four campaigns were needed in fields with moderately resistant varieties.

Fighting powdery mildew was also very intensive. The first infestations were reported starting around the end of May. In spite of numerous control measures, the powdery mildew fungus reappeared throughout the season. Dense stands of the bitter hop variety Herkules were especially affected. This resulted in an emergency approval of the use of Luna Sensation given that most growers had exhausted the use of conventional products. In spite of such drastic measures, in many fields, losses in crop yield and quality could not be prevented.

Verticillium wilt, among the most feared diseases, was also particularly strong this year. The cause was the cool and humid June, which favored infections of the roots. The first signs of plant necrosis were already apparent starting in late June; and in many hop gardens, the damage could be seen even from a distance.

Thanks to the emergency approval of the use of Movento SC and the resulting timely fight against critter pathogens, infestations of hop aphids and spider mites could be kept in check with relatively little effort.

In 2019, shortly before the harvest, a feared viroid from Slovenia, known as Citrus Bark Cracking Viroid (CBCVd), was detected for the first time in the Hallertau. In an extensive risk-based monitoring program, more than 2,300 hop plants in more than 400 hop farms in Bavaria were systematically checked for the viroid in 2020. As a result, four newly infected hop farms had to be added to the three operations that had been identified as infected in 2019. In the Hallertau, a total of only three hop gardens have been infected thus far. In other words, at this point, the infestation with the viroid and its spread are still very limited.

2.3 Out-of-the-ordinary events in 2020

The pest management problems, especially of diseases and their containment campaigns as described in detail above, were unusually demanding in crop year 2020. Especially the massive occurrence of hop wilt and of the discovery of the new CBCVd have emerged as major challenges for hop growers and the entire hop industry.

The initial lag in plant growth and development is also a noteworthy feature of the 2020 crop year. However, this problem had almost solved itself by the time the harvest rolled around.

One special incident was a storm on August 26, which caused significant losses in both quantity and quality from dead branches that had been propelled by wind forces and dislodged many cones. Many lateral shoots were broken off as wells.

Table 2.1: Weather data for 2020 (monthly mean, maximum and minimum values) compared to 10-year * and 30-year ** mean values

Month		**Temperature at 2 m elev.**			**Relative Humidity (%)**	**Precip. (mm)**	**Days w/ Precip. >0.2 mm**	**Sunshine (hours)**
		Mean (°C)	**Min (°C)**	**Max (°C)**				
January	2020	1.4	-5.4	14.0	98.8	23.2	11.0	51.6
Ø	10-y	0.2	-3.2	3.7	92.9	65.8	16.9	41.3
	50-y	-2.3	-5.9	1.1	86.7	50.8	14.8	47.1
February	2020	4.7	-5.1	15.8	90.8	100.3	20.0	75.9
Ø	10-y	0.5	-4.6	5.9	87.4	42.9	11.4	78.6
	50-y	-1.0	-4.9	3.1	81.4	46.8	13.3	72.1
March	2020	5.2	-6.3	19.3	81.3	44.6	13.0	188.0
Ø	10-y	4.9	-1.0	10.9	80.1	38.3	11.6	158.0
	50-y	2.8	-1.7	7.8	78.9	47.7	13.8	132.2
April	2020	10.6	-5.3	24.2	66.3	24.3	7.0	299.6
Ø	10-y	10.2	2.5	16.5	73.1	40.8	9.4	207.6
	50-y	7.1	1.9	12.8	73.8	60.8	14.1	164.3
May	2020	12.5	0.6	25.9	79.9	30.7	13.0	213.4
Ø	10-y	13.3	6.9	20.0	75.6	91.5	14.5	211.4
	50-y	11.9	6.1	17.7	73.9	82.3	15.4	203.6
June	2020	16.3	5.5	29.0	87.2	158.2	17.0	179.0
Ø	10-y	17.3	10.6	24.1	77.1	112.7	13.5	229.4
	50-y	15.1	9.0	20.8	74.6	103.5	15.3	212.3
July	2020	18.4	7.1	32.7	81.0	64.9	9.0	279.5
Ø	10-y	18.9	11.9	26.3	76.2	88.0	12.2	247.9
	50-y	16.7	10.5	23.1	74.3	90.5	14.1	236.8
August	2020	18.8	7.7	34.2	86.9	95.6	12.0	224.0
Ø	10-y	18.4	11.4	26.3	80.4	91.4	11.5	246.0
	50-y	16.0	10.2	22.6	78.2	91.7	13.8	212.4
September	2020	14.4	2.2	28.1	90.6	48.5	9.0	192.8
Ø	10-y	14.0	7.5	21.0	85.8	59.4	11.4	171.4
	50-y	12.7	7.4	19.1	80.7	67.9	11.6	175.0
October	2020	9.2	0.3	22.1	97.2	64.8	17.0	87.7
Ø	10-y	9.2	4.0	15.4	90.6	54.8	11.7	111.7
	50-y	7.6	3.2	13.1	84.2	51.1	11.0	117.2
November	2020	4.0	-8.8	20.5	98.9	19.6	8.0	57.1
Ø	10-y	4.4	0.9	8.5	94.1	47.3	10.5	54.4
	50-y	2.6	-0.6	6.1	85.5	57.5	14.4	52.9
December	2020	1.6	-7.2	16.6	99.4	48.7	11.0	31.0
Ø	10-y	1.9	-1.9	7.0	93.7	52.3	15.0	40.1
	50-y	-0.9	-4.3	1.8	86.5	52.2	15.0	38.7
Ø-Year	**2020**	**9.8**	**-1.2**	**23.5**	**88.0**	**723.4**	**147.0**	**1.879.6**
10-Year Mean		**9.4**	**3.8**	**15.5**	**83.9**	**785.5**	**149.6**	**1.797.8**
30-Year Mean		**7.4**	**2.6**	**12.4**	**79.9**	**802.8**	**166.6**	**1.664.6**

* The 10-year mean covers the years 2011 – 2020

** The 30-year mean covers the years 1961 – 1990

3 Research and Permanent Tasks

3.1 IPZ 5a – Hop cultivation, production technology

Current 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, J. Stampfl	Improving the nutrient efficiency of hops through fertilization systems with fertigation (5612)	2017-2020	Erzeugergemeinschaft HVG *(HVG Hop Producer Group)*	Prof. F. Wiesler, University Hohenheim Prof. T. Ebertseder, HSWT Hop farms IPZ 5c, IPZ 5d
IPZ 5a J. Portner, A. Schlagenhaufer	Nitrogen dynamics in hop soils in commercial hop farms with different types of soil and fertilizer systems (6054)	2018-2021	Erzeugergemeinschaft HVG *(HVG Hop Producer Group)*	21 hop farms; IPZ 5b
IPZ 5a J. Portner, A. Schlagenhaufer	Composting trial using shredded bines to optimize the nutrient efficiency of organically bound nitrogen (6141)	2018-2021	Erzeugergemeinschaft HVG *(HVG Hop Producer Group)*	Prof. E. Meinken, HSWT Dr. D. Lohr, HSWT Prof. T. Ebertseder, HSWT M. Stadler, FZ Agrarökologie, AELF PAF; IPZ 5c

Permanent tasks and product-technical trials

Working Group	Project	Project Duration	Collaborators
5a	Training and continued education of hop growers	Permanent task	
5a	Specialized production-technical and business management consulting in hop production	Permanent task	
5a	Development and updating of documents for consulting services	Permanent task	
5a	Dissemination of advisory strategies and exchange of information with group advisory services	Permanent task	Hopfenring e.V. *(Hop Circle)*
5a	Generation of *Peronospora* infestation forecasts and warning messages	Permanent task	
5a	Generation of business data for calculating profit margins and other business accounting issues	Permanent task	
5a	Optimization of PS applications and device technologies	Permanent task	
5a	Optimization of techniques and measures to prevent soil erosion and to promote soil fertility in hop cultivation	Permanent task	IAB

Working Group	Project	Project Duration	Collaborators
5a	Development of strategies and measures to avoid nitrate movements in the soil and run-off in hop cultivation	Permanent task	IAB, water consultant, AELF PAF u. SR, ECOZEPT
5a	HopNO$_3$ - practical optimization of the nitrogen cycle in hop cultivation	2016-2020 (2022)	Ecozept, LfU Leader-AG
5a	Optimization of settings of multi-tier kilns to adjust for different drying behaviors of different hop varieties	2018-2020	Hop growers
5a	Optimization of drying processes in belt dryers	2018-2020	Hop growers
5a	Investigation of absorption rates of different hop varieties	2020-2021	
5a	Investigation of the nitrogen increases of hops as a function of fertilization with fertigation (master thesis)	2020-2021	TUM Florian Weiß

3.2 IPZ 5b - Crop protection in hop production

Current 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 5b S. Euringer, K. Lutz	GfH project for *Verticillium* research	2017-2023	Gesellschaft für Hopfenforschung e.V. (GfH) *(Society for Hop Research)*	IPZ 5c, Dr. E. Seigner, P. Hager, R. Enders, J. Kneidl, A. Lutz Dr. Radišek, Slovenian Institute of Hop Research and Brewing
IPZ 5b S. Euringer, K. Lutz	*Verticillium* in selected hop gardens: Niederlauterbach (from 2015) Engelbrechtsmünster (from 2016) Gebrontshausen (from 2021)	2015-2024	Erzeugergemeinschaft Hopfen HVG *(HVG Hop Producer Group)*	IPZ 5c
IPZ 5b S. Euringer	GfH technician AMP G. Thalmeier K. Kaindl	2019-2020	Gesellschaft für Hopfenforschung e.V. (GfH) *(Society for Hop Research)*	

3.3 PZ 5c – Hop breeding research

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

Working Groups Project Management, Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5c A. Lutz Dr. E. Seigner	Crossbreeding of the Tettnanger landrace	2011-2020	Ministerium für Ländlichen Raum (MLR) *(Ministry for Rural Affairs)*, Baden-Württemberg; Tettnanger Hopfen-pflanzerverband *(Tettnanger Hop Growers Association)*; Erzeugergemeinschaft Hopfen HVG *(HVG Hop Producer Group)* (up to 2014)	IPZ 5d, Dr. K. Kammhuber & Team; Versuchsgut Straß, *Trial Farm in* Straß, F. Wöllhaf; B. Bohner, G. Bader
IPZ 5c A. Lutz Dr. E. Seigner	Development of high-perfor-mance, healthy, high alpha varieties with particular suitability for cultivation in the Elbe-Saale region	2016-2024	Thüringer Ministerium für Infrastruktur und Landwirtschaft *(Thuringian Ministry of Infrastructure and Agriculture);* Ministerium für Landwirtschaft und Umwelt Sachsen-Anhalt *(Ministry of Agriculture and the Environment in Saxony-Anhalt);* Staatsministerium für Umwelt und Landwirtschaft Sachsen *(State Ministry of the Environment and Agriculture in Saxony);* Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Producer Group)*	IPZ 5d: Dr. K. Kammhuber & Team; Hopfenpflanzerverband Elbe-Saale e.V. *(Elbe-Saale Hop Growers' Association)*; Betrieb Berthold, Thüringen (*Hop Farm Berthold in Thuringia*); Hopfengut Lautitz, Sachsen (*Hop Farm Lautitz in Saxony*); Agrargenoss. Querfurt, Sachsen-Anhalt *(Agriculatural Cooperative Querfurt, Saxony-Anhalt)*
IPZ 5c Dr. E. Seigner A. Lutz	Genome-based precision breeding for future-oriented quality hops	2017-2021	Landwirtschaftliche Rentenbank *(Agricultural Pension Bank)*	IPZ 5d: Dr. K. Kammhuber & Team; IPZ 1d: Prof. Dr. V. Mohler; IPZ 2c: Dr. Th. Albrecht; University Hohenheim: Prof. Dr. J. Wünsche, Dr. M.H. Hagemann; Prof. Dr. G. Weber; Gesellschaft für Hopfen-forschung *(Society for Hop Research)*: W. König; Hopfenverwertungsgen. *(Hop Sales Cooperative)*; HVG: Dr. E. Lehmair

Working Groups Project Management, Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5c Dr. E. Seigner A. Lutz	Subproject for precision breeding of hops: testing of powdery mildew resistance for genome-wide association mapping	2016-2020	Wissenschaftsförderung der Deutschen Brauwirtschaft (Wifö) *(Scientific Funding from the German Brewing Industry)*	EpiLogic, Freising; University Hohenheim: Prof. Dr. J. Wünsche, Dr. M.H. Hagemann; Max-Planck-Institut für Entwicklungsbiologie *(Max-Planck Institute for Developmental Biology)* Tübingen: Prof. Weigel
IPZ 5c Dr. E. Seigner	Research and work on *Verticillium* wilt in hops			

Working Group	Project	Duration	Collaborators
5c	Faster availability of healthy hops through improved *in vitro* tissue culture	Permanent task since 2015	IPZ 5b: M. Mühlbauer; IPS 2c: Dr. L. Seigner
5c	Cultivation, assaying, and harvesting of hops for approval and permitting by the CPVO (Community Plant Variety Office of the EU)	Permanent task	IPZ 5d: Dr. K. Kammhuber & Team
5c	Serial trial cultivation in commercial hop farms	Permanent task	IPZ 5d: Dr. K. Kammhuber & Team
5c	Biogenesis trials to generate information for the hop and brewing industries about ripeness states, as well as hop harvest forecasts	Permanent task	IPZ 5d: Dr. K. Kammhuber & Team; IPZ 5a

3.4 IPZ 5d – Hop quality and hop analytics

Current research projects of IPZ 5d (hop quality and hop analytics) funded by third parties

Working Group Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5d Dr. K. Kammhuber	Isolation, identification, and analysis of multifidols in hops	2019-2020	Wissenschaftliche Station für Brauerei München e.V. *(Scientific station for Brewery Munich e.V.)*	TU Berlin Dr. Wittstock

Permanent tasks: Hop quality and analytics

Working Group	Project	Duration	Collaborators
5d	All analytical investigations in support of the Working Groups of the hop division, in particular of the hop breeding operation	Permanent task	IPZ 5a, IPZ 5b, IPZ 5c, IPZ 5e
5d	Development and optimization of a reliable methods for the analysis of aromas using of 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 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)*

Working Group	Project	Duration	Collaborators
5d	Supervision of IT and Internet for the Hop Research Center in Hüll	Permanent task	AIW ITP

3.5 IPZ 5e – Ecological issues in hop cultivation

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

Working Groups Project Mgt. Project Ops	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5e Dr. F. Weihrauch M. Obermaier	Reduction in the use of copper-containing crop protection agents in ecological and integrated hop cultivation	2014-2021	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Producer Group)*	Betrieb Ludwig Gmeiner *(Farm Ludwig Gmeiner)*, Uttenhofen; Agrolytix GmbH, Erlangen; Forschungsinstitut für Biologischen Landbau (FiBL), Frick, Schweiz *(Research Institute for Organic Agriculture, Frick, Switzerland)*; Boku Wien, IFA-Tulln Institut für Umweltbiotechnologie, Österreich *(Boku Vienna, IFA-Tulln Institute for Environmental Bio-technology, Austria)*
IPZ 5e Dr. F. Weihrauch M. Obermaier	Further development of culture-specific strategies for ecological crop protection with the help of divisional net-works - Hop Div.	2017-2022	Bundesanstalt für Landwirtschaft und Ernährung (BLE), BÖLN-Projekt 2815OE095 (*Federal Agency for Agriculture and Food; BLE)*	Bund Ökologische Lebensmittelwirtschaft (BÖLW e.V.) *(Organic Food Production Alliance; BÖLW e.V.)*
IPZ 5e Dr. F. Weihrauch M. Obermaier	Development of a catalog of mea-sures to promote biodiversity in hop cultivation: What is possible?	2018-2023	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Producer Group)*	IGN Nierderlauterbach AELF PAF, FZ Agraökologie (Dr. S. Gresset); TU München, Department of terrestrial ecology (Prof. Dr. Weiser); LBV, KG PAF (Ch. Huber)
IPZ 5e Dr. F. Weihrauch M. Obermaier	Establishment of predatory mites in hop cultivation practice via cover crops	2018-2021	Bundesanstalt für Landwirtschaft und Ernährung (BLE), BÖLN-Projekt 2815NA131 (*Federal Agency for Agriculture and Food)*; Gesellschaft für Hopfenforschung (GfH) e.V. *(Society for Hop Research)*	Companies practicing ecological and integrated hop cultivation

4 Hop Cultivation, Production Techniques

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

4.1 N_{min}-Investigation 2020

The nitrogen soil analysis required by the DSN (N_{min}) *Düngeberatungssystem Stickstoff* (fertilizer advisory system) has become an integral part of the fertilizer planning on every hop farm. The new Fertilizer Ordinance has become mandatory for certain farms. These include those that have taken advantage of certain exemptions from the Fertilizer Ordinance in 2020 as they relate to reusing shredded bines as fertilizer and those that cultivate hops in designated, so-called red areas.

In 2020, more than two-thirds of the hop farms in the Bavarian growing regions of the Hallertau and Spalt participated in a DSN survey. Within this program, 3,782 hop gardens were examined for N_{min} content. In 2019, the number of participating hop gardens was 4,078. The 2020 studies revealed an average N_{min} content in Bavarian hop soils of 59 kg N/ha, which was slightly lower than the value of the previous year (66 kg N/ha). One explanation for the change could be the high yields of the 2019 harvest and the associated high nitrogen removal from the soil. As is the case every year, this year's N_{min} studies revealed large fluctuations from one farm to the next and even among different hop gardens and hop varieties on the same farm.

According to the new Fertilizer Ordinance (DüV), every hop grower must determine nitrogen (N) fertilizer requirements annually by taking into account the amount of nitrogen already available in the soil before the first round of new fertilization. For this, there are clearly defined specifications that apply to all hop parcels and cultivation units.

Farms in the so-called white and green areas, which did not have to conduct N_{min} tests or did not have to generate N_{min} results for all of their hop fields, can instead use regionalized averages from the table below to calculate N-requirements for their fields:

Table 4.1: Number of samples, preliminary and final N_{min} *values 2020 in the various districts and growing regions*

County/Region	Number of tests	Preliminary N_{min} value (as of March 24, 2020)	**Final N_{min} value**
Eichstätt (including Kinding)	243	56	**58**
Freising	416	63	**63**
Hersbruck	67	65	**50**
Kelheim	1,407	55	**57**
Landshut	239	73	**71**
Pfaffenhofen (and Neuburg-Schrobenhausen)	1,312	58	**58**
Spalt	98	69	**69**
Bavaria	**3,782**	**59**	**59**

Hop growers who have already calculated their nitrogen requirements using the preliminary N_{min} averages for their district or their growing region need to adjust their N_{min} values only if applicable final N_{min} values are more than 10 kg N/ha higher than the preliminary N_{min} values. In 2020, this did not apply to any of the districts or cultivation areas. Nonetheless, such adjustments were recommended for the Hersbruck cultivation region even though the final N_{min} value there was 15 kg/ha lower.

Farms that cultivate hops in red areas had to have at least three hop parcels examined for N_{min} in 2020. If these farms had additional hop parcels in red areas, the farm's average N_{min} value applied to those parcels as well.

The following graphic shows the annual development of the number of N_{min} tests and the N_{min} values in Bavaria by year.

Because the Fertilizer Ordinance now requires that nitrogen fertilizer amounts be calculated for each individual field, average fertilizer recommendations for nitrogen could no longer be issued after 2018.

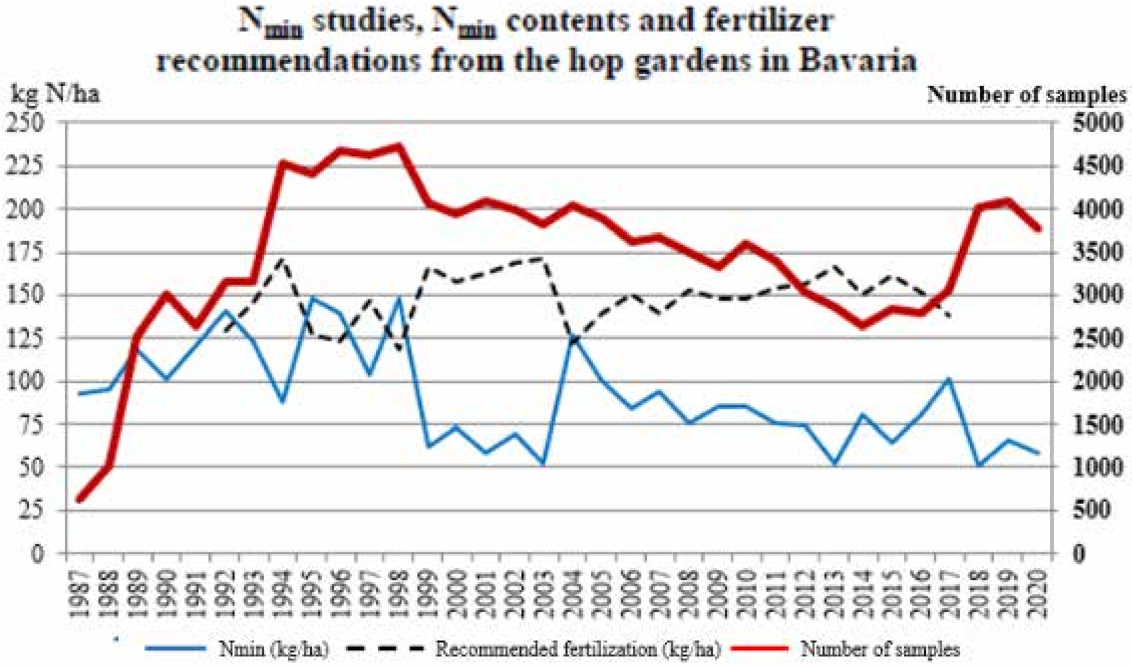

Figure 4.1: N_{min} *analyses,* N_{min} *values and fertilizer recommendations (up to 2017) for Bavarian hop gardens over the years*

4.2 Improvements in the nutrient efficiency of hops through fertilization systems with fertigation (ID 5612)

Sponsor:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenbau, Produktionstechnik (IPZ 5a) *[Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Production, Production Technology (IPZ 5a)]*
Financing:	Erzeugergemeinschaft HVG e. G. *(HVG Hop Producer Group)*
Project Management:	J. Portner
Team:	J. Stampfl, S. Fuß
Collaboration:	Prof. Dr. T. Ebertseder, Hochschule Weihenstephan-Triesdorf *(Weihenstephan-Triesdorf University of Applied Sciences)* Prof. Dr. F. Wiesler, LUFA Speyer Hop farms in the Hallertau
Duration:	March 2017 to December 2020

Hop plants place high demands on the water supply in order to deliver stable yields at a high quality. If the cultivation takes place in areas with a humid climate, both the absolute amount of precipitation and the distribution of precipitation over time are important. However, the global climate change is already causing a measurable rise in temperatures, as well as an increase in the frequency of extreme weather conditions such as dry periods and periods of heavy precipitation. The effects of these worldwide developments have become more pronounced in the German hop-growing regions in recent years. As a result of the deteriorating water supply, the production of hops in sufficient quantity and at high quality is becoming increasingly difficult, which means that it is also becoming more complicated to plan outcomes in the entire hop value chain. In addition to breeding new hop varieties with a higher tolerance for heat spells and dry periods as an adaptation to the consequences of climate change, additional irrigation with water-saving drip irrigation systems is also a possible adaptation strategy.

Figure 4.2: Drip irrigation systems for hops

In principle, irrigation systems not only ensure that the plants receive an adequate supply of water but also open up the opportunity for delivering plant nutrients in a targeted manner together with the water. This form of fertilization, known as fertigation, is highly efficient. It is already used in many agricultural segments, especially in regions of the world with arid and semi-arid climates and thus high irrigation requirements.

Thus far, in hop cultivation, fertigation has been used mainly in the Yakima Valley in the USA. There, the required plant nutrients are delivered dissolved in irrigation water. In German hop cultivation, on the other hand, the plants' nutrient requirements are met primarily through the application of granulated fertilizers. Unfortunately, the plants' availability to take up scattered, granulated nutrients is severely limited, especially under dry conditions.

The most important and most yield-limiting nutrient in hops, as is the case for many other crops, is nitrogen (N). However, because of the potentially large environmental impact of nitrogen, German laws and regulations are increasingly limiting the maximum amount of nitrogen fertilizers that can be used for hops. This means that new fertilization methods, including the targeted and needs-based application of nitrogen via irrigation water (fertigation), could become an option in Germany to achieve a more efficient use of the quantities of nitrogen that are still permitted. This means that both additional irrigation and fertigation represent potential solutions for combatting climate change and securing hop cultivation in Germany long term. The Bavarian State Research Center for Agriculture has been investigating the effects of irrigation and fertigation since 2017, as part of a research project funded by the HVG producers' association.

Nitrogen fertilization systems with fertigation

Initially, this research focused on the development of nitrogen fertilization systems with fertigation. The aim was to achieve a more precise dosage of N-fertilizations relative to the plant's N-uptake, as well as its soil-derived N-replenishment. Various field tests conducted in the Hallertau since 2017 served as the conceptual basis for the study. In these tests, the effects of different N-addition, varied in terms of timing and amounts, were analyzed.

Figure 4.3: Fertilizer dispensing device for fertigation

One essential finding was that the plant absorbs nitrogen immediately if it is applied via irrigation water and that this allows for short-term interventions in the plant's nitrogen balance.

In contrast to nitrogen fertigation, the availability of nitrogen supplied to plants exclusively in the form of granulated N-fertilizer is strongly dependent on the vagaries of precipitation. Both dry spells and periods of heavy precipitation can, therefore, interfere with the plants' nitrogen uptake. Fig 4.4 juxtaposes the data for an N-fertigation system with one that relies exclusively on granulated N-fertilizer. For this, starting in calendar week 25, the plants received two-thirds of the total nitrogen additions, spread over six individual applications over a six-week period, during the plants' main biomass formation. The remaining one-third of the nitrogen was applied in granular form. The amount of N that can be applied in practice via fertigation depends primarily in whether a farm applies organic fertilizers as well and whether nitrogen-containing nutrient solutions are used during hop culling.

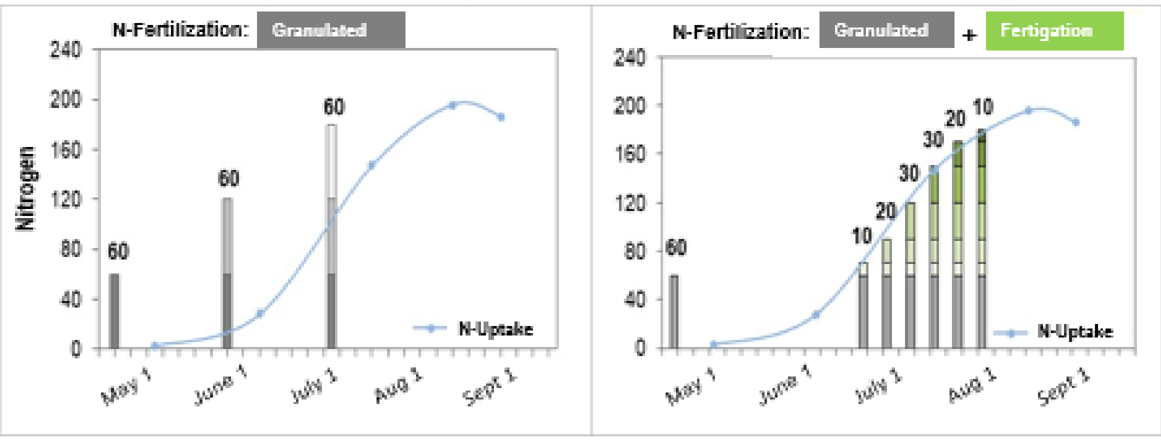

Figure 4.4: Comparison between a fertilization system exclusively with granulated N-fertilizer (left) and a combination system with two-thirds N-fertigation and one-third granulated N-fertilizer (right).

Effects on yield and quality

In addition, the three-year study investigated the effects on yield and quality from additional above-ground drip irrigation in conjunction with fertigation. This was a static field test planted with Perle on sandy soil. The study lasted from 2017 to 2019 (Figure 4.5). It showed that additional irrigation in conjunction with an N-fertilization level of 150 to 180 kg/ha of N, distributed in granulated form over 3 applications, increased the yield over three years by an average of 7% and that of the alpha acid content by 15%. However, if one-third of the total N-fertilization was in granulated form and two-thirds via fertigation, the yield increased by an average of 15% and the alpha acid content by 23%. The differences between the processes are especially noticeable when comparing alpha amounts. In addition to these averages, the effects are of decisive importance for growing hops in dry years. In the 2017 crop year, there was a severe drought from mid-June to the end of July while the cones were developing. For this year, the yield and alpha acid increases amounted to 12 and 17%, respectively, for just irrigation, and to 20 and 27%, respectively, if fertigation was added.

The positive effects of N-fertilization systems that include fertigation compared to those that rely exclusively on spreading N-fertilizers were confirmed in all field tests. Thus, it is clear that an effective stabilization of the yield and of the quality of hop crops is possible through a combination of irrigation and fertigation. Combination irrigation systems are plainly more efficient.

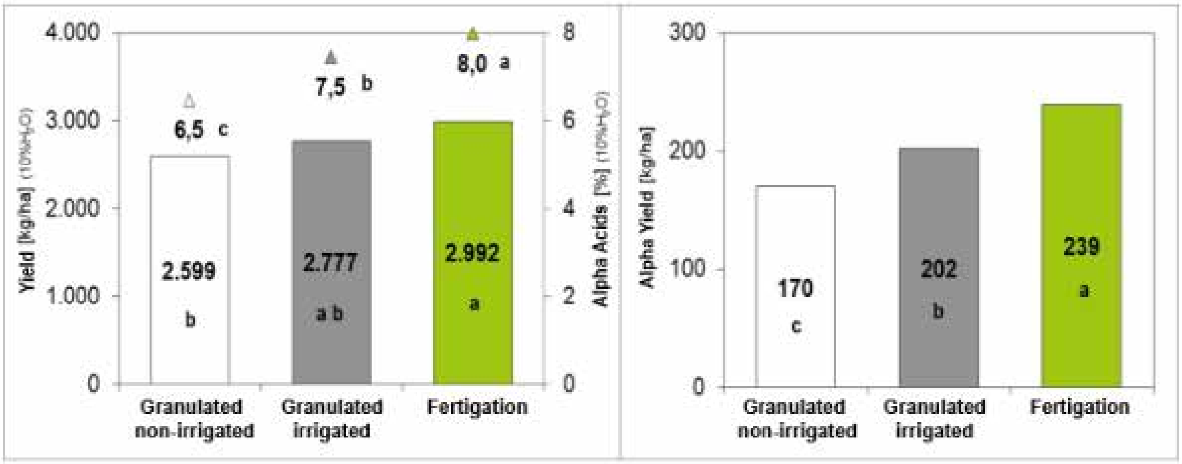

Figure 4.5: Perle variety - sandy location - 3-year test mean values (2017 to 2019); Cone yield, alpha acid content and alpha yield. Statistical evaluation: values with the same letters do not differ significantly from one another.

During irrigation and fertilization tests in plots with Herkules, it was also found that high levels of N-supplies, starting in early August when the plant synthesizes alpha acids, can lead to significant reductions in both alpha acid content and alpha yield. The reasons for high N-supplies can be late or excessive N-fertilization, as well as a high amount of mineral nitrogen in the soil (N_{min}) or a high N-replenishment. For plots where nitrogen was applied in granulated form only, periods of drought led to a delayed nitrogen effect, meaning that there was an increased carry-over risk of too much nitrogen available as the plant was synthesizing alpha acids. By means of targeted N-applications via fertigation, on the other hand, need-based nitrogen nutrition became a possibility and a reduction of the alpha acid content was effectively avoided.

Effects on nitrogen utilization and nitrogen efficiency

The effects of irrigation and fertigation on the plants’ nitrogen use will continue to be studied with the goal of determining the most efficient uptake by the plants of nitrogen supplies. It has already been shown that above-ground irrigation, in conjunction with a combination system of N-fertilization at constant total levels of nitrogen, results in an increase in nitrogen uptake by the plants through improved biomass formation (Figure 4.6).

At the same time, the soils had lower residual N_{min} levels in the fall after the harvest. Therefore, additional irrigation during dry periods leads to a diminished risk of nitrates leaching into groundwater.

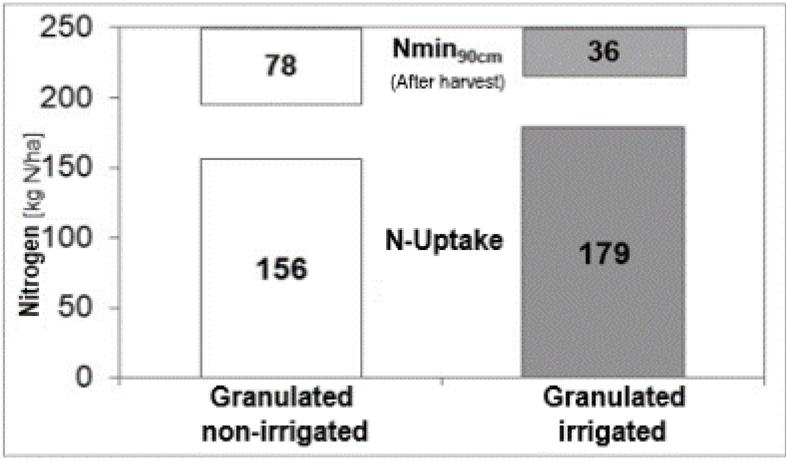

Figure 4.6: Perle variety - sandy location - trial year 2017: Nitrogen uptake by the plants and N_{min} content in the soil in the fall after harvest.

The study also determined that in different test years at different locations, the application of a proportion of the total amount of N-fertilization via irrigation water leads to a significant increase in the effectiveness of N-fertilization, especially under conditions of limited N-supplies. For example, the effects of N-fertilization on Perle planted at a loamy location in crop year 2018 is shown in the table below. N-fertilization systems with fertigation produced both an increase in the percentage of N-utilization (as a percentage of the total amount of applied N) and an improvement in the yield per kilogram relative to the amount of nitrogen used (agronomic N-efficiency).

Table 4.2: Perle variety - loamy location - trial year 2018: Comparison between the effects of granulated N-fertilization and fertigation on agronomically and ecologically relevant factors.

	Yield [kg/ha]	**N-Depletion** [kg N/ha]	**N-Utilization** [%]	**Agro. N-Efficiency** [kg Cones/kg N]
Granulated irrigated	2.242	135	30	4,6
Fertigation	2.719	177	72	9,4

To sum up, it is a fair conclusion that irrigation and especially N-fertilization systems with fertigation represent an effective solution for counteracting the effects of climate change in German hop growing in the future. Agronomic parameters, such as the yield and alpha acid content, can be stabilized. In addition, such ecologically relevant indicators as the N-balance can be improved, thereby reducing the risk of nitrate leaching into groundwater.

More detailed information about the subject can be found in a set of LfL brochures entitled “Drip irrigation and fertigation in hops.” A summary will also be published online in an ALB information leaflet, which was not yet completed at the time this annual report went to press. In addition, all research results of the project presented here can found in greater detail in a dissertation by Johannes Stampfl, to be completed in the spring of 2021, entitled “Need-based nitrogen nutrition of hops (Humulus Lupulus L.) through fertilization systems with fertigation.”

4.3 Nitrogen dynamics in hop gardens with different soil types and different fertilizer systems (ID 6054)

Sponsor:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenbau, Produktionstechnik (IPZ 5a) *[Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Production, Production Technology (IPZ 5a)]*
Financing:	Erzeugergemeinschaft HVG e. G. *(HVG Hop Producer Group)*
Project Management:	J. Portner
Team:	A. Schlagenhaufer
Collaboration:	Hallertau hop farms
Duration:	March 1, 2018 to February 28, 2021

Background

In the Hallertau, hops are cultivated intensively as a high-density specialty crop, principally because it generates very high added-value. In the past, therefore, the use of nitrogen fertilizers has never been a limiting production factor. In addition, older hop varieties are not very efficient in their nitrogen uptake, which is why, after the harvest, especially during drought and low-yield years, more residual nitrogen remains in the soil and poses a risk to other ecosystems.

Objectives

As part of the project, the nitrogen dynamics in hop soils are being investigated at 21 hop farms. In addition, intensive N_{min} samples are being taken in the spring, fall, and winter. Finally, nitrogen requirements are determined for each of these locations, after which the amounts of nitrogen that were actually administered are tracked. The two values are then compared to determine nutrient utilization. As a result, the nitrogen path and its depletion potential during the vegetation period can be estimated for different types of farms, fertilizer systems, and soil types. This allows for the development of possible approaches for optimizing nitrogen management in hop cultivation. The aim is to optimize operational nitrogen management in such a way that the best yields and qualities can be achieved while observing and complying with the requirements of the Fertilizer Ordinance, without negatively impacting water protection requirements.

Method

In each of the 21 farms, 3 subareas were selected. The total of 63 subareas reflects the wide variety of hops grown in the Hallertau, as well as the different operating and fertilizing systems in use there. The first set of N_{min} samples is collected at the start of the vegetation period in March; the second set, after the harvest in October to determine the residual amounts of nitrogen left in the soil; and the third, during the remaining vegetation period in the winter to determine any possible changes in N-locations. As a convenient reference, the available nitrogen is measured as ammonium and nitrate, up to a soil depth of 90 cm. This sampling is divided into three 30-cm tiers to determine any N-shifts in the soil layers. Each farm receives individualized advice on fertilization issues. All nitrogen fertilizer applications are recorded in terms of quantity and timing. During the harvest, cones and residual plant matter are sampled to calculate the exact amount of nitrogen uptake. From this, an area-specific nutrient balance is assessed and related to the required N_{min} content in the soil.

Figure 4.7: N_{min} soil-sampler

Results

After the initial trial years between 2018 and 2021, the first findings about nitrogen dynamics in hops could be compiled. The first nine samples show the distribution of N_{min} values within the respective layers as a function of the sampling date (Figure 4.8). One early result of the study is the higher N_{min} level, in the fall, in the top 30-centimeter section of the plant.

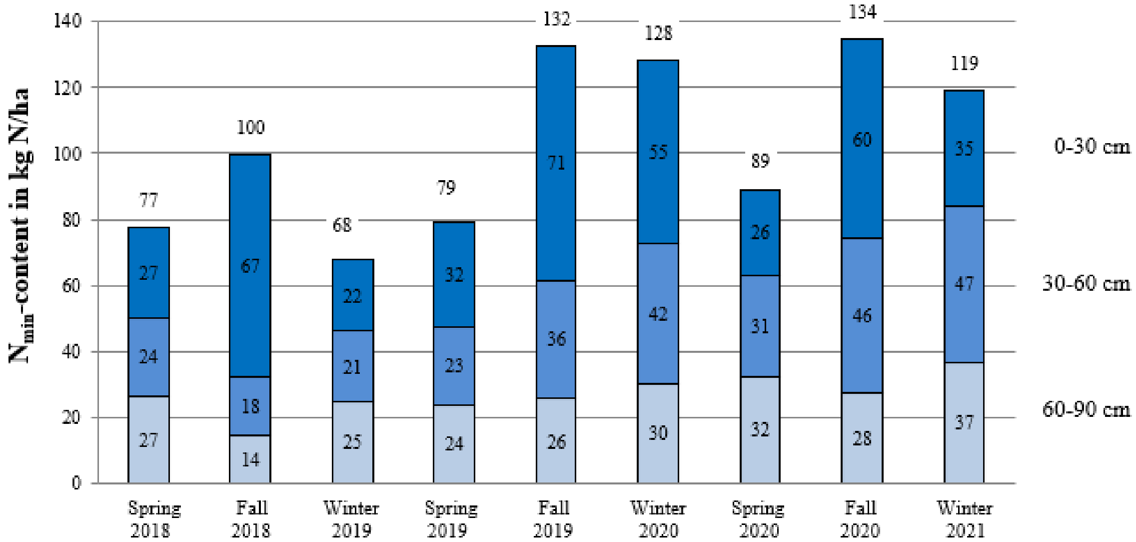

Figure 4.8: N_{min} values taken on 9 sampling dates, divided by soil layers (n = 62)

Comparing the N_{min} content in terms of different hop variety grown at the same sampling site, aroma varieties have significantly higher average Nmin levels than do bitter varieties (Figure 4.9).

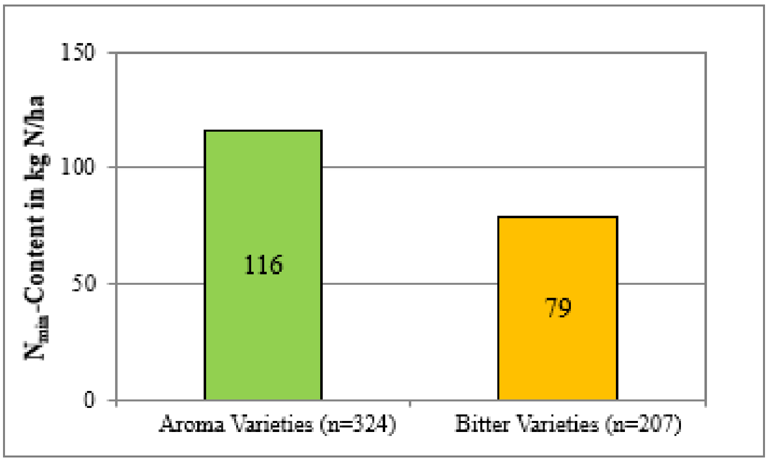

Figure 4.9: N_{min} values taken on 9 sampling dates by hop varieties (2018-2020)

4.4 Experiments with composting and recycling of shredded hop bines to optimize the nutrient efficiency of organically bound nitrogen (ID 6141)

Sponsor: Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenbau, Produktionstechnik (IPZ 5a)
[Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Production, Production Technology (IPZ 5a)]

Financing: Erzeugergemeinschaft HVG e. G.
(HVG Hop Producer Group)

Project Management: J. Portner

Team: A. Schlagenhaufer, J. Stampfl, S. Fuß

Collaboration: Prof. Dr. Meinken, Institut für Gartenbau, *(Horticultural Research Institute)* Hochschule Weihenstephan-Triesdorf (HSWT)
Prof. Dr. Ebertseder, Fakultät Nachhaltige Agrar- und Energiesysteme, *(Faculty of Sustainable Agriculture and Energy Systems)* Hochschule Weihenstephan-Triesdorf (HSWT)
M. Stadler, Fachzentrum Agrarökologie, *(Centre of Expertise for Agroecology)*, AELF Pfaffenhofen

Duration: September 1, 2018 to February 28, 2022

In the Hallertau hop-growing region, 880 farms cultivate 17,233 ha of hops and produce a total of roughly 230,000 MT of shredded bines each year. Around 80% of this plant matter is currently being returned to the fields as fertilizer. These bines, however, contain substantial amounts of nitrogen. With the implementation of the new Fertilizer Ordinance, a farmer is required to use the nitrogen contained in the shredded bines as efficiently as possible and to avoid N-dispersion into other ecosystems. To meet these requirements, extensive composting and field trials with shredded hop bines will be conducted over three years.

Objectives

- Risk assessment of increased nitrate leaching as a result of the application of shredded hop bines in the fall in accordance with current practice
- Development of environmentally compatible and practicable composting processes for shredded hop bines
- Investigation of the nitrogen effects of the various composts/substrates in field trials
- Comparison of the different processes with regard to economy, ecology, and practicality
- Reduction of nitrogen losses in shredded bines
- Legally compliant, practical, and environmentally friendly recycling of the shredded bines with optimal use of the organically bound nitrogen

Method

The experimental setup of the project is divided into four "work packages" (AP 1 to 4): The experiment is based on composting tests (AP 1), to develop the basic conditions for aerobic composting on a small scale (size approx. 1.5 m³). At the same time, in a further experiment, after the harvest, shredded bine material is simply stored aerobically and composted or siloed (AP 2) using the Witte method (MC composting). This composting trial under practical conditions has several objectives. On the one hand, the knowledge gained under small-scale conditions should be verified for its real-world practical applicability. Also, aerobic composting should be compared to the three other trial variations with regard to the practicality and the conservation potential for the nitrogen present in the shredded hop bines. Furthermore, these trials produce the material for plot tests to determine the N-efficiency of the four materials (stored shredded hop bines, aerobic and MC compost, silage), which form the third project part (AP 3). The material for the fourth part of the project, that is, practical experiments to determine N-dynamics in hop gardens (AP 4), also stems from these tests. All four sub-projects were started at the same time after the hop harvest in the fall of 2018. In addition, in 2017, as part of a bachelor's thesis, vascular tests with shredded bines were conducted. These will be continued as part of this project.

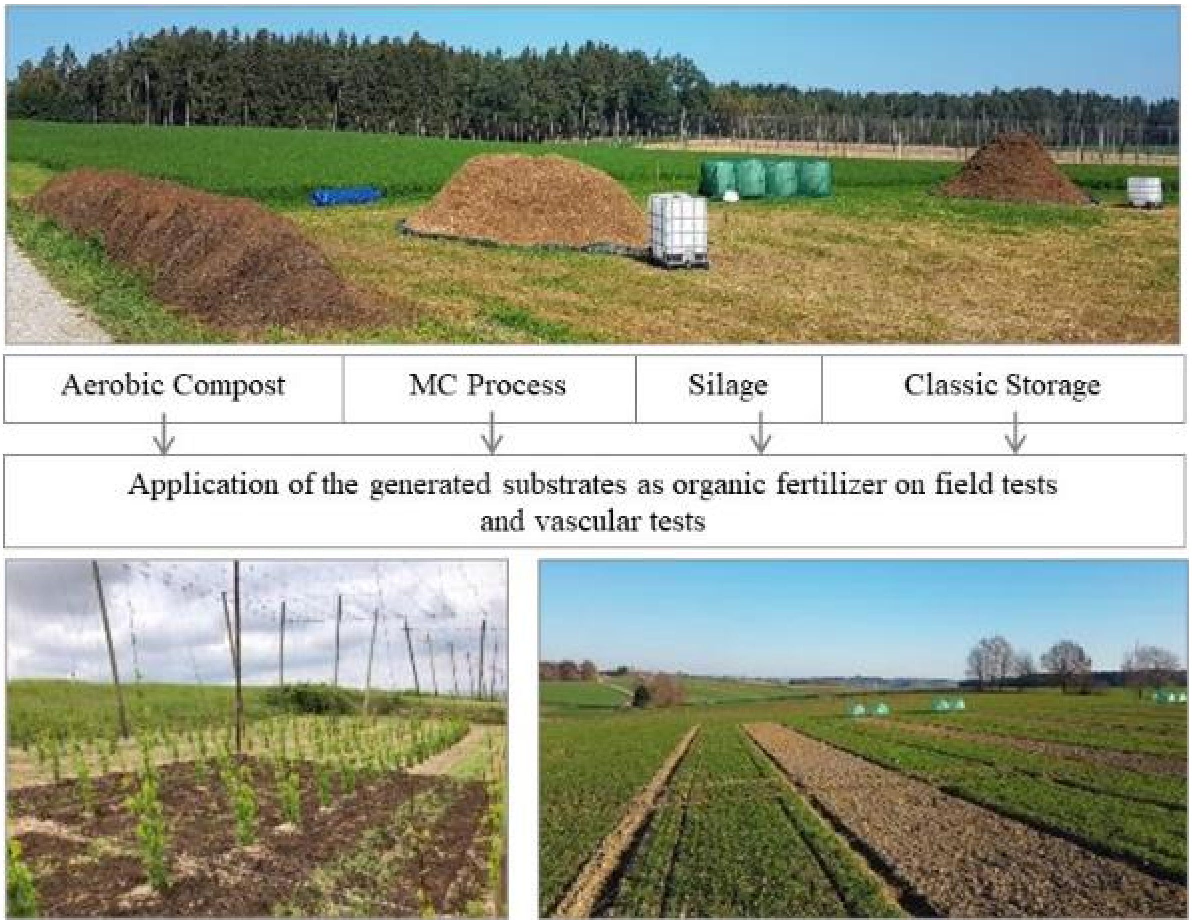

Figure 4.10: *Representation of the experimental scheme: Above: AP 2, practical composting experiment Bottom left: AP 4, field trial with hops, shredded bines applied in MayBelow right: AP 3, plot tests with shredded bines*

Results

Composting Tests

In 2018, after the shredded bines had been stored according to current practice for no more than 4 weeks, dry matter losses were around 20% and nitrogen losses, just under 10%, mainly because of gaseous losses. As expected, there were no such losses in the silage. With the two composting processes, loss rates increased in a near-linear fashion with longer storage times.

Field trials

During the initial trial years 2018/19 and 2019/2020, there was no increase in nitrogen mineralization from the shredded bines between the fall, when they were placed outside, and the beginning of the vegetation period. This suggests that this organic fertilizer has a low mineralization potential. Similar findings could be obtained in vascular tests. This mineralization behavior suggests that the timing for placing shredded bines outside in the fall has no effect on the risk of nitrate leaching into the groundwater.

The fertilizing effect of chopped hop vines could be determined based on nitrogen uptakes at harvest time, as well as in field trials with hops. In the field trials, the N-depletion of plots fertilized with shredded bines was only slightly higher than that of the controls in 2019 and 2020, which indicates a low short-term N-fertilization effect (Figure 4.11). A conclusion regarding the long-term N-fertilization effect of shredded bines, however, will only be possible after the results of the next test years are in.

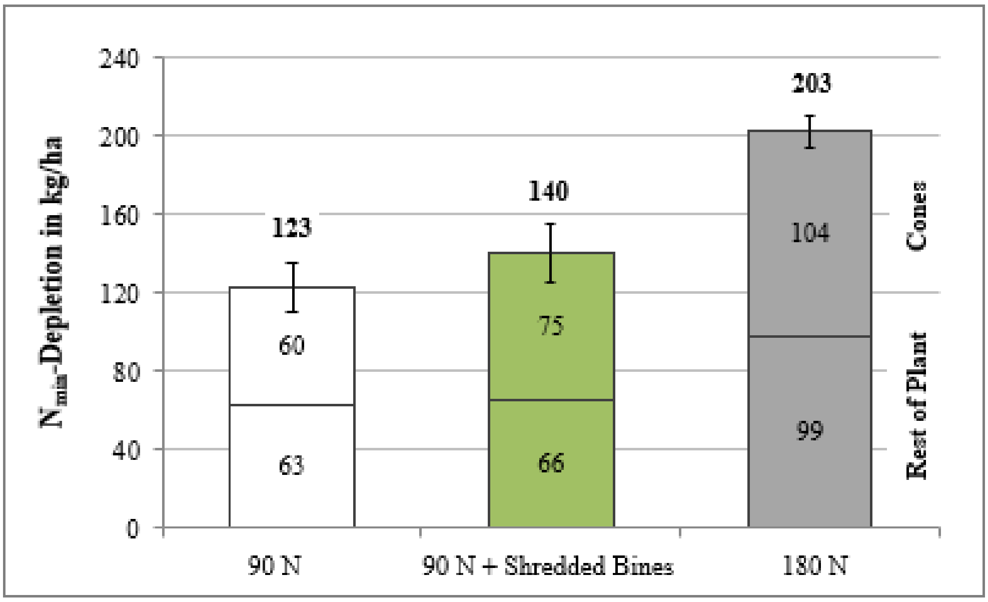

Figure 4.11: Nitrogen detected at harvest time and divided into cones and residual plant matter in kg/ha relative to either mineral or organic fertilization, for the year 2020, for Herkules, at an easy growing location, using three fertilization levels: = 90 kg N mineral (control), = 90 kg N mineral + 100 kg N organic (bines), and 180 N = mineral

4.5 Investigation of the roots and nutrient supply in the soil profile as a function of irrigation and the position of the drip hose

Team: I. Riedl (Bachelor Thesis)
F. Weiß (Bachelor Thesis)
J. Stampfl

Collaboration: Dr. Sabine von Tucher,
(Chair of Plant Nutrition, Weihenstephan, Munich Technical University)
Lehrstuhl für Pflanzenernährung, Technische Universität München

Duration: May 2019 to November 2019

Background and objectives

Between 2017 and 2019, the Bavarian State Institute for Agriculture was the site for extensive N-fertilization tests as part of a project entitled "Improving nutrient efficiency in hops through fertilization systems with fertigation." Among other tasks, the effects of fertilization, irrigation, and the position of drip hoses were closely examined. Two drip hose positions, one on the furrow (AB) and below ground next to it (NB), are associated with different effectiveness with regard to biomass and yield generation. This led to studies of the soil profiles in terms of their root distribution, macronutrient content, and other soil properties in the irrigated area, relative to the different irrigation methods.

Methodology

The area for this test is located in the center of the Hallertau, on a favorable growing site (IS) that is planted with Perle. The following variations were investigated:

Table 4.3: Test variations with respect to irrigation and fertilization

Variation	Irrigation	Fertilization
A	none	none
B	none	Granulated, scattered
C	AB	none
D	AB	Granulated, scattered
E	AB	Fertigation
F	NB	none
G	NB	Granulated, scattered
H	NB	Fertigation

To investigate the root distribution, soil volumes of 2 meters wide and 1 meter deep were excavated with a small excavator. The blocks of soil were equidistant between two hop plants and in a perpendicular direction to the rows. Next, using a spade, the sides of the soil block were smoothed. This ensured a straight profile even for looser soil blocks. To expose the fine roots, water at a pressure of 6 bar was sprayed with a nozzle against the sides. This caused about 1.5 to 2 cm to be washed off. A 5 x 5 cm wire mash grid was placed over the sides, whereby each square served as a counting unit for the number of roots. (Figure 4.12). Only the exposed root tips were counted. In addition, soil samples were taken from the sides according to a precisely calibrated sampling scheme. These were examined for macro-nutrient content (N_{min}, P, K, Mg) and dry matter content. The density of the soil to be irrigated below the respective drip hose positions was determined with the help of sample cylinders.

Figure 4.12: Soil block side perpendicular to the hop row, with counting grid

Results

After examination of all test soils, a pattern emerged: The fine-root density in very top soil layer was significantly higher it was than below the soil surface (Figure 4.13). Between 40 and 58% of the total number of fine roots was in the very top layer. Another 35-50% were in the first 20 cm below the soil surface. In the deeper soil layers, however, there were virtually no fine roots.

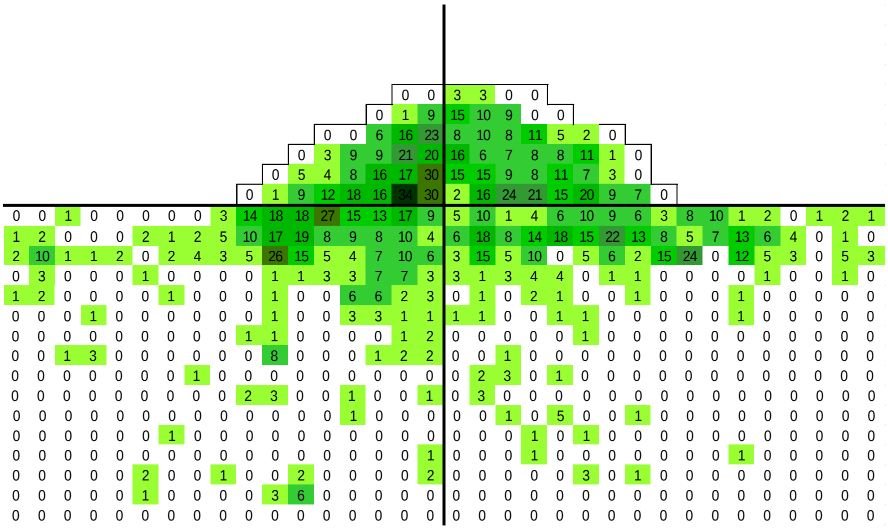

Figure4.13: An example of fine root distribution in the side of a soil fertilized via above-ground fertigation (E), with Perle, 2019. The deeper the green color, the more roots were counted for squares of 5 x 5 cm.

A comparison between the fine root distribution relative to the irrigation method, the AB examinations showed that plants irrigated above-ground had higher root densities below-ground than did plants irrigated underground. Especially in the center row, the NB examinations showed a reduction in fine-root formation. Compared to the non-irrigated portions (B), the root density in the dam was 24% lower in the below-ground irrigated portions (F, G, H) (Table 4.4).

Table 4.4: Distribution of fine roots in the soil depending on irrigation method and N-fertilization

Variation			**Fine Roots (Number/m^2 Sample Soil Block Side)**		
	Irrigation	N-Fertilization	Summary Profile	Row	0 to -70 cm
A	none	none	1250	3278	771
B	none	Granulated, scattered	1444	4573	741
C	AB	none	1437	4116	829
D	AB	Granulated, scattered	1566	4314	1101
E	AB	Fertigation	1400	4587	823
F	NB	none	1191	3241	762
G	NB	Granulated, scattered	1235	3799	757
H	NB	Fertigation	1241	3365	863

Analyses of the soil macronutrients revealed no deficiencies in any of the soil layers.

Analyses of the densities below the two drip hose positions showed that the soil underneath the surface irrigation had an average density of 1.3 g/cm³ compared to 1.7 g/cm³ underneath the underground irrigation. This difference is significant. The density differences can also explain why, for underground irrigation methods, the root density below the soil surface was not significantly higher than with above-ground irrigation methods or without any irrigation at all. In the loose top soil layer, however, surface irrigation had a positive influence on the number of fine roots there.

Outlook

The method of analyzing the side wall of a sample soil block provided interesting findings that help explain the influence of the drip hose position and the type of fertilizer application on yield and quality. However, any analysis must also take into account the huge variability of individual hop plants. This is necessary because it has not yet been possible to repeat the tests described above for 20 samples which would allow for the averaging-out of such individual plant variations.

4.6 Investigation of the hop yields a function of the amount and timing of nitrogen fertilization

Team:	A. Baum (Bachelor Thesis) S. Arnold (Bachelor Thesis) J. Stampfl
Collaboration:	Prof. Dr. T. Ebertseder, Fakultät Nachhaltige Agrar- und Energiesysteme, *(Faculty of Sustainable Agriculture and Energy Systems)* Hochschule Weihenstephan-Triesdorf
Duration:	July 2019 to November 2019

Background and objectives of the project

Between 2017 and 2019, the Bavarian State Research Center for Agriculture conducted extensive N-fertilization tests as part of the project, "Improving nutrient efficiency in hops through fertilization systems with fertigation." In these experiments, different amounts and variations of the timing of nitrogen fertilization resulted in yield variations. To better understand these differences from a plant physiology perspective, in 2019, two bachelor theses examined the differences in yield and the differences in the seasonal plant evolution as a function of the type and timing of fertilization for Perle and Herkules.

Methods

The investigations were carried out at two locations in 2019. One was planted with Perle, the other with Herkules. Figure 4.14 shows the fertilization regimen for the Perle site, and Figure 4.15, the one for the Herkules site.

At both locations, controls without N-fertilization (A) served as references, as did a plot fertilized with three equal rounds of granulated fertilizer (B). For the fertigated plants (C to F), one-third of the fertilizer requirement was administered in the form of granulated fertilizer and two-thirds via irrigation. The fertigated plants had different start dates for their 6-week fertigation period.

Perle

Variation	Month / Calendar Week (KW*)	April 14	15	16	17	May 18	19	20	21	22	June 23	24	25	26	July 27	28	29	30	August 31	32	33	34	35	Total [kg N/ha]
A	Control																							0
B	Granulated				33						33				33									100
C	Fert. KW 23				33						6	11	17	17	11	6								100
D	Fert. KW 24				33							6	11	17	17	11	6							100
E	Fert. KW 25				33								6	11	17	17	11	6						100
F	Fert. KW 26				33									6	11	17	17	11	6					100

*) KW= Calendar week; Fert.= Fertilization

Figure 4.14: Perle fertilization schedule, favorable growing location, 2019, granulated additions are colored in gray; fertigated additions, in green

In addition, for the Herkules study, there was a separate test H (next to tests A to F), in which the total amount of applied N was 50% higher.

Herkules

Variation	Month / Calendar Week (KW*)	April 14	15	16	17	May 18	19	20	21	22	June 23	24	25	26	July 27	28	29	30	August 31	32	33	34	35	Total [kg N/ha]
A	Control																							0
B	Granulated				40						40				40									120
C	Fert. KW 23				40						7	13	20	20	13	7								120
D	Fert. KW 24				40							7	13	20	20	13	7							120
E	Fert. KW 25				40								7	13	20	20	13	7						120
F	Fert. KW 26				40									7	13	20	20	13	7					120
H	Fert. KW 25				60								10	20	30	30	20	10						180

*) KW= Calendar week; Fert.= Fertilization

Figure 4.15: Herkules fertilization schedule, medium location, 2019, granulated additions are colored in gray; fertigated additions, in green

The development of all plants except the controls was tracked over time. For this purpose, bines were culled from each of the plants under investigation and analyzed in terms of their yield development. Timing for the sampling was determined by the variety-specific optimal harvest date; and the bine selection was guided by the similarity of the bines compared to the average appearance of the plants in the neighboring "normal" production plots. This scheme is represented in Figure 4.16.

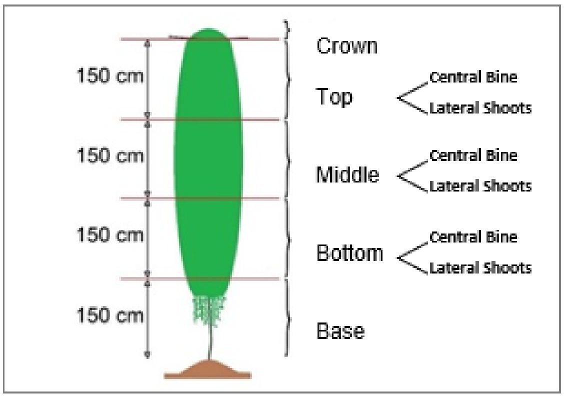

Figure 4.16: Division of bine into segments and areas

1. Division of the bine into **sections**: crown, top, middle, bottom, base (the crown section was the part of the bine that grew above the height of the poles)
2. Separation of sections into the **areas**: central bine and lateral shoots (this separation was only possible and useful in the top, middle and bottom sections; shoots were considered lateral if they arise from the leaf axils and were at least 10 cm long)
3. The cones of the 8 **bine fractions** were **plucked by hand** and placed in separate containers
4. To determine the **cone size and number** per fraction, a sub-sample of around 150 to 250 cones was spread out on white trays and recorded. An image processing program then counted the number of cones and determined the mean cone size. Using the weight of the partial sample and the weight of the entire fraction, the number of cones for each fraction could be extrapolated. At the same time, the mean cones weight could be determined
5. Finally, the **length and number** of the culled **lateral shoots** were determined

Figure 4.17: Culled lateral shoots next to the central bine with the so-called (Hallertauer vernacular) "axil hops" of a section

Results

Representative bines of the test group (B) served as a reference for the subsequent assessment of yield developments as a function of different types of nitrogen fertilization. In both varieties, the crown, top and middle sections held most of the cones: some 80% in Herkules and 82% in Perle. The differences between the central bine (the so-called "axil hops") and the lateral shoots showed that only a very small part of the cone yield resided on the central bine (13% in Herkules and 10% in Perle) and that a much larger portion forms on the lateral shoots (Table 4.5).

Table 4.5: Distribution of cone yields in Herkules and Perle, divided into different bine sections and areas (in % of cone yield/bine in g)

Segment	**Herkules** (in % of 928 g)				**Perle** (in % of 782 g)			
	Total Plant	Central Bine	Lateral Shoots	Crown	Total Plant	Central Bine	Lateral Shoots	Crown
Crown	11			11	8			8
Top	36	9	27		37	7	30	
Middle	34	4	30		37	3	35	
Bottom	18	1	17		17	1	16	
Base	2	0	2		1	0	1	
Sum	**100**	**13**	**76**	**11**	**100**	**10**	**82**	**8**

Because of the importance of the lateral shoots for yield formation, they were examined more closely. From the length and number of side shoots per section, the total side shoot length per section could be calculated.

Table 4.6: Lengths of lateral shoots by bine sections and percentage changes per section depending on N-fertilization methods, Herkules, 2019

Section	**Lateral shoot length in m**				
	Granulated	Fertigation starting at calendar week 25		Fertigation starting at calendar week 26	
Top	12.0	15.9	+32 %	13.7	+14 %
Middle	16.9	17.9	+6 %	14.8	-12 %
Bottom	24.4	22.0	-10 %	14.2	-42 %
Base	22.9	16.0	-30 %	11.4	-50 %
Sum	**76.2**	**71.8**	**-6 %**	**54.1**	**-29 %**

Table 4.6 shows changes in the length of the lateral shoots in the individual sections depending on the fertilization method, using Herkules as an example. It turns out that later fertilization dates (starting in calendar week 25) shifted the formation of lateral shoots into the upper bine sections without a significant decrease in the total length of the lateral shoots. At an even later start of fertigation (starting at calendar week 26), 14% more or longer lateral shoots were formed in the upper section, but the lateral shoot length was reduced in all other sections. As a result, the sum of the lateral shoot lengths as measured in the reference plants could no longer be achieved (- 29%).

Next was the calculation of the amount of cones (in grams) formed per meter of lateral shoots, in the respective sections. This is a key figure that can be used to define the yield relevance of the length of the lateral shoots for the respective sections. The values are as follows:

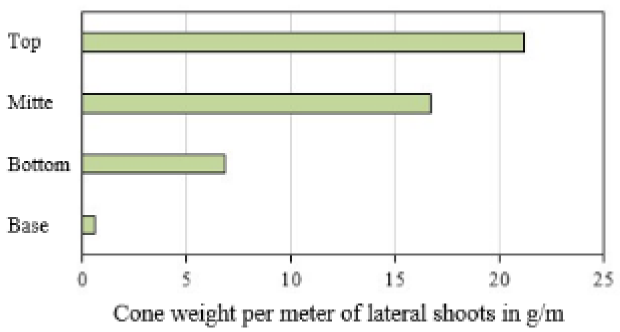

Figure 4.18: Aggregate cone weight per meter of side shoots in g/m relative to the reference, divided by bine sections

The results show that the timing of nitrogen fertilization has a significant influence on the growth of the lateral shoots and thus on the cone yield. The later the N-fertilization, the further up the lateral shoot growth shifted. At a certain point in time, when N-fertilization was too late, an overall reduction in lateral shoot lengths was the result, which, in turn, can have a negative effect on come yield.

4.7 Investigation of uptake rate and distribution of nitrogen (^{15}N) applied via fertigation

Team: M. Waldinger (Master Thesis), J. Stampfl

Collaboration: Prof. Dr. U. Schmidhalter,
Lehrstuhl für Pflanzenernährung, Wissenschaftszentrum Weihenstephan, TU München
(Chair of Plant Nutrition, Science Center, Weihenstephan, Munich Technical University)

Duration: May 2019 to October 2019

Background and objectives of the project

In many plants, including hops, nitrogen (N) is the most yield-limiting nutrient. Within the current, increasingly restrictive legal framework, it is particularly important that the right amount of nitrogen is available to the plant at the right time. In this context, nitrogen administered in excess, as well as nitrogen not taken up by the plant, can be equally problematic. In the research project "Improving the nutrient efficiency in hops through fertilization systems with fertigation," various fertilization systems were tested in extensive field trials between 2017 and 2019.

To be able to draw conclusions about the uptake, distribution, and storage of nitrogen, field tests with the nitrogen isotope ^{15}N and its corresponding ^{15}N-Tracer-Method were conducted for this master thesis.

Method

The investigations were conducted in 2019 at two locations with sandy loam. The varieties were Perle and Herkules. Figure 4.19 shows the fertilization regimen for the Perle location; Figure 4.20, the one for the Herkules location.

At both locations, controls without N-fertilization (A) served as references, as did a plot fertilized with three equal rounds of granulated fertilizer (B). For the fertigated plants (C to F), one-third of the fertilizer requirement was administered in the form of granulated fertilizer and two-thirds via irrigation. The fertigated plants had different start dates for their 6-week fertigation period.

	Month	April				May					June				July				August					Total
	Calendar Week (KW*)	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	[kg N/ha]
A	Control																							0
B	Granulated				33						33				33									100
C	Fert. KW 24				33							6	11	17	17	11	6							100
D	**Fert. KW 23**				**33**						6	11	**17**	17	11	6								**100**
E	Fert. KW 26				33									6	11	17	17	11	6					100
F	**Fert. KW 25**				**33**								6	11	**17**	17	11	6						**100**

*) KW= Calendar week; Fert.= Fertilization

Figure 4.19: Perle fertilization schedule, loamy location, 2019

In addition, for the Herkules study, there was a separate test H (next to tests A to F), in which the total amount of applied N was 50% higher.

	Month	April				May					June				July				August					Total
	Calendar Week (KW*)	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	[kg N/ha]
A	Control																							0
B	Granulated				40						40				40									120
C	Fert. KW 24				40							7	13	20	20	13	7							120
D	**Fert. KW 23**				**40**						7	13	**20**	20	13	7								**120**
E	Fert. KW 26				40									7	13	20	20	13	7					120
F	**Fert. KW 25**				**40**								7	13	**20**	20	13	7						**120**
H	**Fert. KW 25**				**60**								10	20	**30**	30	20	10						**180**

*) KW= Calendar week; Fert.= Fertilization

Figure 4.20: Herkules fertilization schedule, loamy location, 2019

Only the partial nitrogen additions marked in yellow (Figure 4.19 and Figure 4.20) were enriched with ^{15}N-isotopes. Nitrogen has a stable ^{14}N-isotope ratio of 99.634% and of ^{15}N of 0.366%. In these experiments the amount of ^{15}N-content of the nitrogen fertilizer was increased to 2.55%. This allowed for the ^{15}N-content to be determined during subsequent plant analyses. From these results, we can derive the distribution and uptake of nitrogen enriched with ^{15}N in the course of the vegetation, as well as during trial harvests.

After fertilization with enriched nitrogen, leaf, flower, and cone samples at three heights (bottom: 1.5 m; middle: 3.5 m, and top: 5.5 m) could be analyzed. They could also be divided into values for the main bine and the lateral shoots. The analyses were scheduled to take place on a weekly basis until harvest time. In addition, the enriched N-content of the residual plant material and cones could be determined. Finally, after the harvest, the roots were also tested for their ^{15}N-content.

The enriched nitrogen recovery rate is called ^{15}N-recovery.

Results

At each measurement date, the tested plants showed an increase in ^{15}N-content. This was the case for both varieties, in all examined plant sections. In the leaf samples, enriched nitrogen could be detected even within just 24 hours from the time of fertilization.

At both locations, higher ^{15}N-contents could be detected in the middle and upper plant segments compared to the lower segments. In addition, the measurement values for the lateral shoots were generally higher than those for the main bine. This means that nitrogen applied at a relatively late point in time can increasingly be found in the younger, above-ground parts of the plant.

During the harvest, between 65-67% of the enriched nitrogen could be found in the above-ground parts of all plants in the test series, in both varieties, whereby the ^{15}N-recovery in Herkules was higher in the cones than in the rest of the plant. In Perle, by contrast, the recovery rate was roughly the same in the cones and the main bine (Figure 4.21).

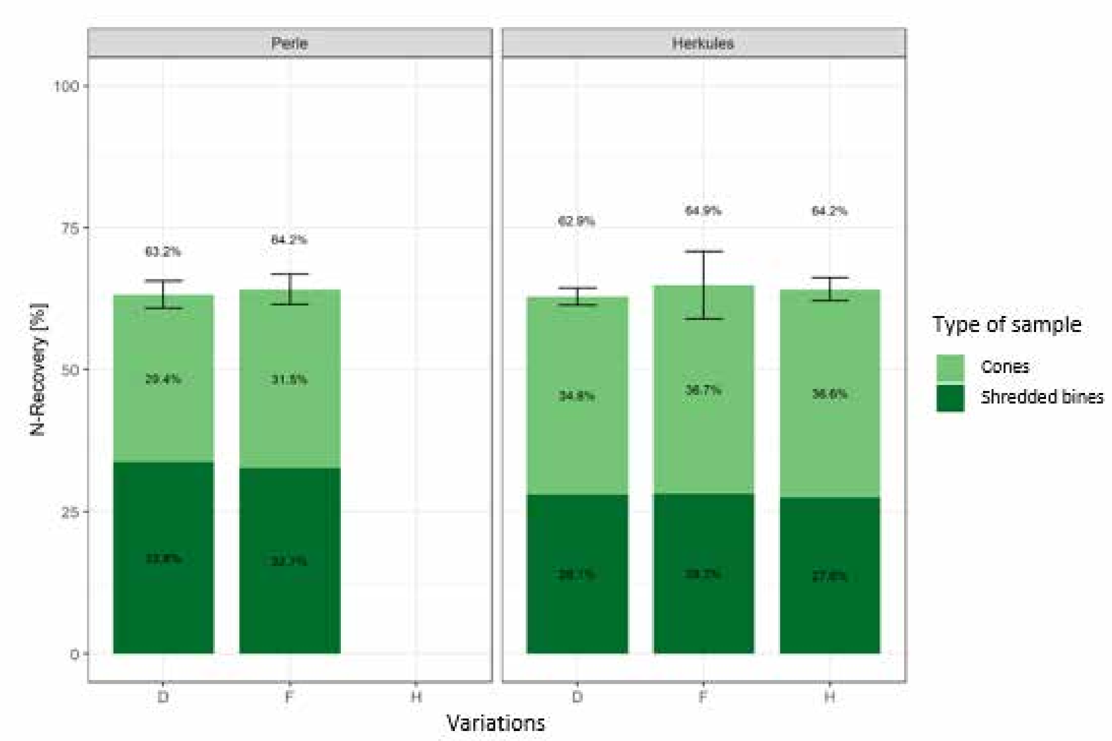

Figure 4.21: N-recovery [%] by cones, the rest of the plants, and the entire plants for both Perle and Herkules at the regular harvest date. The error bars represent the standard deviation of the total N-recovery by the cones and the rest of the plant

An examination of the roots revealed that they had elevated ^{15}N-levels regardless of which plant and variety. Because it was not possible to determine the dry root mass, no conclusion can be drawn about the exact N-efficiency through fertigation. Therefore, it remains uncertain which amounts of nutrients are stored in the below-ground parts of the plant.

4.8 LfL projects as part of the production and quality initiative

During the period from 2019 to 2023, the Bavarian State Research Center for Agriculture is collecting, recording, and assaying a certain number of agricultural products that are considered representative of agriculture in Bavaria. This is part of a production and quality initiative designed to generate yield and quality data. For the IPZ section working on hops, these activities are being carried out in conjunction with the association Hopfenring e.V. as a partner. Below is a summary of the objectives of the hop projects, as well as the results for 2020.

4.8.1 Dry matter and alpha acid monitoring

Between August 18 and September 29, 2020, several plants were harvested and dried separately at 10 commercial hop gardens spread across the Hallertau. Four of the sample plants were aroma varieties and two were bitter varieties. Aroma varieties were sampled five times in weekly intervals, while bitter varieties were sampled seven times, also in weekly intervals. After each harvest day, an accredited laboratory determined the green hops' dehydration level, amount of dry matter, and alpha acid content at a moisture level of 10%. This data then went to the LfL hop advisory service for evaluation. The results were averaged, prepared in tables and graphs, and posted with comments on the Internet. This information allowed farmers to determine in real time the optimum harvest maturity of the most important hop varieties.

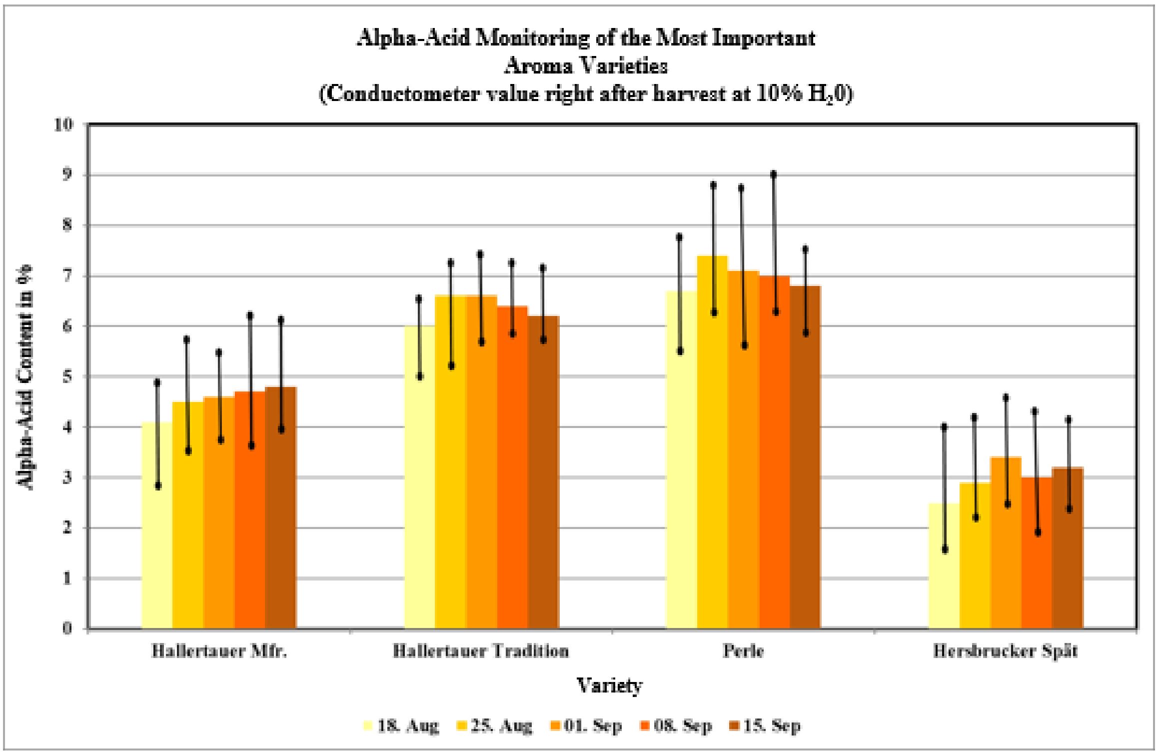

Figure 4.22: Monitoring of the development of the alpha acid content in 2020 of the most important aroma varieties

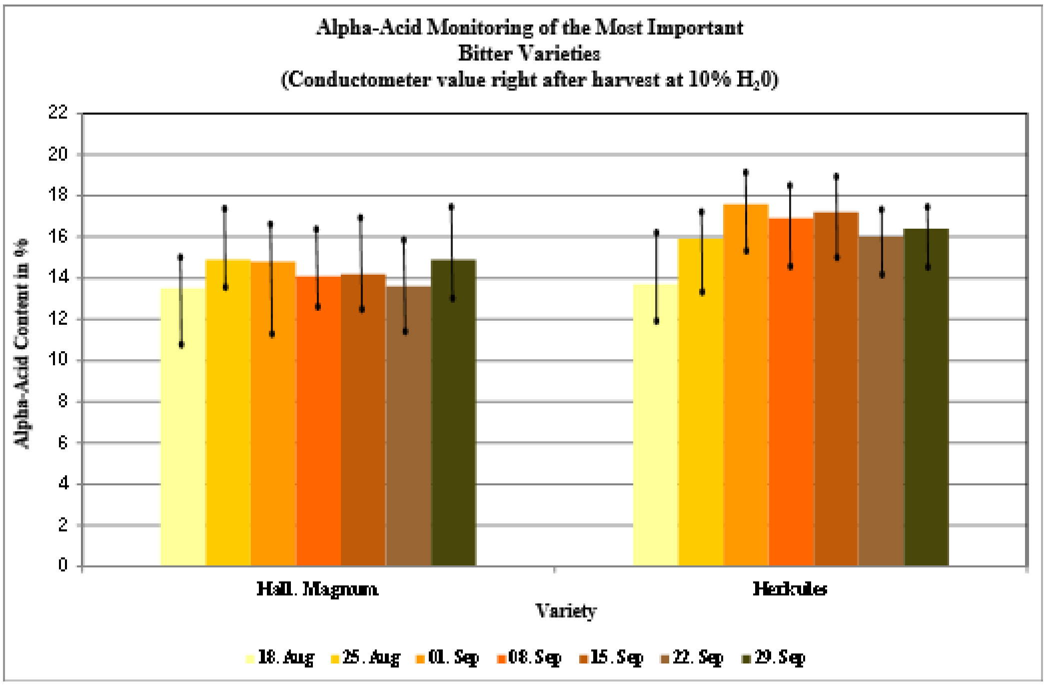

Figure 4.23: Monitoring of the development of the alpha acid content in 2020 of high alpha varieties

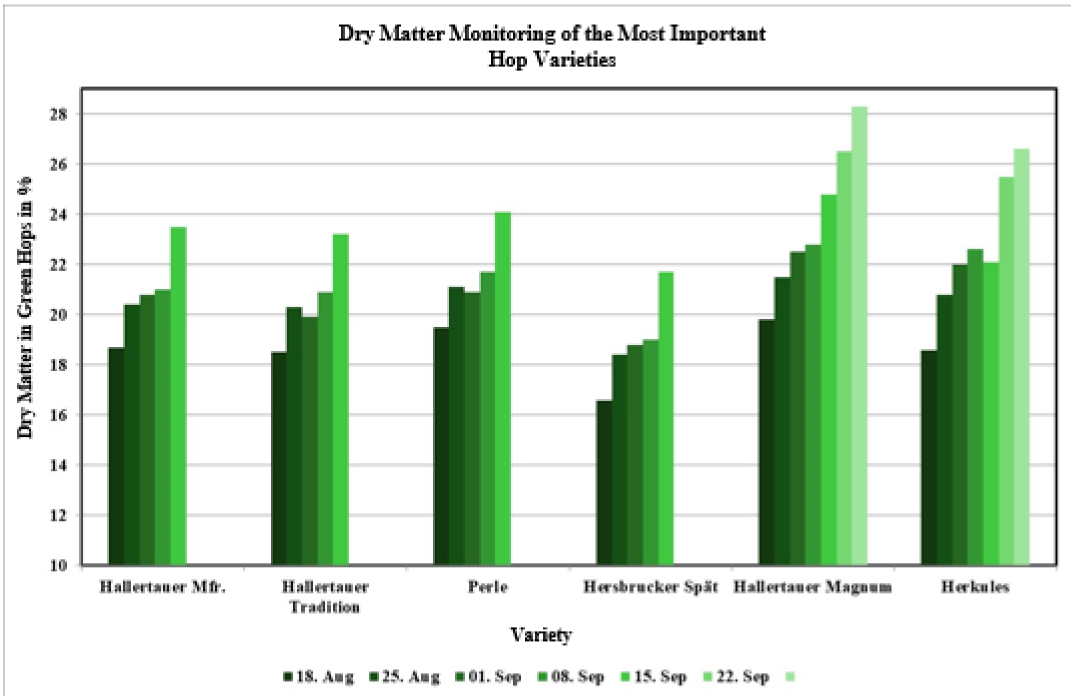

Figure 4.24: Monitoring the development of the dry matter content in 2020 of the most important hop varieties

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

To assess aphid and spider mite infestations, to formulate advice, and to determine control strategies for commercial hop gardens, it is necessary to survey the infestations and to assess their extent with precision.

Such assessments were made between May 18 and August 3, 2020 on 12 dates, in weekly intervals, at 33 representative hop gardens (including 3 organic ones), planted with different varieties. Twenty-three of these hop gardens were in the Hallertau, seven in Spalt, and three in Hersbruck. These gardens were tested for infestations with hop aphids and common spider mites. The raw data for aphids was averaged. For spider mites, it was transferred into a spider mite infestation index.

This summary data reflected the course of the infestations and served as the basis for advice to famers and for control strategies.

4.8.3 Chlorophyll measurements of hop leaves to assess the nitrogen supply and fertilizer requirement

Objectives

The new German Fertilizer Ordinance with its requirements and restrictions pose great challenges for hop growers. On the one hand, it is important to maintain high hop yield levels per hectare and to achieve optimal quality, while, on the other hand, the goals of water protection need to be pursued with consistency and vigor as well. For nitrogen fertilization, this means that the nitrogen has to be administered with ever greater precision in a targeted and nutrient-efficient manner. Because the main uptake period of nitrogen by hops is during June and July, it can happen that, in dry weather, nitrogen fertilizer is not dissolved or, in moist soils, is mineralized. Therefore, nitrogen supplies in the soil and the required amounts of fertilizer are sometimes difficult to estimate. Regular leaf examinations at different locations and for different varieties, however, can provide information about the nutritional status of hop plants, which, in turn, can contribute to pertinent advice about proper fertilizer strategies.

Method

From the end of May to mid-August, ten times a week, chlorophyll measurements were carried out with a “soil plant analysis development” meter (SPAD-502 plus) on hop leaves of two hop varieties at two different locations in the Hallertau. For a representative statement, 20 measurements per variety are gathered from several plants at two different heights. In order to draw conclusions about the current N-supply state, the 20 measured leaves must be collected, dried, and examined together for total N-content (Dumas method). For each variety and location, the SPAD values are recorded individually for each height and then entered into averaging calculations. In this way, the relationship between measured chlorophyll values and the actual N-contents can be examined using linear regression models.

In 2019, the chlorophyll measuring device was able to clearly identify N-supply differences in a mineral fertilizer experiment (see 2019 annual report).

In test year 2020, measurements were taken for the first time in field trials, as part of the project “Experiments on composting and recycling shredded hop bines.” The focus was on testing whether the analyzer instrument can detect N-supply differences caused, among other factors, by fertilization with shredded hop bines (Figure 4.25).

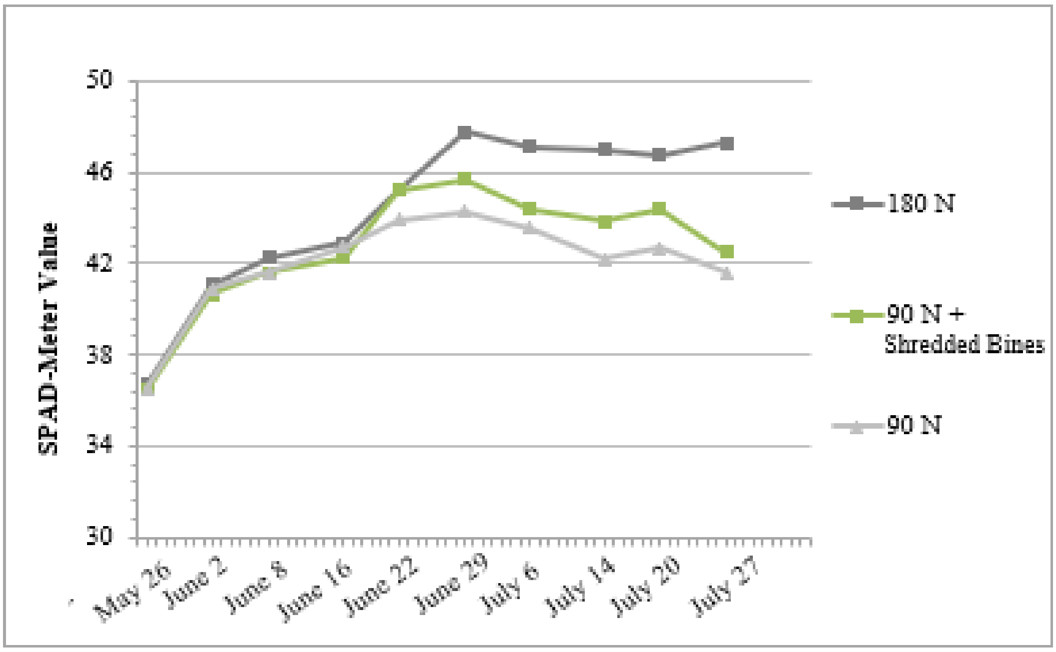

Figure 4.25: SPAD values over the course of 2020 for Herkules on an easy site with three fertilization levels: 180 N = 180 kg N-mineral; 90 N + shredded hop bines = 90 kg N mineral + 100 kg N-organic (shredded bines); and 90 N = 90 kg N-mineral (control)

4.8.4 Ring analyses for quality assurance in the determination of alpha acids for hop supply contracts

For years now, hop delivery contracts have included an appendix specifying that the alpha acid content of the delivered batch be taken into account in payments. Depending on available testing capacities, such determinations of alpha acid contents is carried out by laboratories operated by the state, by corporate laboratories, and by private laboratories. The procedure (sampling method, storage) is precisely defined in specifications issued by the “Working Group for Hop Analysis.” The Group also defines, which laboratories may conduct follow-up examinations and which tolerance ranges need to be adhered to in the results. To ensure the quality of alpha acid analyses in the interest of hop growers, the Bavarian State Institute for Agriculture as a neutral body organizes, executes, and evaluates ring analyses.

Within the scope of the project, it is the task of the Hopfenring to take samples from a total of 60 randomly selected batches of hops on nine or 10 dates, in the Hallertau, and make them available to the LfL laboratory in Hüll.

4.9 Advisory and training activities

In addition to applied research in the field of production technology in hop growing, the Hop Growing, Production Technology Working Group (IPZ 5a) is tasked with preparing the test results so they can be used in practice; and for giving uniform advice, for instance, via special consultations, lectures, working groups, training courses, seminars, print media, and the Internet. The organization and implementation of the downy mildew warning service and its updates are just as much a part of this tasks as is the cooperation with hop organizations or the training and technical support of the Hopfenring, its network partner.

The training and consulting activities of the past year are summarized below:

4.9.1 Information in print

- The “Green Booklet” *Hops 2020 - Cultivation, Varieties, Fertilization, Plant Protection, Harvest* was updated in collaboration with the Plant Protection Working Group and in coordination with the advisory centers of the states of Baden-Württemberg and Thuringia. The press run was 2,200 copies, which were distributed by the LfL, the ÄELF, and research institutions. The Hallertau Hopfenring also distributed it to hop growers.
- The 96-page LfL information leaflet *Drying and conditioning of hops* summarizes many years of test results and practical experience in the post-harvest treatment of hops in a comprehensive reference work. The producer association HVG made it available to all hop growers.
- The Hopfenring sent out 30 faxes of the latest hop growing instructions and LfL warnings to the hop growers. It used its ring fax list of 970 subscribers in 2020. Of these, 73 are in the Hallertau, Spalt, and Hersbruck.
- Additional publications include 2 Hopfenring circulars; 8 monthly issues of the Hopfen-Rundschau; and 4 articles in the Hopfenrundschau International. They dealt with advice and specialist topics for hop growers and the brewing industry.

4.9.2 Internet and Intranet

Hop growers could access the warning and advice service, as well as technical articles online.

4.9.3 Telephone advice, announcement services

- The *Peronospora* warning service was active between May 13 and August 31, 2020. It was offered by the Working Group Hop Growing in Wolnzach in collaboration with the Working Group Plant Protection in Hüll. Queries came in via the telephone answering machine (Phone: 08442 / 9257-60 and -61) and the Internet. The service was updated 75 times.
- The specialist advisors of the Hop Growing, Production Technology Working Group provided information by telephone to roughly 1,300 special questions relating to hop growing. They also offered advice in one-on-one meetings or on-site.

4.9.4 Lectures, conferences, guided tours, training, and meetings

- Weekly exchange of experiences among specialists during the growing season.
- 9 hop grower meetings in cooperation with the ÄELF.
- 27 specialist lectures.
- 8 conferences, specialist events, seminars or workshops

4.9.5 Basic and advanced training

- Preparing content for 4 work projects and 4 examinations as part of the master craftsman's examination process.
- 13 lessons at the Agricultural School in Pfaffenhofen for students in the field of hop cultivation.
- 1 school day as part of the summer semester of the Pfaffenhofen Agricultural School.
- 1 information event for Pfaffenhofen vocational school students.
- 3 meetings of the Working Group Hop Management.

5 Plant Protection in Hops

Simon Euringer, M.Sc. Agricultural Management

5.1 Pests and diseases of hops

5.1.1 Peronospora warning service 2020

During crop year 2020, a total of seven spraying campaigns against downy mildew secondary infections were necessary. In four of these, treatment of tolerant varieties was also required.

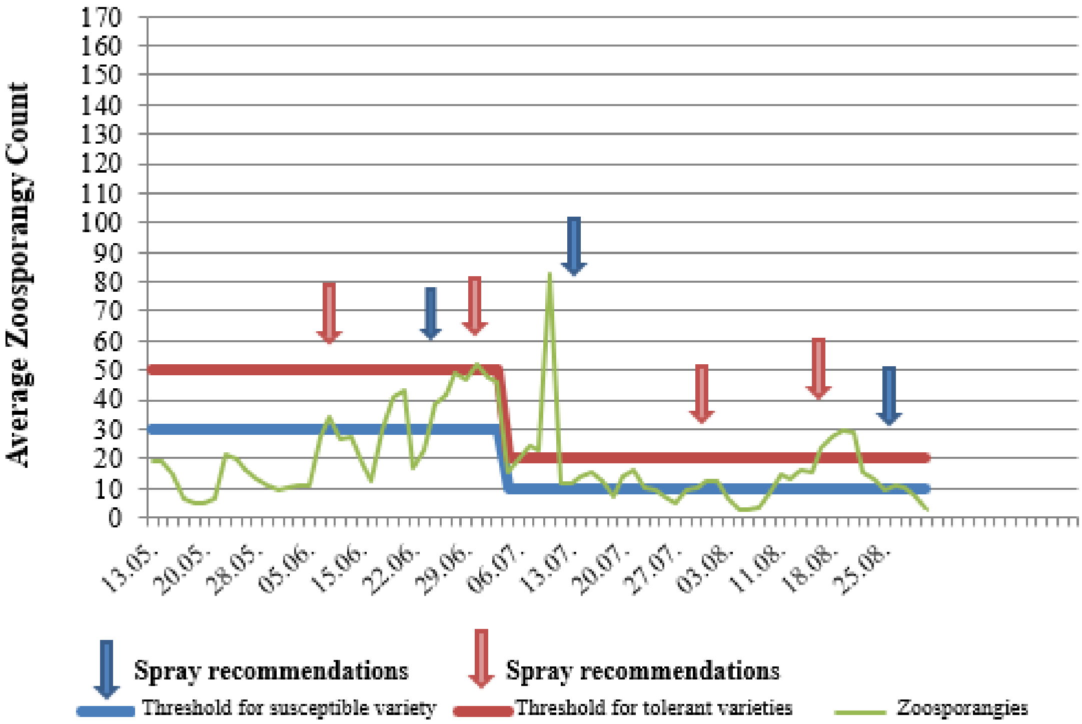

Figure 5.1: Representation of the Peronospora *warning service 2020 [Dates=dd/mm]*

5.1.2 Arrival of aphids in 2020

No peculiarities were found in the influx of aphids in 2020 at the Hüll site. The first aphids were discovered on winter crops in April. The influx increased by the end of May and then subsided by the middle of June.

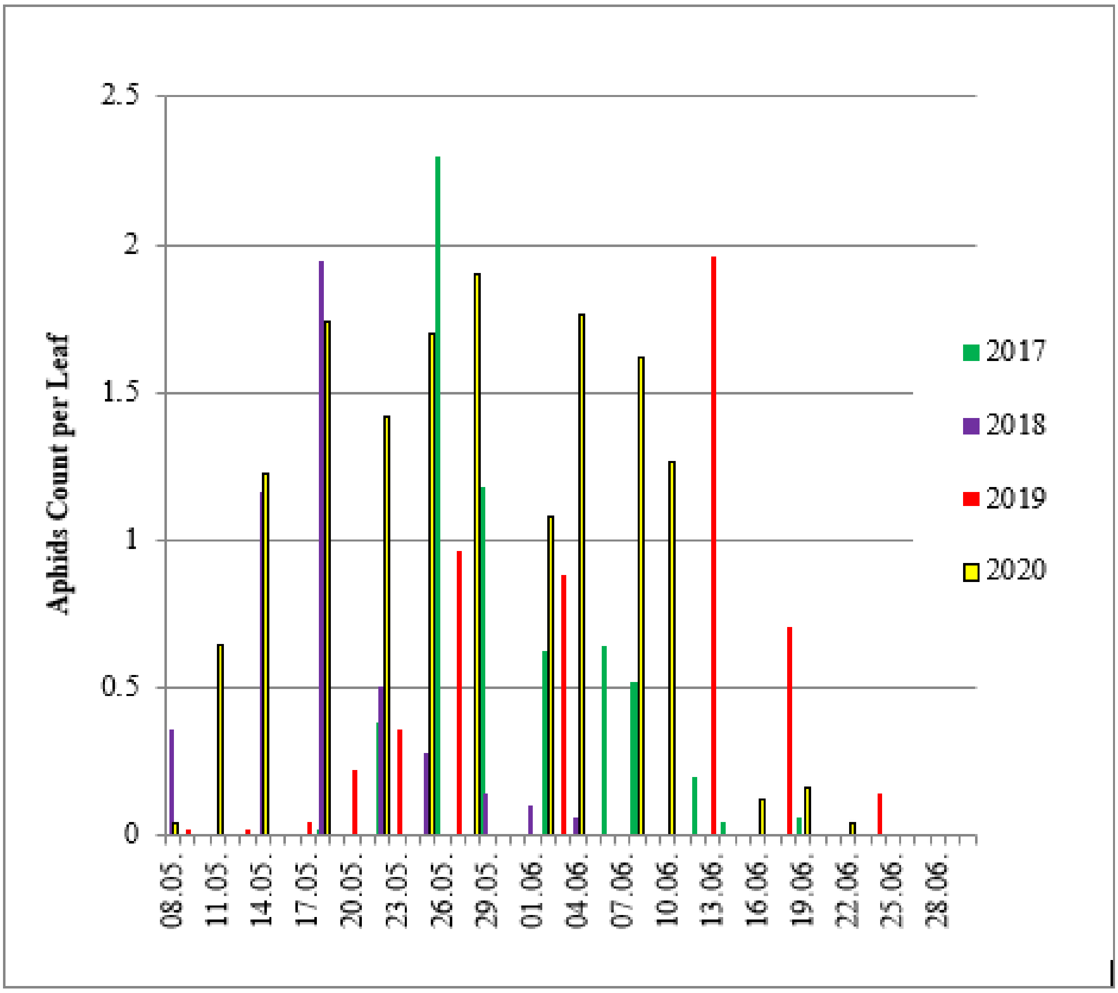

Figure 5.2: Aphids influx at the Hüll site in 2017-2020 [Dates=dd/mm]

5.2 GEP Quality Audits

Project Management: S. Euringer

Team: R. Obster, A. Baumgartner, M. Felsl, K. Kaindl
K. Lutz, M. Mühlbauer, M. Obermaier (IPZ 5e), J. Weiher

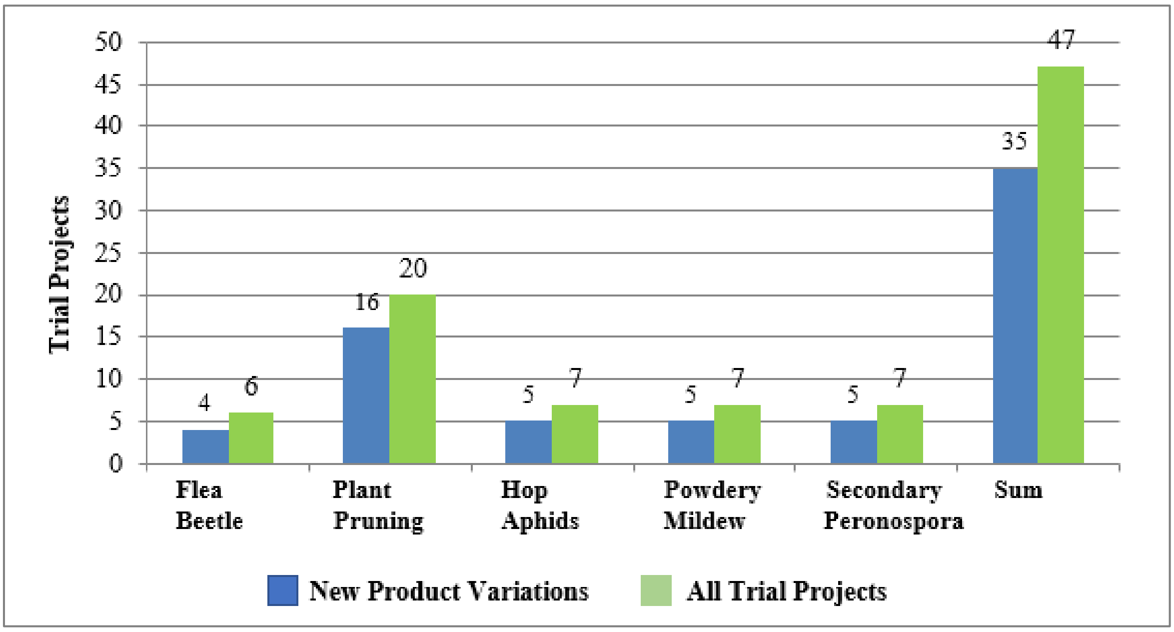

Figure 5.3: Official quality audits 2020

In crop year 2020, six AMP ("Amtliche Mittelprüfung") quality audits were conducted in accordance with GEP standards (Good Engineering Practices). Five issues were resolved. A total of 35 new products or combinations were audited in 47 project categories (Figure 5.3)

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

Project Management: S. Euringer

Team: A. Baumgartner, M. Felsl, M. Mühlbauer

The hop aphid attacks all hop varieties every year. The recent banning of important insecticides makes it much more difficult to alternate active ingredients to avoid resistance. Repeated use of the same active ingredient or active ingredients relying on the same mechanisms leads to a one-sided selection of harmful organisms. As a result, resistance develops and combating the harmful organism is no longer successfully. Therefore, current and new active ingredients with regard to resistance to hop aphids are tested in spray tower tests. The results from these tests can vary greatly from results in real-world applications, depending on the active ingredient. Therefore, the results are not published. In 2020, 15 active ingredients were used in each of seven concentrations.

5.4 Enzyme-linked Immunosorbent Assay (ELISA) for the identification of Hop Mosaic Virus (HpMV) and Apple Mosaic Virus (ApMV) Infections in Hops

Project Management: S. Euringer

Team: M. Mühlbauer, M. Felsl, O. Ehrenstraßer

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

Table 5.1: Results of ELISA tests in 2020

	Investigation of Plant Material in 2020						
	Total Number of Plants	ApMV		HpMV		Sum	
		n.d.	positive	n.d.	positive	n.d.	positive
Female plants for hop Part 2	150	149	1	141	9	141	9
Breeding material IPZ 5c	511	497	14	501	10	487	24
	Investigation of Plant Material in 2021						
Female plants for hop Part 1	258	258	0	256	2	256	2
Breeding material IPZ 5c	Spring 2021						

* n.d. = not detectable

Samples showing results close to the detection limit are counted as positives. This minimizes the risk of potentially infected material entering the propagation stream.

Of 919 plants tested, 35 were discarded. The healthy plants were made available to hop breeders as breeding material and as mother plants (Table 5.1).

5.5 GfH-Project in Research

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

Financing: Förderung aus Mitteln der Gesellschaft für Hopfenforschung (GfH)
(*Supported by the Society for Hop Research*)

Project Management: S. Euringer

Team: K. Lutz, Team IPZ 5b

Collaboration: AG Züchtungsforschung Hopfen (IPZ 5c):
(*WG Breeding Research*):
Dr. E. Seigner, P. Hager, R. Enders, A. Lutz, J. Kneidl
Dr. S. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia

Duration: June 1, 2017 to October 29, 2023

Objectives

Since the first appearance of lethal strains of *Verticillium nonalfalfae*, we have been able to observe a continuously increasing spread of the infestation of this aggressive, wilt-causing agent in the hop growing region of the Hallertau. The pathogen is a fungus that lives in the soils of a wide range of hosts where it can survive in the form of a permanent mycelium for up to 5 years. There are no direct countermeasures against it. To manage the disease infestation, therefore, requires an integrated approach consisting of sanitary measures, breeding efforts, adaptation of cultivation technologies, and remedial concepts. A rapid dissemination of new knowledge serves to help hop growers with the implementation of management measures in infested plots and contributes to recovery work as quickly as possible.

Method

Surveys of practices at hop farms with wilting problems are intended to generate data that can lead to effective cultivation-technical measures that can be implemented in practice to prevent and reduce attacks of this fungus. The recovery of infested plots needs to be supervised scientifically in order to develop innovative approaches for optimizing soil remediation. In addition, there is a need to develop and optimize existing detection and analysis methods for the pathogen. One approach is to use eggplants as sensitive indicator plants. This biotest allows for an assessment of the effects of recovery measures, the infection potential of soils and shredded hop bines, and the effects of such individual parameters as the nutrient supply on the course of the disease.

Collaboration with commercial hop farms

This year, 606 hop samples, corresponding to 2,822 PCRs (polymerase chain reactions) were analyzed for *Verticillium* using real-time PCR in addition to visual assays in the field. These samples came from the breeding garden in Hüll and from gardens used for selections in Niederlauterbach, Engelbrechtsmünster, and Gebrontshausen, as well as from 147 plots from 43 commercial farms. These analyses are carried out by AG Züchtungsforschung (*Work Group Breeding Research*) (see 6.7). They are indispensable for validating the visual assays.

The results generated by the qPRC analyses confirmed that the spread of lethal *Verticillium* strains is on the rise, as is especially noticeable in the analyzed plot, which was purposefully selected for its likelihood of being infected. However, the study confirms the increasingly aggressive nature of the fungus. A probable explanation is the lack of remediation, as well as the cultivation of increasingly tolerant varieties, which, in turn, amounts to a selection of the fungus. The less tolerant varieties have been replaced by new tolerant varieties and are therefore increasingly rare to find in hop gardens.

Niederlauterbach selection garden

In the selection gardens, the cultivated varieties and breeding lines are checked for wilt tolerance. These plots are verifiably infested with the lethal form of the wilt and were selected for analyzed that purpose. In the 2020 season, the breeding material was tested at three locations in the Hallertau.

Starting in mid-May, assessments are scheduled every two weeks. Each bine is checked and evaluated for typical wilting symptoms. At the end of the season, each variety is ranked on a wilt index. The ranking indicates the resistance of the different varieties and breeding lines to hop wilt. This tolerance can vary slightly within each variety depending on the location and the year in which it was planted. This, in turn, forms the basis for further research and breeding work.

In the spring of 2015, some 37 varieties or breeding lines were planted in three-fold repetitions in the Niederlauterbach selection plot. In 2016, the hop garden was expanded to include an additional 14 varieties and breeding lines. As a result, not all evaluation results obtained in the selection plots can be compared directly with one another. While 2015 was an unfavorable year for young hops because of the weather, the hops planted in 2016 were able to better establish themselves in the first season and usually show the wilting symptoms later and to a lesser extent.

After the 2020 season, the hop garden in Niederlauterbach was cleared because the five-year wilt test at this location was complete. Table 5.2 shows a portion of the results of this evaluation. To better compare the different years and locations, Herkules, a variety that is considered wilt tolerant, was chosen as the reference. After each season, it is assigned a withering index of 1.0. All other varieties and breeding lines are then assessed in relation to this reference. If a variety has a wilt index of less than 1.0, it has a greater *Verticillium* tolerance than the reference variety, Herkules, at this location in this year.

Table 5.2: Evaluation of the Niederlauterbach selection garden for 2017, 2019, and 2020; the table shows the wilt tolerance of the individual varieties in relation to the tolerant reference variety, Herkules, the rating of which is set at 1.0. Varieties with a value smaller than or equal to 1.0 have good Verticillium tolerance and are marked in green.

Variety	Reference 2017	Reference 2019	Reference 2020
Northern Brewer	5.0	*	*
Hallertauer Mittelfrüh	4.5	*	*
Hallertauer Tradition	3.8	*	*
Hallertauer Magnum	1.2	1.9	1.6
Herkules	1.0	1.0	1.0
Polaris	0.3	1.0	0.4
Target	0.3	1.0	0.5
Callista	2.0	1.9	1.8
Ariana	0.2	0.7	0.3
Cascade	0.2	1.3	0.6
Mandarina Bavaria	0.3	1.0	1.1
Hallertauer Blanc	0.7	1.8	0.9
Hüll Melon	0.2	1.2	0.4
Opal	0.3	1.3	1.3
Smaragd	0.8	2.2	2.4
Spalter Select	1.5	2.9	2.2

* Plowed under after severe infestations in the fall of 2018

Outlook

The testing of varieties and breeding lines for their *Verticillium* tolerance should be continued. Assaying of the two selection gardens in Engelbrechtsmünster and Gebrontshausen will also take place in the 2021 growing season. However, the assays in Gebrontshausen will have true significance only after 2021, because the plants there were too young in 2020. Furthermore, a few new varieties will be planted there as well. This serves as an early collection of data, which, in turn, can influence the direction of future breeding projects.

The new Gebrontshausen selection garden was put in place in the spring of 2020. Starting in the 2021 season, it will replace the Niederlauterbach selection garden as a location for testing in heavy soils. The facility not only has room for 26 test varieties with three repeat plantings each, but also for a remediation test, an intermediate crop experiment, and experiments for identifying the effectiveness of various pesticides against hop wilt. Valid results from these tests are expected to be available after the 2022 season, at the earliest.

Remediation attempts

As part of the research within the *Verticillium* wilt project, there will be tests and the development of practical methods for restoring hop gardens that are infested with *Verticillium*. Therefore, a remediation attempt was started in a hop garden near Engelbrechtsmünster. The area was cleared and plowed under in the fall autumn 2016 and then left fallow.

In some parcels, rye or rye and corn have been planted as crop rotations since 2017. In the spring of 2020, the hop garden was again planted with the wilt-susceptible variety Hallertauer Tradition. The purpose was to assess the influence of remedial measures on infection pressures.

In the 2021 growing season, the remediation tests are being expanded to include additional plots; and these tests will be supervised scientifically until the end of 2023.

A bio-test using eggplants as indicator plants: thermal hygienization of shredded bines

The eggplant (*Solanum melongena L.*) is a suitable indicator plant for hop wilt because it is very susceptible to this pathogen. It is also suitable for growing in a pot system in the greenhouse; and it quickly develops the typical wilting symptoms. With the help of eggplants, therefore, potential sanitary measures can be tested quickly for their effectiveness against the *Verticillium* fungus and its diverse variants.

With the help of repeated tests, using the eggplant biotest, it was possible to confirm that a four-week period of hotrot composting reduces the infection potential of shredded bines significantly. For an effective thermophilic sanitizing of shredded bines, it is important to turn the pile over so that the outer layers can be brought into the warmer core area. In addition, before any application in the field, the full rest period should be observed when working with susceptible varieties. Also, the requirements of the Fertilizer Ordinance must be observed.

Figure 5.4 shows the temperature curves of a hotrot compost pile in 2020. The variations in the data are the result of different lengths of the shreds and their degree of compaction. During a long rest period at high temperatures, the fungus decomposes sufficiently, which reduces its potential for infection significantly.

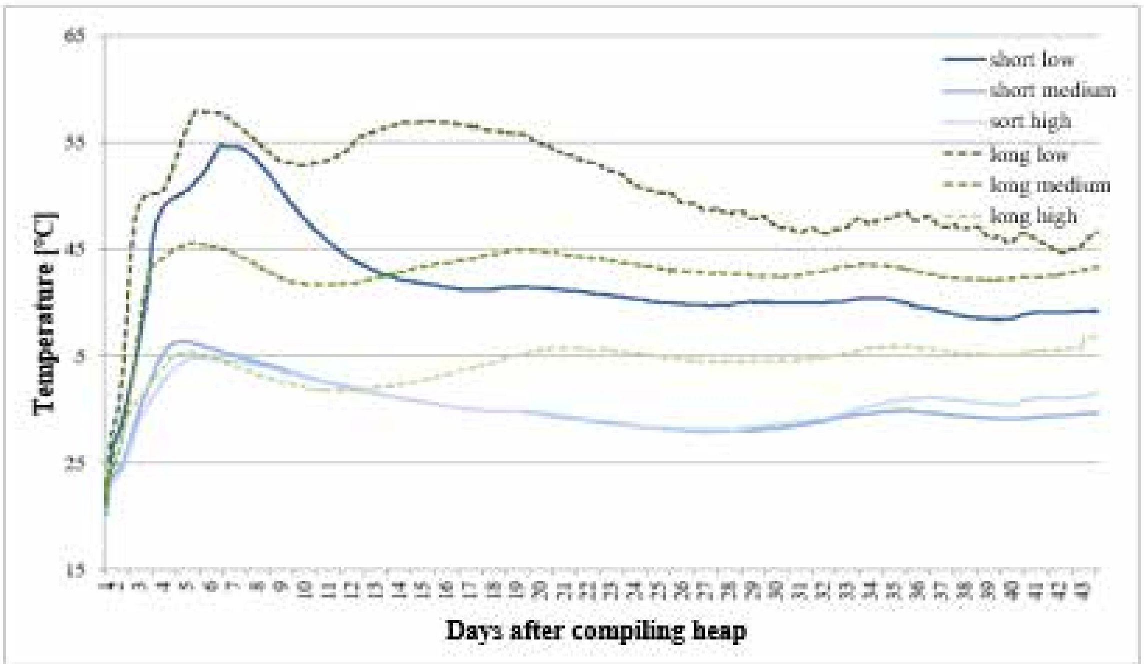

Figure 5.4: Temperature profile of bine shreds after four weeks in compost heaps of the HSWT in Freising; different length of the bine shreds (short/long) and compaction of the compost heaps (low/medium/high) influence the temperature profile of the hotrot

Remote sensing as an objective means of assessing spread in hop gardens

Assessing the efficacy of measures against *Verticillium* wilt requires objective observations over a period of several years. Because testing individual plants is very time consuming, remote sensing is a potentially useful alternative. Drones offer the possibility of monitoring individual plots. To assess the spread of *Verticillium* across the Hallertau, for the years 2106 and 2018, an infestation map of the entire growing region was created with the help of aerial imaging by BayernAtlasPlus, an online application of the Bavarian Surveying Administration. A well-advanced infestation with *Verticillium* can be identified by aerial photography as irregularities in hop gardens. A diagnosis that there are no problems requires a confirmation through an inspection and the collection of samples on location. The photographs from May 2020 proved unsuitable for an update of the map, because it was too early for the *Verticillium* damage to be visible. To obtain a better impression of the spread of *Verticillium*, significantly more plots than usual were sampled in the 2020 season. They were evaluated in the breeding group's laboratory using a qPCR analysis. The infestation map for 2020 was subsequently drawn up based on this data.

Biological soil disinfestation as a possible alternative remedial measure

One possible remedial measure is biological anaerobic soil disinfestation. It involves using anaerobic microorganisms that live in the soil, as well as adding protein-containing preparations to it. This combination deprives the *Verticillium* fungus of oxygen and leads to its gradual degradation. To disinfect a hop garden quickly, a protein-rich granulate is worked into the soil in the summer. Then, the surface is soaked with water and covered with a special foil as an oxygen barrier. The objective is to reduce the oxygen content in the soil underneath the foil by as much as possible (<3%) to obtain promising results. This promotes the break-down of fungi by anaerobic microorganisms in about four to six weeks. In addition, the fungus itself is harmed by the anaerobic conditions, as well as by the high temperatures that develop under the foil.

Such a decontamination was carried out in an experimental garden at Bruckbach, in the summer of 2018. The plot was planted with Hallertauer Tradition in the spring of 2019. As a reference, a plot directly adjacent was planted with the *Verticillium*-susceptible variety Hallertauer Mittelfrüh, as well as the *Verticillium*-tolerant variety Herkules. Furthermore, rye was sown on part of the plot for a year. An additional plot was covered with foil but without any granulate to carry out soil solarization.

In 2019, four other locations in the Hallertau were also subjected to this same disinfection measure. This part of the project was carried out in cooperation with Hopsteiner. The hop gardens were replanted in the spring of 2020. All locations will be subject to intensive visual assessments over the next few years.

Outlook

Should the investigated method for quick, efficient, and successful disinfestation of hop garden segments prove successful, further tests for commercial applications must follow. In the experiments conducted thus far, attention was paid to the effectiveness rather than the economics of the procedure of biological disinfestation. Even though hop cultivation can resume within just one vegetation period after treatment, the purchase of granules and foil and the involved application do represent substantial costs to the farmer. In the future, therefore, the amount of granulate should be reduced to avoid unnecessary costs for farmers using this disinfestation method.

5.6 CBCVd-Monitoring 2020

Sponsor: Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung

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

Financing: Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (StMELF)

(The Bavarian State Ministry for Food, Agriculture and Forestry)

Erzeugergemeinschaft HVG

(*Hop Producers Group)*

Project Management: S. Euringer, Dr. D. Kaemmerer (IPS 4b)

Team: IPZ 5b, IPZ 5a, IPS 4b, IPS 2c

Sampling Period: 06.2020 to 09.2020

In the 2020 crop year, CBCVd monitoring was carried out in all German cultivation areas. The implementation and intensity of the measures were adapted to the size of the cultivation area and to local conditions. No infestation was found in Spalt, Tettnang, Elbe-Saale. The results of the Bavarian CBCVd Monitoring 2020 are presented below.

Table 5.3: Classification of CBCVd-Monitoring, 2020

Classification of CBCVd-Monitoring, 2020		Plots	Samples	Farms
Monitoring of cultivation regions with infestations	Risk-based	422	~ 1760	
	Grid	117		
	Sum	539		
HVG Biogas monitoring		65	195	
Voluntary Monitoring (HVG)		~ 15	~ 45	
Plots of newly infested farms (2020)		~ 40	~ 300	
Sum		~ 656	~ 2300	~ 400

Table 5.4: Classification of CBCVd-Monitoring, 2020

Farms	Infected Region	Infection Detected [Year]	Severity of Infection
5	Hallertau Central	2019	Low to very high
1	Hallertau South 1	2020	High
1	Hallertau South 2	2020	Low

The following findings were generated by CBCVd-Monitoring in 2020:

- Despite a risk-based approach and a massive effort, “only” four additional farms in Hallertau is not (yet) contaminated!
- The severity of the infestation in the farms affected ranges from low to high
- Within a farm, the spread (without a mitigation concept) can progress very quickly

- There is less transmission between neighboring fields from two different farms (requirement: no shared use of machines; no exchange of planting material)
- High uncertainty in plots that tested negative but belonged to infested farms
- There is evidence that infections with CBCVd have existed for years in the Hallertau cultivation region
- Heterogeneous conditions (soil, cultivation, variety) make visual assessments more difficult. Therefore, laboratory tests are mandatory.

Outlook 2021

- Development and implementation of the CBCVd criteria for a clean pass
- Monitoring will continue in 2021 and 2022

The Hop Research Center Hüll (LfL IPZ) is supported financially and in terms of its personnel by StMELF, LfL IPS, GfH e.V. and the producer group HVG e.G.

Other research activities and official audits are only marginally affected.

6 Hop Breeding Research

Bureau Director (RDin) Dr. Elisabeth Seigner, Dipl.-Biol.

The Hop Research Center in Hüll develops modern, high-performance varieties that meet the requirements of the brewing and hop processing industries. Our work is guided by the following objectives:

- The development of classic aroma varieties with fine hop-typical aroma characteristics.
- The breeding of aroma varieties with broad brewing potential and significantly increased climate tolerance and efficiency in nutrient uptake.
- The creation of robust, high-performance, high alpha varieties.
- Development of bio-technological and genome-analytical techniques that have been part of the classic breeding program in Hüll for years.

6.1 2020 crosses

In 2020, the Center created a total of 95 crosses.

6.2 Aurum – “Green gold” from Hüll for hop growers and brewers

Management:	A. Lutz, Dr. E. Seigner
Team:	A. Lutz, J. Kneidl, Dr. E. Seigner, Team IPZ 5c
Collaboration:	Dr. K. Kammhuber, Team IPZ 5d
	Beratungsgremium der GfH *(Society of Hop Research Advisory Committee)*
	Forschungsbrauerei Weihenstephan, Technische Universität München-Weihenstephan, Lehrstuhl für Getränke- und Brau-technologie (Prof. Becker, Ch. Neugrodda) *(Research Brewery Weihenstephan, Munich Technical University, Chair of Beverage and Brewing Technology)*
	Versuchsbrauerei *(Pilot Brewery)* Bitburger-Braugruppe, Dr. S. Hanke
	Versuchsbrauerei *(Pilot Brewery)* St. Johann, A. Gahr
	National and international brewing partners
	Partners in hop processing and the hop trade
	Verband Deutscher Hopfenpflanzer *(Association of German Hop Growers)*
	Hop growers

Aurum is the latest „noble“ hop variety from the Hop Research Center in Hüll. It has a subtle, very fine hop aroma, “placed” into the cones by its mother, Tettnanger. It provides classic beers with their much-valued hoppy-spicy aroma and taste. In cultivation, Aurum impresses above all with its improved plant health and increased climate tolerance, as well as higher and more stable yields compared to its progenitors.

In creating this new aroma variety, the former Hüll hop breeder Herbert Ehrmaier succeeded in an ideal fashion in combining both top-quality hop aromas and competitive and environmentally friendly characteristics. During several years of cultivation trials in LfL-owned test plots, as well as commercial plots, the new variety demonstrated its increased agronomic performance, as well as its broader disease resistance, even under climatic stress conditions.

Large-scale cultivation trials in various commercial plots have been conducted since 2016. They further confirmed the breeding advances and suitability of the new aroma variety in the real world.

These large-scale trials took place on many hectares, where they yielded plenty of hops for brewing trials. This, in turn, allowed the Hüll center to gain extensive experience with the new crop.

Table 6.1: Agronomic characteristics and key brewing compounds of Aurum

Yield potential	2,000 kg/ha. This yield approaches the level, for instance, of Hallertauer Tradition, and is, thus, significantly higher than that of comparable landraces from the same region.
Resistance/tolerances	Medium resistance or tolerance to diseases and pests
Stress and climate tolerance	No early flowering, medium
Maturity	Medium early
Alpha acids (%)	5 (4 – 7)
Beta acids (%)	6 (5 – 8)
Cohumulone (as % of alpha acids)	20 (18 – 22)
Xanthohumol (%)	0.4 (0.3 – 0.6)
Total oil (ml/100g)	1.7 (1.4 – 2.0)
Farnesene (mg/100g)	< 10
Linalool (mg/100g)	12

Figure 6.1 The new Hüll aroma variety Aurum – cones and cross-section of cone

Hop aroma in the beer

When rubbing the cones, Aurum develops a particularly fine, classic hop aroma, which is characterized by hoppy and herbaceous aromas accompanied by nuances of fresh citrus. Brewing trials with Aurum revealed its impressively strong aromatic potential, which can be attributed to the high content of essential oils. Linalool, in particular, as a key aroma component, gives the beer a classic hop aroma.

Depending on the timing and the amount of hop additions, Aurum develops a range of hoppy-spicy to subtle citrus-fresh aromas, as well as a fine, pleasantly mild bitterness.

Fig.6.2: Aroma profile of Aurum hop cones

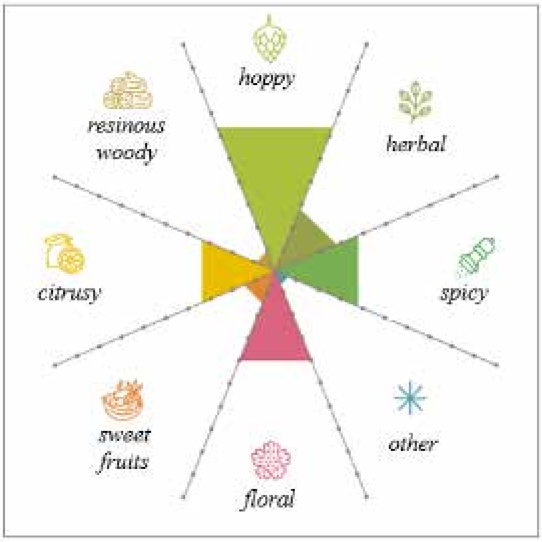

Fig.6.3: Aroma profile of Aurum in beer

References

Seigner, E., Lutz, A., Kammhuber, K and König, W. (2020): Aurum – Grünes Gold für klassische Bierstile. Brauwelt –Wissen Rohstoffe Nr. 46-47, 1232-1235.

Gesellschaft für Hopfenforschung und Bayerische Landesanstalt für Landwirtschaft (2020): Aurum - Feinwürziger Hüller Aromahopfen der Extraklasse.

Flyer: https://www.hopfenforschung.de/sorte/aurum/

6.3 Crossbreeding with the Tettnanger landrace

Objectives

The local variety Tettnanger with its fine, spicy hop aroma is still very popular with brewers who value classic beer aromas. However, because of the Tettenanger variety's lower yield per ha, rather unstable alpha acid levels, early flowering as a result of rising temperatures (Mozny et al., 2009), and lower disease resistance, the cultivation of this terroir variety is becoming more and more difficult for growers, especially from an economic perspective. During the last decade, there have been purely selective breeding attempts within the natural variability of this landrace, but they did not produce clear improvements.

This was the reason for the start of a crossbreeding program in 2011. The goal was to develop a variety that would be very similar to the original by exhibiting its typical aroma expressions, but with significantly improved yields, greater resistance to fungi, and the ability to adapt to climate change, especially by not flowering too early during stretches of higher temperatures. In addition, a modern variety must optimize its nutrient uptake efficiency, which is also required by the new Fertilizer Ordinance. To achieve all these objectives and improvements in a single cross with Tettnanger as the mother while maintaining the Tettnanger aroma, was obviously not easy.

Method

- Classic crosses with Tettnanger and preselected Hüll aroma lines
- Mildew resistance testing in the greenhouse and laboratory (see 6.5)
- Seedling tests (single plants) in the greenhouse
- Cultivation trials with reduced use of pesticides and fertilizers
  - Three-year cultivation test in Hüll
  - Four years of repeated confirmation trials at two locations in the Hallertau and in Tettnang
- Chemical analysis of cone compounds (IPZ 5d)
- Organoleptic flavor assessments by the breeding team and with the support of the GfH expert committee
- Virus testing using DASELISA (Double Antibody Sandwich Enzyme Linked Immunosorbent Assay) technology (IPZ 5b und IPS 2c, Seigner et al., 2014)
- Tests for *Verticillium* infestation using real-time PCR technique (Maurer et al., 2013; Seigner et al., 2017; see 6.7)..
- Pathogen elimination via meristem culture (Seigner et al., 2017; see 6.8.)

Result

Seedling testing

Since 2010, a total of 41 targeted crosses have been produced. More than 1,600 seedlings raised in a greenhouse were pre-selected for disease resistance and then planted in the breeding garden in Hüll, where they were tested over a three-year period.

Thanks to the minimal use of pesticides and the reduced use of nitrogen in the cultivation tests with seedlings and plants in the breeding gardens, the most robust, resistant and nutrient-efficient candidates were selected.

Plant evaluations

Eleven promising seedlings were then grown twice over a period of 4 years at two locations in the Hallertau and nine seedlings from this small selection were also tested in the trial farm in Straß. Unfortunately, of the total of 20 trials from 2015, 2016, and 2017 not a single one produced convincing results, neither in the Hallertau nor in Straß/Tettnang. There were several reasons: early flowering, too low/fluctuating alpha acid levels, downy mildew or wilting susceptibility, and others. Therefore, these plants were or will be cleared.

Since 2019, five strains have been cultivated in the 4-year test phase in the Hallertau. In addition, three of the most promising strains were planted in Straß, in 2020. Now, at the end of the project, early results from the three locations are available. Two strains are currently judged to be particularly promising. With their fine aroma and slightly increased bitter acid content as well as their positive agronomic properties, these two breeding lines come close to the breeding goals set at the beginning of the project. However, reliable prognoses about their vigor, yield, resistance, compounds, and aromas will be available only in two to three years.

Another six seedlings were selected after the 2019 seedling harvest (individual results from 2 harvests) as candidates for the 2020 and 2021 plant evaluation. After confirming their virus- and *Verticillium*-free status, the seedlings were propagated. Three breeding lines were planted in succession in the Hallertau at the Hüll and Stadelhof locations; the other three are being tested in 2021. In Straß, only the most promising candidates will be accepted for the examination phase in 2021 and 2022.

Outlook

Even though the funding of this breeding project ended on December 31, 2020, the most promising breeding lines should still be evaluated in further tests.

After the examination phase, the main test will follow, when a strain must prove itself in plot tests on commercial farms (row cultivation and large-scale experimental cultivation). There are currently no practical cultivation attempts with promising candidates. The first new breeds from this crossbreeding program can be expected to start in row cultivation trials in 2023/2024 at the earliest.

Economic and breeding significance of the project results

The aim of this project was to develop powerful and at the same time climate-tolerant and thus stable aroma breeding lines that were adapted to the special growing conditions of the Tettnang hop-growing region.

Future, modern flavor varieties with a Tettnanger flavor profile should ensure the long-term competitiveness of hops grown in the Tettnang region in world markets. But they must exhibit all the advantages sought in the project objectives: more stable alpha acid yields, broad disease resistance, especially improved powdery mildew resistance, climate tolerance, and nitrogen uptake efficiency. At the same time, these varieties should also allow for more environmentally friendly and cost-effective production methods with less use of pesticides and fertilizers.

Within the funding period 2011-2020, not all of the breeding goals could be achieved by arriving at promising strains. To repeat, realizing all relevant improvements in a single cross, using Tettnanger as the mother, while maintaining the typical Tettnanger aroma, is a challenging task.

However, the new aroma varieties Diamant (Lutz et al., 2019) and Aurum (Seigner et al., 2020), which are derived from earlier Hüll breeding programs and which are direct descendants of the terroir varieties Spalter and Tettnanger, respectively, demonstrate that such significant improvements as yield increase, no early flowering, doubled oil content, and better disease resistance, are possible.

Even though none of the new aroma varieties developed thus far with a Tettnanger background and based on this research project meet all economic objectives, they nonetheless represent decisive breeding advances for individual strains. In our tests under the extreme climatic conditions of recent years, we have selected the most robust strains that can cope with higher spring temperatures, extreme hot and dry spells in the summer, and receiving only two-thirds of the conventional amount of nitrogen fertilizers. Furthermore, the strains were tested under high *Verticillium* wilt and particularly high powdery mildew infection pressures. This has allowed us to continue our work with only the best seedlings or strains. Thus, we have created valuable genetic resources for our future aroma breeding in Hüll.

It should also be pointed out that this project has resulted in a very fruitful cooperation between Bavaria and Baden-Württemberg in the field of hop breeding. Since 2011, eight new Hüll aroma varieties, one new high alpha variety, as well as three aroma and four high alpha strains with a very high potential for success have been tested in serial cultivations at the trial farm in Straß. They are all products of the current hop breeding programs of the LfL. Straß has proven to be a meaningful test site in the development of new hop varieties, because it ensures that they are suitable also for cultivation in the Tettnang hop-growing region. This aspect is becoming increasingly important for growers in Tettnang because in 2020, Hüll cultivars will be planted in Tettnang on more than 600 ha, of which 301 ha are devoted to aroma varieties and 302 ha to high alpha varieties. This amounts to 40.8% of the total hop acreage cultivated in the Tettnanger region.

Keywords: Tettnanger substitute, aroma quality, resistance, climate adaptation, competitive production, breeding cooperation between Bavaria and Baden-Württemberg

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6.4 Development of healthy, high-performance hops with high alpha acid content and particular suitability for cultivation in the Elbe-Saale region

Initial Situation

The Elbe-Saale hop growing region covers 1,550 ha, which amounts to 7.6% of the total German hop growing area. The region thus makes a significant contribution to Germany's role in the world hop markets. Bitter and high alpha varieties dominate in the region. For the past 25 years, the main variety there has been the robust, high alpha Hallertauer Magnum. Yet, in more recent times, the share of the cultivation area devoted to Magnum has decreased from 65% to 39.8%, while the range of other varieties has expanded noticeably. Part of the reason for the decline of Magnum is its alpha acid yield of only 280 kg/ha. This is no longer competitive with yields of the Hüll-bred high alpha variety Herkules, which can produce more than 500 kg/ha of alpha acids. However, simply switching from Magnum to Herkules has not been successful in the Elbe-Saale region, because, in that region, Herkules is highly susceptible to crown rot.

Objectives

This project is designed to breed and test new, powerful and robust hop strains that can be cultivated economically under the special growing conditions of the Elbe-Saale region. The new plants must have a high alpha acid content and broad resistance especially to rot-causing pathogens. Furthermore, the plants must excel in climate adaptation and nutrient efficiency. The latter trait is particularly important within the context of the new Fertilizer Ordinance.

This task was assigned to the Hüll Hop Research Center of the Bavarian State Research Center for Agriculture because of its world-renowned breeding expertise. The agriculture ministries of the three hop-growing states of Thuringia, Saxony-Anhalt and Saxony support this work financially.

Implementation and method

Crossings

- Targeted crossings with pre-selected Hüll breeding material
- Mildew resistance testing in the greenhouse and laboratory (see 6.5)
- Seedling testing (single plants) in the greenhouse
- Cultivation tests with reduced use of pesticides and fertilizers
  - 3-year cultivation test in Hüll
  - 4-year extended tests at two trial locations in the Hallertau
- Series of cultivation trials on commercial farms in the Hallertau and the Elbe-Saale region
- Chemical analyses of cone compounds (IPZ 5d)
- Organoleptic assessment of flavors
- Virus testing using DASELISA (Double Antibody Sandwich Enzyme Linked Immunosorbent Assay) technology (IPZ 5b)
- Tests for *Verticillium* infestation using the real-time PCR (Maurer et al., 2013; Seigner et al., 2017)
- Pathogen elimination via meristem culture

Series of cultivation trials with Hüll high alpha strains in the Elbe-Saale region

Promising breeding lines from the LfL's high alpha breeding program have been tested under real world conditions in the Elbe-Saale cultivation area since 2014 and 2018.

Berthold farms in Monstab, Thuringia
Agricultural cooperative Querfurt, Saxony-Anhalt
Hopfen Estate, Saxony

Results

Since the start of the project in 2016, more than 200 targeted crosses with specially selected parents from Hüll breeding materials have been created to implement the goals of the project. In July 2020 alone, more than forty crosses were created.

At the start of this breeding program in the spring of 2020, more than 57,000 seedlings were tested for fungus resistance in the greenhouse in Hüll. Starting in May 2020, more than 1,900 seedlings that were pre-tested for disease resistance became available for further assessment „vegetation hall“ to determine their vigor and resistance under natural infection conditions as well as their stability when exposed to high winds. This work will last until the fall. In addition, the plants‘ gender was identified so that the prerequisites for cone development could be assessed in female individuals.

As is done every year, female seedlings from previous-year crosses, which had received a positive assessment in the vegetation hall, were planted in the test garden in Hüll, in the spring of 2020. Male individuals will prove their potential in the test garden for "boys" in Freising.

Promising seedling candidates from previous years are currently undergoing the 3-year seedling test in Hüll. With minimal plant protection and reduced fertilizer application over the entire vegetation period, only the most robust and, therefore, the most promising seedlings were selected on the basis of roughly 40 pertinent criteria. Of the 2017/2018/2019 vintages, 71 seedlings were harvested in the fall.

The cone samples of the respective candidates were chemically analyzed in Hüll by IPZ 5d.

Seventeen promising seedlings from individual plants that proved to be impressive after two to three years were selected for two sequential cultivation tests at two locations (in Hüll and Stadelhof), in 2020. Before the selected plants were propagated, they were tested for virus and *Verticillium* infections. Virus testing was carried out in the laboratory of the Plant Protection Working Group in Hop Cultivation (IPZ 5b), in Hüll. The results were negative. The absence of *Verticillium* was confirmed by the breeding team's genome analysis team in Freising using the highly sensitive real-time PCR technique.

In order to achieve faster breeding progress, the tests in 2017 to 2019 were performed almost exclusively on seedlings from the Hüll high alpha breeding programs that were active before the start of the project. There are currently 54 breeding lines in trials in Hüll and Stadelhof. For the project, 41 candidates from the tests in 2017, 2018, and 2019 were harvested in 2020.

A reliable assessment of all selection criteria, in particular reliable prognoses for yield, compounds, and disease resistance, especially against crown rot pathogens, will be possible only after the completion of the 4-year cultivation test in the Hallertau.

Two high-yielding strains with high to very high alpha acid contents turned out to be promising candidates for serial cultivation on farms in the Elbe-Saale area.

One hop grower in the Elbe-Saale region is currently testing four high alpha breeding strains from the Hüll breeding program. The tests involve comparisons of these breeding strains with Hallertauer Magnum, Herkules, Polaris, and Ariana to determine their location-specific suitability for cultivation (see Table 6.2). The LfL, in conjunction with the Thuringian State Institute for Agriculture, participates in these cultivation experiments by providing scientific and technical assistance. In addition, two breeding lines are being tested for their location-specific suitability on one farm each in Saxony and Saxony-Anhalt.

Meaningful assessments of all high alpha breeding strains, especially in terms of their required resistance to crown rot, are expected to be available only in two to three years.

In the current series of trials on farms in Thuringia, Saxony and Saxony-Anhalt, as well as in the Hallertau, one promising high alpha strain has already emerged. It not only has a very high alpha acid content and a good yield potential, but it also shows stability under stress conditions. In addition, it meets the requirement of extensive disease resistance, especially against crown rot and powdery mildew. Even the results of brewing trials with this strain are promising.

Therefore, the Society for Hop Research (GfH) approved this high-performance, high alpha strain (2011/071/019) for larger-scale testing on a hectare basis. In the summer of 2020, this hop was planted in the Hallertau on 5.4 ha. In 2021, this breeding line will also be tested on 0.5 ha in the Elbe-Saale region.

This large-scale cultivation trial over two to three years generates reliable assessments of this strain‘s cultivation and resistance characteristics at various locations. In addition, there is a need to confirm its heat and drought tolerance in the Elbe-Saale region. Trials in the Hallertau thus far have been convincing.

Outlook

The new strains show promising signs already. However, as candidates, they still have to prove themselves in further trials on farms in the Elbe-Saale hop region. It was clear already from the start of this breeding work in 2016 that the breeding and testing tasks (see figure) in the series of trials in the Elbe-Saale regon could not be completed successfully during the first project phase (2016 to 2020). Thus, it is gratifying that funding for this promising breeding and selection work by the LfL will be available for another five years. The funds are contributed by the Thuringian Ministry of Infrastructure and Agriculture, the Ministry for the Environment, Agriculture and Energy of the State of Saxony-Anhalt. and the Saxon State Ministry for Energy, Climate Protection, Environment and Agriculture.

Economic significance of the project results

This project will develop healthy, high-performance, high alpha breeding lines that combine all the advantages of modern varieties with future potential. These include highly stable alpha acid yields, broad resistance to pathogens such as powdery mildew, downy mildew and crown rot, as well as high efficiency in the uptake of nitrogen. They make hop production more environmentally friendly; conserve resources by reducing the use of pesticides and fertilizers; and help to save production costs. In addition, these new breeds are selected for the special cultivation conditions in the Elbe-Saale region. Finally, they have proven to be well armed against increased periods of heat and drought stress from climate change.

This means that these new varieties can increase the competitiveness of hop cultivation in the Elbe-Saale region and thus decisively strengthen the region's position long-term on the world markets.

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Table 6.2: Results of the serial cultivation test of Hüll high alpha strains with Hallertau Magnum, Herkules and Polaris as reference varieties at an Elbe-Saale grower; [1]a-acid content in wt.-% lfr. according to EBC 7.4

Properties	Hallertauer Magnum	Herkules	Polaris	Ariana	Breeding Line 2010/80/728	Breeding Line 2011/71/19	Breeding Line 2010/75/78	Breeding Line 2015/58/58
Crop year	1998	2001	2012	2016	June 2015	June 2015	May 2019	May 2019
Aroma assessment	pleasant	pleasant	pleasant, fresh	pleasant, fruity	medium	pleasant	pleasant	pleasant
Alpha acids (%)	**12.4** (10.6 – 14.5)	**13.9** (13.5 – 14.5)	**16.4** (13.7 – 18.2)	**9** (8.2 – 10.2)	**18** (17.1 – 20.2)	**15.9** (14.3 - 17.2)	**14.7**	**14.9**
Yield (kg/ha)								
Harvest year 2014	2 210	3 230	2 850					
Harvest year 2015	1 640	1 640	1 900					
Harvest year 2016	2 830	2 500	2 435	1 650 (young hop)	2 210	2 230		
Harvest year 2017	2 925	1 950	2 785	4 490	3 375	2 930		
Harvest year 2018	2 420	No longer planted due to crown rot	2 255	3 090	2 100	2 395		
Harvest year 2019	2 740		2 555	3 175	2 145	2 335		
Harvest year 2020	2 585		2 515	3 930	1 815	1 955	2700	2700
kg α-/ha	**313** (174 – 410)	**325** (221 – 453)	**405** (309 – 507)	**328** (272-376)	**426** (274-637)	**381** (280-466)	**367**	**580**
Plant health	very good	low	very good	very good	good	good	good	good
Agronomic assessment	robust, strong growth	yield reduced due to crown rot	robust, slow growing	robust, broad resistance	powdery mildew resistance, low density	powdery mildew resistance, good development	robust, vigorous	good development, high yield potential

6.5 Powdery mildew isolates and their use in breeding of mildew resistant hops

Sponsor:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenbau, Produktionstechnik (IPZ 5a) *[Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Production, Production Technology (IPZ 5a)]* AG Züchtungsforschung Hopfen *(WG Hop Breeding Research)*
Financing:	Gesellschaft für Hopfenforschung e.V. (GfH) *(Society of Hop Research*) (2013 -2014; 2017 – 2021) Erzeugergemeinschaft HVG e. G. *(HVG Hop Producer Group)* (2015 - 2016)
Project Management:	Dr. E. Seigner, A. Lutz
Team:	AG Züchtungforschung Hopfen *(WG Hop Breeding Research)*: A. Lutz, J. Kneidl EpiLogic: S. Hasyn
Collaboration:	Dr. F. Felsenstein, EpiLogic GmbH, Agarbiologische Forshung u. Beratung, *(Agri-biological Research and Consulting),* Freising
Duration:	January 1, 2013 to December 31, 2021

Objectives

Improved resistance to diseases, especially to powdery mildew, is a top priority in the development of new hop varieties. This is why seedlings from all breeding programs are tested for powdery mildew resistance each year.

Starting in 2000, powdery mildew isolates with virulence properties have been used for powdery mildew resistance tests in the greenhouse and the laboratory (Seigner et al., 2002). In conjunction with constantly improving test systems in the greenhouse and laboratory, these resistance tests form the backbone of effective resistance breeding (Seigner et al., 2005; Seigner et al., 2006; Seigner et al., 2009). For this purpose, 10 powdery mildew isolates with all currently known virulence genes are obtained from EpiLogic, Agrarbiologische Forschung und Beratung (*Agri-biological Research and Consulting)*, in Freising. These isolates are made available for the various efforts related to mildew resistance breeding.

Description of work

Powdery mildew isolates – preservation and characterization of their virulence properties

- Before the start of testing, the virulence properties of all mildew isolates are checked once a year in February. To this end, a range of eleven hop varieties that carry all the resistance genes known to date are used to differentiate the virulence levels. This ensures that available isolates have not lost their virulence genes through mutation, even years after the culture was first created. In addition, as new mildew populations appear in the growing regions or in the greenhouse, these are also examined for their virulence properties.

Testing for powdery mildew resistance in the greenhouse in Hüll

- In the greenhouse, under standardized infection conditions, all seedlings (approx. 100,000) that were produced from the crosses of the previous year are artificially inoculated with three mildew isolates. In this process, only powdery mildew strains are used that are known to have virulences that are widespread in the Hallertau. This allows for a large number of seedlings to be tested, which, in turn, clarifies the extent to which they show the type of resistances that are urgently required for cultivation in the Hallertau. Only seedlings that are classified as resistant move on for further selection.

Figure 6.1: Resistance test in the greenhouse with seedling trays amidst inoculator plants

Testing for powdery mildew resistance in the laboratory using the leaf test system

- In addition, breeding strains, varieties and wild hops that have proven their resistance in the greenhouse in previous years, are examined in the laboratory at EpiLogic using the leaf test system. An English powdery mildew isolate ("R2 resistance breaker") and a Hallertau isolate ("RWH18 breaker"), which has regional significance, are used for inoculation. Only breeding lines and varieties that show broad resistances to powdery mildew in both tests (greenhouse and leaf test) are used for further breeding.

Assessment of the state of virulence in growing areas and assessment of resistance sources using the leaf test system

The virulence genes of current powdery mildew populations in German hop gardens are identified every year. The reactions of 11 cultivated and several wild varieties that carry all the resistance genes known to date worldwide (= so-called hop differential assortment), are tested against all currently available mildew isolates. This makes it possible to assess whether existing resistances are still fully effective in current varieties (such as the fully mildew-resistant Hallertauer Blanc aroma variety). Last year, the powdery mildew strain, which is starting to affect Herkules in more and more regions of the Hallertau, was examined by EpiLogic for its virulence properties. The presence of well-known virulences that break the R1 and R3 resistance gene could be confirmed.

The virulence was also identified on mildew-infected leaves of Callista in commercial plots. According to our current understanding, the R18 resistance in Callista in these commercial plots appears to have been broken by regionally specific mildew strains with complementary v18 virulence.

- These virulence tests provide crucial insights into the mildew strains that are found in commercial plots or greenhouses. These insights are necessary for assessing if the resistance of our varieties is still effective or has since ceased.

Phenotypical data about powdery mildew resistance of the assortment of hop reference varieties for the GHop project as a contribution to the establishment of precision breeding

Starting in mid-2015, work has been underway to develop the foundations for precision breeding in hops. The project is a collaboration between the Universität Hohenheim (*University of Hohenheim*), and, since 2017, the Gesellschaft für Hopfenforschung (*Society for Hop Research*) and Hopfenverwertungsgenossenschaft (*Hop Sales Collaborative*) HVG.

The resistance tests were conducted with defined mildew strains in the greenhouse, as well as in subsequent leaf tests at EpiLogic. These provided crucial insights into the mildew resistance or susceptibility of all individuals in the hop reference assortment, which consists of 192 cultivated varieties, both female and male breeding lines, as well as wild hops. These powdery mildew tests on a range of reference plants in the greenhouse and in the laboratory (leaf test) allowed for controlled, reliable assessments about mildew resistance under controlled conditions, which could never have been possible in field tests. In addition, resistance reactions could be associated with actions of special resistance genes (complementary to the virulence of the mildew strains used).

Table 6.3: Overview of mildew resistance tests in 2020 with mildew isolates of defined virulence

2020	Tests in greenhouse		Leaf tests in laboratory	
	Plants	**Assay data**	**Plants**	**Assay data**
Seedlings from 89 crossings	approx. 100,000 mass-selected		-	-
Breeding lines*	133	136	189	1,455
Varieties*	22	39	23	81
Wild hops*	1	2	1	0
Virulence powdery mildew isolates	-	-	10	485
Total (Individual tests)	**156**	**177**	**223**	**2,029**

Mass selection in plant trays; Single tests = selection of individual plants in pots

* *partial data for the GHop project (precision breeding)*

6.6 Leaf test system for assessing the tolerance of hops to downy mildew ( )

Project Management: Dr. E. Seigner, A. Lutz

Team: B. Forster

Collaboration: Th. Eckl, IPZ 1e (biometrics)

Objectives

A standardized test system for leaf evaluations, known as “detached leaf assay,” was established in the laboratory. It allows for the collection of reliable data about a breeding line’s *Peronospora* tolerance. These tolerance tests rely entirely on so-called secondary infections, that is on the degree to which a hop is resistant or susceptible to fungal zoosporangia that are administered to the leaf surface. At high air humidity, the sporangia release the zoospores, which then penetrate through openings in the leaf surfaces into the interior of the leaf, where they grow into a fungal mycelium unless the hop mounts a defense reaction. Vulnerable hops, therefore, develop fungal mycelium sporulating on the leaf as a typical infection symptom.

Method

The first step is to spray the underside of the hop leaves with a *Peronospora* sporangia suspension. Five to 14 days later, the reactions of the leaves (no visible symptoms, chlorosis, necrosis, sporulation) are assessed visually.

The evaluation is rated on a scale from 0 to 5, with a focus on sporulation: 0 (highly tolerant) = no symptoms, 1 (tolerant) = 1-10% of the leaf surface affected, 2 (medium) = 11-30%; 3 (vulnerable) = 31-60%; 4 (highly vulnerable) = 61-80%; 5 (extremely vulnerable) = 81-100%. The disease index was calculated according to Townsend and Heuberger and evaluated statistically using this rating data.

On the leaves of hops that are more susceptible or less tolerant, chlorotic leaf spots with clear signs of sporulation appear on the underside of the leaves a few days after inoculation. Strong, early sporulation is a clear indication of a strong susceptibility to the fungus. Dark brown necrosis spots become visible at a later stage. These leaf responses vary depending on leaf age. Young leaves in the growth phase show clearer symptoms than do older ones.

Tolerant hops, on the other hand, suppress sporulation completely or they show smaller necrosis spots on the leaves as a defense reaction, especially in the early stage of infection (hypersensitive reaction of the host cells).

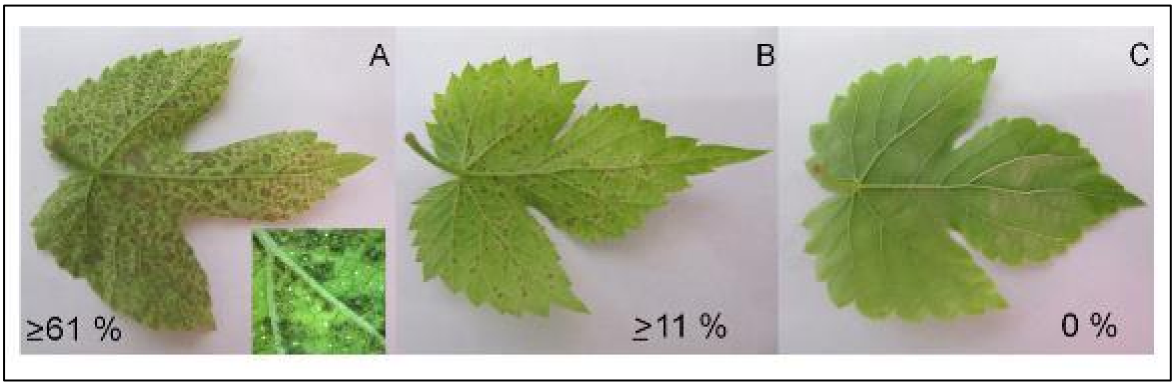

Figure 6.2: Different reactions of hop leaves 6 days after inoculation with Peronospora*: susceptible (A), medium tolerant (B) and highly tolerant (C) to the fungus; % of infected leaf area = sporulation; Photo A also shows a close-up of* Peronospora *infestation with black spore areas*

Results

We have been working on optimizing the leaf test system since 2015. Improvements include inoculation conditions, the vitality of the zoospores, temperature control during leaf incubation in the incubator, and the cultivation of test plants.

In 2020, the test season began at the end of April. Up to mid-September, 13 serial tests were conducted, each with one variety and five breeding strains. Leaves from Hallertauer Tradition (high resistance) and Polaris (low tolerance) were used as references for different degrees of downy mildew tolerance. Only experiment 5, in which generally too little leaf infestation was found, was not included in the statistical calculations. With the exception of Aurum, which had already been examined with the leaf test system in 2018 and 2019, the five breeding lines were up for testing for the first time in 2020. Therefore, only 2020 results are represented in the illustrations.

Next, indices ranking the disease severity were compiled according to a statistical method developed by Townsend and Heuberger. This method uses *Peronospora* evaluation results collected on examined varieties and breeding lines in the year 2020. The following picture emerged:

The high *Peronospora* tolerance of the Hüll variety Hallertauer Tradition could once again be confirmed statistically, while the high alpha strain 2010/075/078 and the aroma strain 2015/21/35 were found to be highly susceptible to downy mildew. All other strains tested were found to be more sensitive to downy mildew compared to Polaris (Figure 6.6). In 2021, all hops will be tested again for their reaction to downy mildew using this leaf test system.

By and large, field ratings confirmed the tolerance assessments generated by the leaf test system for the varieties and breeding lines examined thus far, except for the aroma strain 2015/21/35, which had been identified in the field assessments as being not especially susceptible to downy mildew. A repetition of the examinations during the 2021 test season should create clarity.

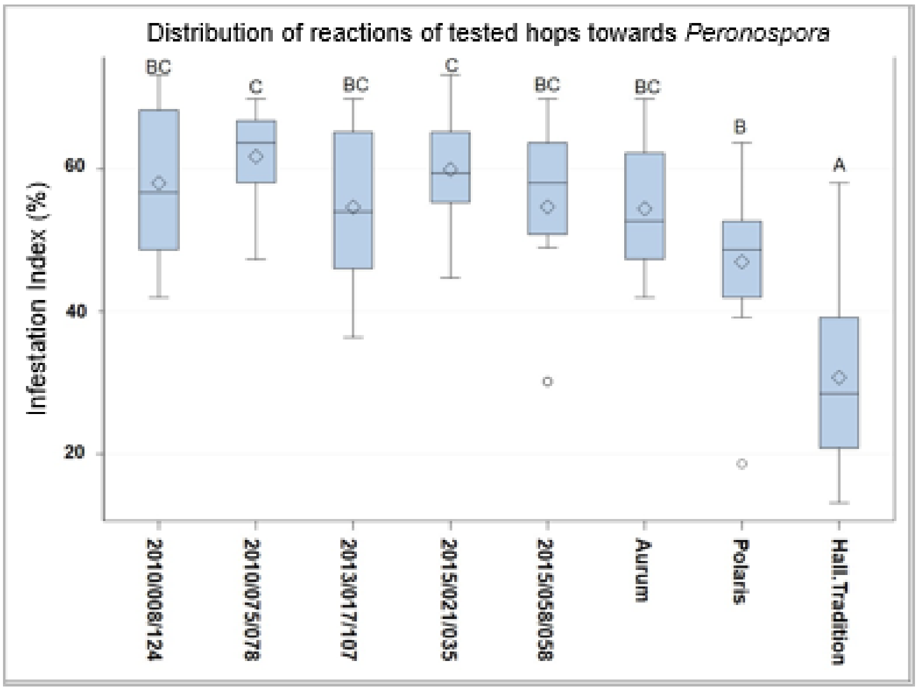

Figure 6.3: Distribution of the reaction of tested hop varieties/strains to Peronospora *in the 2020 season. Only hops indicated by two capital letters showed statistically significant differences in their* Peronospora *infestations (Student-Newman-Keuls-Test with p< 0.05).*

As a rule, a suspension of zoospores is used as the inoculation material for leaf testing. These come from so-called bobbed heads (= hop shoots that are strongly stunted because of downy mildew). In the current test season zoospores from artificially infected leaves are also used. These are grown in an incubator. The advantage of using such laboratory-grown inoculation material is the young age of only a few days, because it comes from freshly sporulating zoosporangia. Our results of the 2020 test season show that these zoospore suspensions have a slightly higher infection capacity compared to zoospore suspensions of free-range „spikes.“ This positive effect is evident in Figure 6.7 for the disease index in test series 10 to 13 where all the tested hops show higher downy mildew rates.

For a number of years, attempts have also been made to freeze the zoosporangia to ensure that inoculation material is available regardless of any downy mildew that can be collected in the field. This means that leaf tests, for example, can begin as early as mid-March. Various approaches have been investigated since 2018. Cryoprotective substances such as DMSO (Mitchell, 2010) or skimmed milk (Gulya et al., 1993) were added to the zoospore suspension before freezing.

Furthermore, leaves with freshly sporulating zoosporangia were frozen in their entirety and the zoospores were used as inoculation material after thawing. In addition, different protocols (Mitchell, 2010; Gulya et al., 1993) were checked when thawing the frozen zoospore suspensions.

According to the current state of knowledge, zoospores that are cyroptotected in skimmed milk, as well as zoospores that have been frozen on leaves, have plenty of viability and are thus capable of causing infections even after thawing. When the spore suspensions were thawed at room temperature or by briefly immersing them in a 40 °C water bath, the inoculation materials showed no clear differences in their infectiousness.

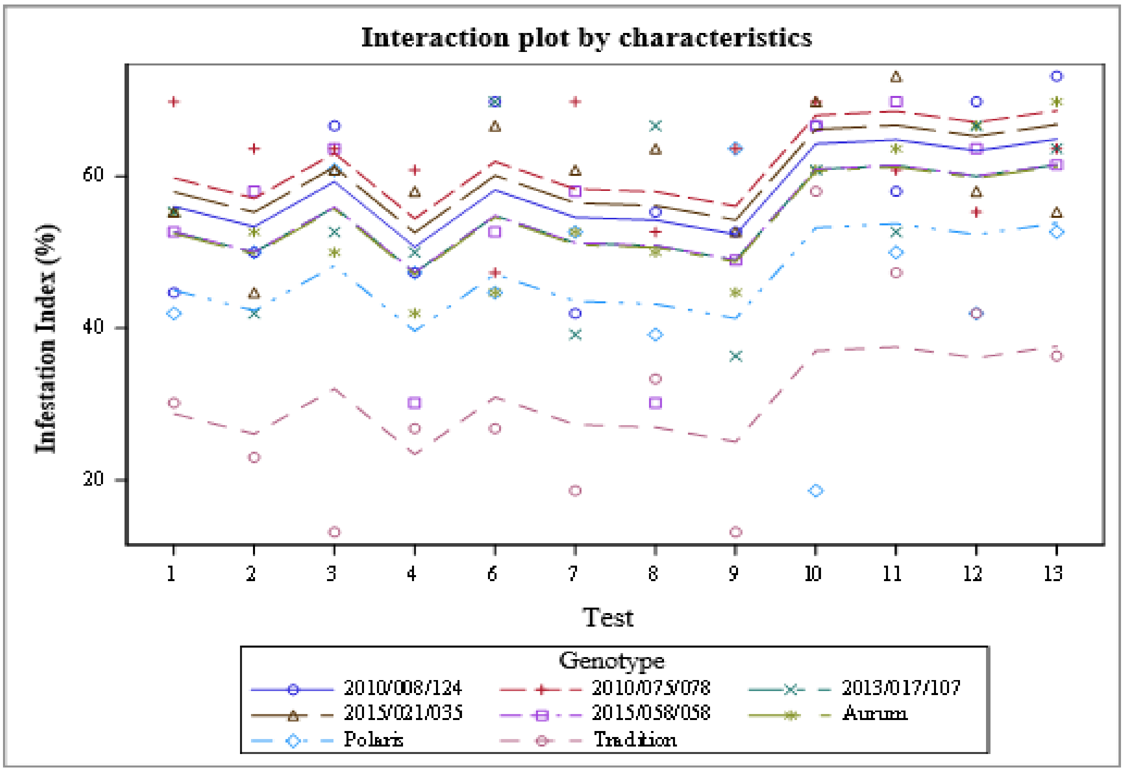

Figure 6.7: Reactions of the tested hop varieties/strains to Peronospora *in the 2020 season. The results of test 5 have been eliminated because the infectiousness of the zoospore material used was far too low.*

Outlook

One decisive advantage of the leaf test system is its ability to generate assessments of the disease tolerance of different hop varieties or strains under standardized conditions, regardless of weather conditions and location influences. The key point for the practical suitability of the leaf test system for use in the breeding process is, on the one hand, the correlation between tolerances or sensitivities of hops to secondary *Peronospora* infections as determined in the laboratory, and field ratings, on the other.

The *Peronospora* leaf test system has emerged in recent years as a reliable test system for tolerance assessment. It can used to confirm field assessments.

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6.7 Research and other work on the problem in hops: Molecular detection of directly in the bine using real-time polymerase chain reaction (PCR)

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

AG Züchtungsforschung Hopfen
(WG Hop Breeding Research)

Financing: Erzeugergemeinschaft HVG e. G.
(HVG Hop Producer Group)

Project Management: Dr. E. Seigner

Team: AG Züchtungsforschung Hopfen *(WG Hop Breeding Research)*: P. Hager, R. Enders, A. Lutz, J. Kneidl

Collaboration: AG Pflanzenschutz im Hopfenbau *(WG Hop Plant Protection)*: S. Euringer, K. Lutz

Dr. S. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia

Duration: Starting in 2008 to December 31, 2023

Combating *Verticillium* wilt in German hop growing regions is a long-term task. Research and the advisory function of the LfL, as well as the implementation of preventive measures by hop growers, are of central importance in the common fight against *Verticillium* in hop gardens.

Objectives

In addition to conventional phytosanitary or other cultivation techniques, planting *Verticillium*-free material is key in preventing *Verticillium* wilt from spreading through hop growing regions.

Since 2013, hop seedlings have been tested for *Verticillium* using a highly sensitive PCR-based detection method. This is to ensure that only wilt-free hops are included in the LfL's testing program and then passed on to the Gesellschaft für Hopfenforschung (*Society for Hop Research*) (GfH), and from there to hop growers.

Method

Molecular detection directly in the bine using real-time PCR according to Maurer, Radišek, Berg and Seefelder (2013).

Based on systematic research, it was possible to establish a very reliable and highly sensitive molecular detection technique for *Verticillium* directly in the hop bines (Maurer et al., 2013).

This detection system uses a Multiplex TaqMan®-based real-time PCR method. It has been used in practice since 2014. As described by Maurer et al. (2013), the test was first applied on *V. nonalfalfae* and *V. dahliae*.

The first step in this analysis is the preparation of a sample of the interior of the bine (marrow). It contains the plant’s water-conducting vessels and thus possibly also *Verticillium* spores or mycelium. The sample material is collected and prepared for examination by macerating it in a homogenizer. Then the hop DNA and the DNA of the fungal contaminations (if present in the vascular elements) are isolated.

With real-time PCR using the specific primer pairs for *Verticillium nonalfalfae* and *V. dahliae* and the respective probes, the fungal attack is ultimately represented as an increase in fluorescence starting at reproduction cycle 18 and lasting up to approximately 35.

Results

We are constantly working on optimizing the test system. Since *Verticilllium dahliae* was only found very sporadically in the Hallertau hop samples, full attention should be paid instead to *V. nonalfalfae*. The aim is not only to test for *V. nonalfalfae* in general in one PCR run, but also to test and differentiate between mild and lethal strains of *V. nonalfalfae*. This is the only way to draw conclusions as to whether wilt infects a special hop variety; and, if so, which wilt strain is of decisive importance for hop breeding, the test plots, and the Hallertauer growing region in general.

- **Differentiation between mild and lethal strains of using real-time PCR**

To goal is to differentiate between mild and lethal strains of *Verticillium nonalfalfae* not just by way of conventional PCR techniques as was used by Seefelder (2014), but also by way of much more sensitive real-
and the primer pair from Seefelder and Oberhollenzer (not published) were used to identify lethal strains.

Because all primer pairs had previously been used only in conventional PCR (Seefelder) or only in a SYBR Green-based, real-
gene probes required for real-time TaqMan PCR had to be created first and subsequently verified. This involved the use of a software package (CLC Genomics Workbench, Qiagen; B. Büttner, not published).

Since 2017, quite reliable differentiations between lethal and/or mild strains of *V. nonalfalfae* have been routinely carried out with our real-time system on hop infestations, using primers from Seefelder and Oberhollenzer, as well as the Büttner probe. The results match the symptom assays (S. Euringer and K. Lutz).

- **Multiplex real-time PCR with internal controls**

Previously, a separate conventional PCR was used to test for polyubiquitin (Maurer et al., 2013) as an internal hop-specific gene. As part of this project, internal controls have been introduced in every multiplex real-tim
(2015) were tested for the hop genes CAC (clathrin adapter complex medium subun.) and DRH1 (DEAD box RNA helicase). Better standardization was achieved by using Cox primers and a Cox-specific probe as an internal control (COX = cytochrome oxidase modified from Weller et al., 2000). Today, the detection of the hop-specific Cox-DNA as an internal control confirms that the PCR is running trouble-free. This, in turn, means that “false negative” results can be excluded.

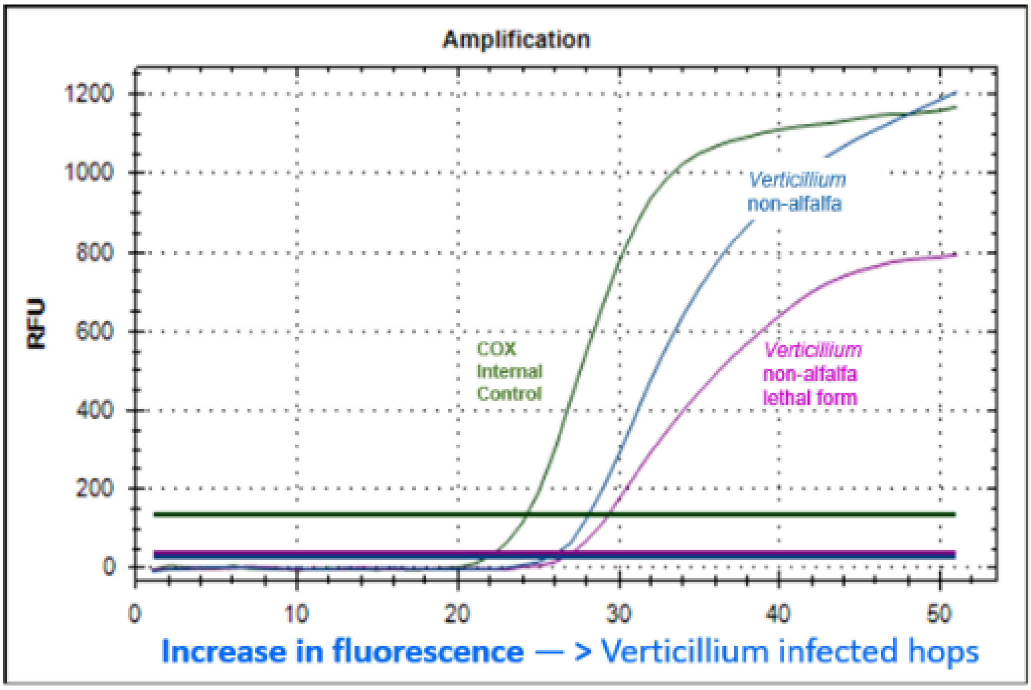

Figure 6.8: Multiplex real-time PCR of a bine sample from a real-world plot

Explanation of Figure 6.8

An increase in fluorescence of the blue curve means that the sequences specific to *V. nonalfalfae* were both present in the sample extract and were being multiplied, thus releasing the fluorescent dye "FAM" that is coupled to the probe. The examined bine is thus infected with *Verticillium nonalfalfae*. Since this primer pair does not differentiate between mild and lethal strains, it can only be concluded here that a *Verticillium* infection is present, but without a determination of its type.

At the same time, the PCR offers primers and probes (Cy5-marked) for lethal strains of *V. nonalfalfae*. With the increase in the fluorescence signal "Cy5" (violet curve), therefore, it can be determined whether or not the *Verticillium* infestation detected in the sample should be classified as the lethal strain of *V. nonalfalfae*.

The amplification curve of the hop-specific COX gene for the detection of the PCR reactions without interference appears in green in the figure.

The curves of other samples that were examined in this run are not shown in this figure in order to make the overview easier to understand.

- **Improvements in the molecular detection and validation of the real-time PCR detection system**

In addition to the introduction of constant internal controls (see 2.2), test series were conducted in 2016 and 2017 to optimize the real-
published primers for the detection and differentiation of *V. nonalfalfae* mild and lethal strains. These were tested in cooperation with Dr. B. Büttner, IPZ 1b, and Dr. L. Seigner, IPS 2c. Furthermore, the temperature curve of the PCR reaction was checked and optimized. The validation process also included checking different primer and probe concentrations to improve the detection system.

The next step was to increase the number of PCR cycles from 40 to 50. Because real-time PCR proved to be much more robust than conventional PCR, with respect to inhibiting compounds in the plant extract, the hop extract intended for testing was no longer prediluted as in Maurer et al. (2013) to 20 ng DNA/µl (hop DNA and fungal DNA, with the hop specific DNA making up the main portion). Instead, the tested extract was used in real-time PCR in its raw state, either undiluted or diluted at 1:10. The decisive advantage here is that the highest possible concentration of the wilt fungus is always captured, thus lowering the detection threshold and significantly increasing the sensitivity of the test.

The comparison of the sensitivities of the various detection methods, including fungal growth, real time-PCR, and conventional PCR, was developed in cooperation with S. Euringer, IPZ 5b, and Dr. P. Büttner, Mycology, IPS 2a.

Advantages of the real-time PCR detection method

Especially when compared to the fungal growth test, the following advantages became apparent:

- High degree of specificity
- No risk of confusing *Verticillium* infections with other fungal infections (*Fusarium*), which usually grow faster and therefore partially smother the *Verticillium* fungus
- Even the smallest amounts of infection are captured
- The only method that makes the distinction between mild and lethal strains possible
- Result is already available after two instead of seven growth days of the infection

Disadvantage of the real-time PCR detection method

- The determination is based on the existence of DNA, which, however, can be detected even during the rotting process. Real-time PCR therefore does not provide a clear indication as to whether the *Verticillium* fungus is still infectious or has already died.

Real-time PCR proved to be more sensitive not only compared to a fungal growth test, but also to conventional PCR.

The real-time TaqMan® PCR protocol from Maurer et al. (2013), including with improvements in some procedures (see 2.2 and 2.3), was included in the updated EPPO protocol for the diagnosis of *Verticillium* (in the coordination phase since June 2019).

In addition, work is continuing on a systematic validation of the real-time PCR system with regard to reproducibility, sensitivity, etc. This work is being supported by Dr. L. Seigner, IPS 2c. Initial findings are already available.

Conventional PCR with -specific primers

In addition to the real-time TaqMan-PCR, conventional PCR with specific primers according to the EPPO guidelines (Down et al., 2007) is also used to diagnose *Verticillium*. This PCR serves as a supplemental and supporting method. Until mid-2017, it was the only method available to differentiate between mild and lethal strains of the fungus, using primers developed by Seefelder and Oberhollenzer (not published). In addition, conventional PCR was used to confirm the results obtained with real-time PCR.

Conventional PCR has recently been replaced by the more sensitive real-time PCR, especially because the real-time version works much more robustly in the presence of interfering factors. Otherwise, especially with cones and older leaves, higher concentrations of polyphenolic substances often have a detection-inhibiting effect.

· **Tests for**

Between 600 and 1,000 plants are tested for *Verticillium* every year. Since the wilt fungus cannot be assumed to be homogeneously distributed in the test material, two to three samples per plant need to be taken from different segments of the plant (such as roots or bine pieces close to the base). Then the DNA is extracted separately from each sample and each DNA extract is used undiluted, as well as diluted to 1:10, in the real-time PCR and tested for *Verticillium* infestation in general and for mild and lethal strains in particular. If the results are not clear, the real-time PCR test is repeated.

Hop bines, roots/rhizomes, leaves, and cones, as well as shoot tips and *in-vitro* plants are examined with the following objectives:

In most cases, testing with this highly sensitive real-time PCR technology is intended to ensure that only *Verticillium*-free plants collected from the *Verticillium*-contaminated breeding plot in Hüll are released to test sites in Stadelhof, (owned by the LfL) and, for field trials in rows and entire plos, to larger cultivation sites in the Hallertau, in Tettnang, and in the Elbe-Saale region.

Examination of mother plants destined for the GfH propagation operation, to ensure the delivery of for *Verticillium*-free rhizomes.

The mother plants propagated by the GfH are checked for wilt infestation at regular intervals. This ensures that only *Verticillium*-free plants are made available to hop growers.

Examination of Hüll breeding material generated in the LfL breeding plots and *Verticillium* selection plots to identify strains or varieties that are only minimally or not at all infested with *Verticillium*, or that are particularly tolerant of the lethal form. This work is carried out in cooperation with A. Lutz.

Molecular verification of wilt symptom assays in the wilt selection plot. This work is carried out in cooperation with S. Euringer and K. Lutz, IPZ 5b. The work is significant for remediation measures applied to soils that are contaminated with *Verticillium*. It is also significant for work on the sanitizing of shredded bines.

Assistance in real-time investigations regarding artificial *Verticillium* infection attempts of hops and eggplants in the greenhouse of K. Lutz, IPZ 5b.

Investigation of regenerated meristem plants after the "desired" elimination of *Verticillium* from infected seedlings via meristem culture.

Studies on the spread of a root-borne *Verticillium* infection in lateral shoots, leaves, and cones at different heights.

Studies on the spread of *Verticillium* infections in commercial plots in the Hallertau, especially to determine if lethal strains of the wilt fungus are involved.

Examination of samples from plots after wilt remediation or eradication attempts.

· **Development of a reference collection and supply of inoculation material**

At the beginning of 2017, work was carried out to build up a new *Verticillium* reference collection based on single spore isolates, after Dr. Seefeld's wilt collection was lost as a result of contamination. Mild as well as lethal *Verticillium* strains (from Hüll breeding plots, *Verticillium* selection, plots and also individual commercial plots) were isolated, characterized with real-time and conventional PCR, and ultimately preserved as glycerine stock solutions.

These were frozen at -80 °C to preserve their virulence properties over a long period of time. They are required as positive control samples for all PCR tests.

This strain collection is also available for research in other areas surrounding the topic of *Verticillium*, for instance, for infection tests of hop strains, whose wilt tolerance for mild or aggressive strains needs to be checked, or for the eggplant test system.

- **Support for research into through reliable molecular cellular diagnostics**

The Society for Hop Research has been supporting a research project on *Verticillium* problems in hops since June 2017. This makes it possible to tackle questions with practical relevance around the wilt fungus.

Development of new *Verticillium*-tolerant breeding lines and varieties

Rehabilitation of *Verticillium*-infected soils

Eggplant as a *Verticillium* pointer plant

Thermal sanitizing of shredded bines

All approaches are supported by this project on *Verticillium* wilt, whereby the focus is on the molecular detection of the fungus. This is the only way to verify the suspected existence of the pathogen in plots that show wilt symptoms after a visual assay. In this context, it is crucial to understand that a distinction between mild and lethal strains of the wilt pathogen can be made only by way of the PCR method.

Details of all research approaches presented here regarding wilt are available online at https://www.lfl.bayern.de/ipz/hopfen/181766/index.php.

- **Soil tests and quantification of infestations that are not part of this research plan**

In principle, it is possible to detect *Verticillium* using real-time PCR even in a highly complex matrix such as a soil sample. There are publications on *Verticillium dahliae*, the microsclerotia of which can usually be concentrated and subsequently even quantified by sieving soil samples (Wei et al., 2015; Borza et al., 2018). *V. nonalfalfae* does not form microsclerotia. Therefore, any attempts to concentrate its permanent mycelia in soil samples cannot produce results. The conidia cannot be concentrated either. Thus, the PCR method can be used only to examine soils in a range of 100 mg for *Verticillium*. Reliable conclusions about whether a soil sample is *Verticillium*-free cannot be drawn even after examining thousands of 100 mg samples (at various depths and scattered over a hectare). Therefore, the development of a PCR-based soil test on *Verticillium* is not part of our agenda.

Furthermore, we do not see a need to use the highly sensitive real-time PCR method to quantify fungal infestation, even though this method is sometimes used for academic reasons and publishing purposes. Because the distribution of conidia, mycelium, and permanent mycelium in all examined hop parts is inhomogeneous, the quantitative assessment of *Verticillium* infestations of one or even several 100 mg samples makes no sense. It is much more important to differentiate between infected and non-infected material, whereby the earlier the fluorescence radiation exceeds the threshold value (the lower the Cq value), the higher the concentration of the pathogen. A certain probability statement whether a great or a small amount of *Verticillium* is present in a sample is definitely possible via the Cq value.

Outlook

We are constantly working to optimize the real-time PCR method. This involves continuously verifiying that the primers used in the PCR reaction for the detection of *Verticillium nonalfalfae* can still detect all mild and aggressive versions that occur in the Hallertau.

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6.8 Meristem culture for the production of healthy seedlings

Project Management:	Dr. E. Seigner, A. Lutz
Team:	B. Haugg
	P. Hager, R. Enders, IPZ 5c
Collaboration:	Dr. L. Seigner, and the Virus Diagnostics Team, IPS 2c

Objectives

Infestations of *Verticillium*, viruses, and viroids can lead to dramatic losses in yield and quality. Since these diseases cannot be combated with pesticides, a biotechnological method, such as meristem culture, is used to produce *Verticillium*- and virus-free material.

In 2020, the main focus was on improving the method for eliminating apple mosaic virus (ApMV), which is often more stubborn than the hop mosaic virus and can still be detected in regenerated plants, even after a meristem culture intervention.

Method

To produce *Verticillium*- and virus-free hop plants, the meristem (the uppermost growth zone of the tip of the shoot) of an infected plant grown in the greenhouse is surface-sterilized and then treated with heat *in vitro* for several days (see Figure 6.9). It is assumed that existing viruses and fungal structures in the meristem are inactivated. After the heat therapy, the meristem is prepared under a binocular. It is then placed on a special culture medium and finally regenerated into a complete plant *in vitro* (see Figure 6.10 A-C). To confirm the successful elimination of viruses and *Verticillium* via the meristem step, the mature plants are examined for these at the end of the tissue culture phase.

The leaves are examined by the Working Group IPS 2c for various hop-typical viruses and in some cases also for viroids using the DASELISA (Double Antibody Sandwich Enzyme Linked Immunosorbent Assay) technique or the RT-PCR (Reverse Transcriptase Polymerase Chain Reaction).

Only healthy little plants are finally placed in the soil (Figure 6.10 D).

Results

In 2020 there were no *Verticillium*-infected hops ready for release. Therefore, the focus was on virus elimination. This opened an opportunity to also improve the method for eliminating especially "persistent" viruses, such as the apple mosaic virus (ApMV). Also considered were the effects of different heat therapies and different sizes of the prepared meristems on the elimination rate of viruses, especially of ApMV.

To clear out the virus, the shoot tips were first subjected *in vitro* for three days to heat adaptation phase at 30 °C, followed by a heat therapy for five to 11 days at 35 °C. The longer the heat phase lasted, the more stress-related effects (yellowing, browning) became visible in the vitro-treated shoot tips (Figure 6.10), which ultimately also had a negative effect on the regenerative capacity of the meristems.

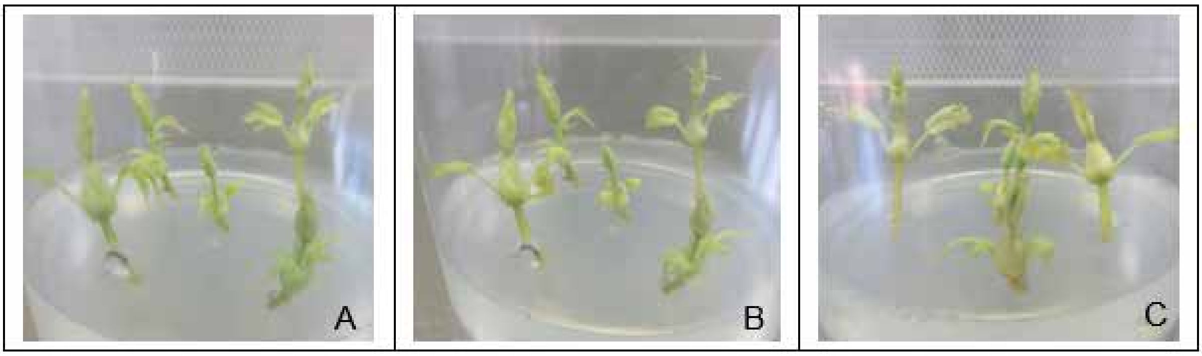

Figure 6.9: Shoot tips of ApMV-infected hops were subjected to heat therapy for 8 (A), 10 (B) and 14 (C) days (3 days @ 30 °C plus 5, 7, or 11 days at 35 °C). The longer the heat treatment lasted, the more obvious became the browning. Despite the poor external appearance of the shoot tips after 14 days, the meristems were still viable and capable of regeneration.

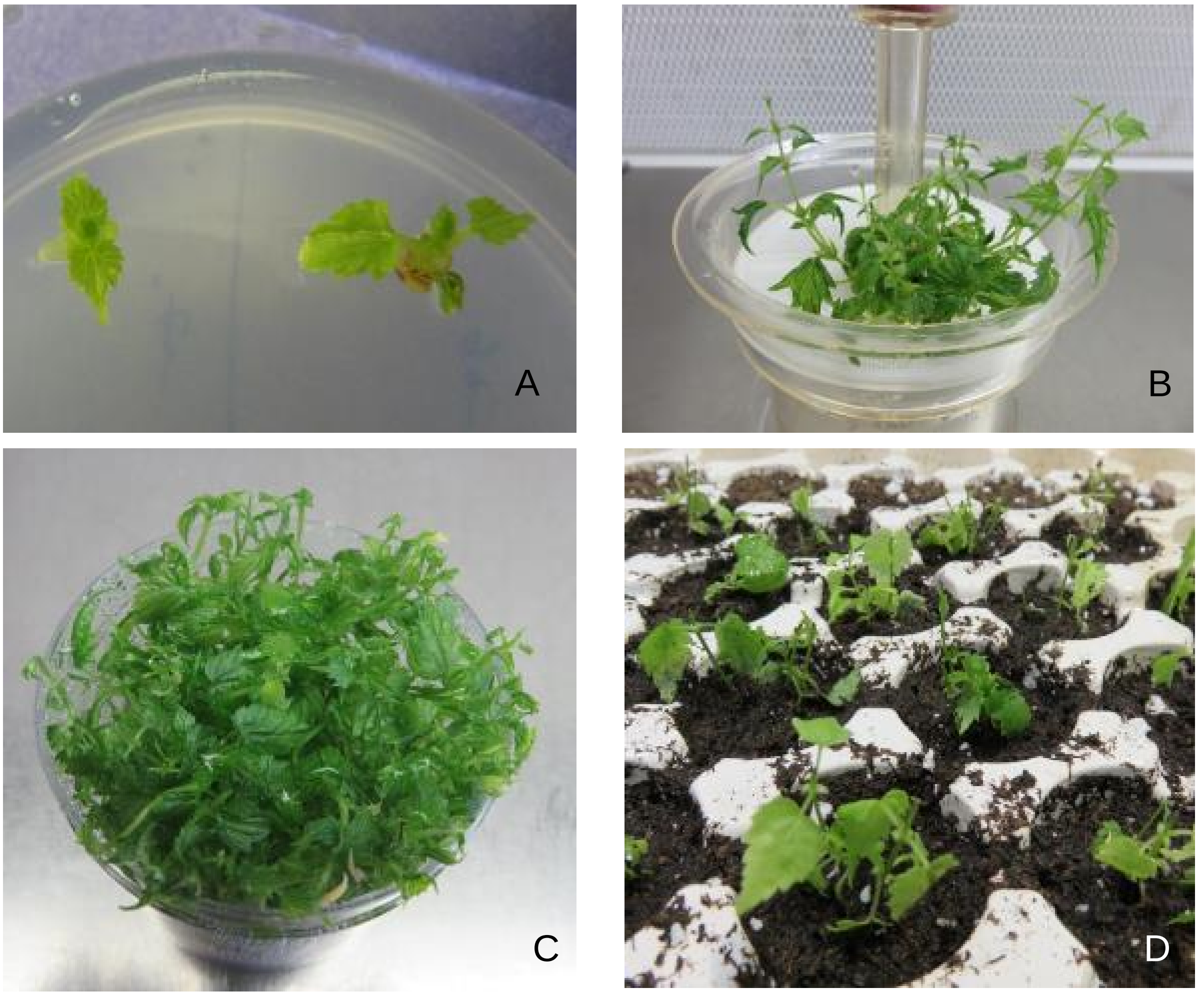

Figure 6.10: Regeneration of the little plants created from the meristems A) 3 weeks after preparation and still on solid medium in the Petri dish; B) 10 weeks after preparation in the RITA® liquid culture system; C) after an in vitro *cloning step, five months after preparation of the meristems in a culture box with solid medium; and D) 9-10 months after the start of the meristem culture in soil.*

On the other hand, a longer heat phase (10- and 14-day heat treatment) resulted in higher virus elimination rates. The results from 2020 demonstrated that an extention of the the 35-degree phase from three days (the time frame used up to 2016) to seven or even 11 days increased the elimination rate of ApMV from 55% (2010 to 2016) to 80% (additional results are pending).

In 2018 and 2019, a wide variety of temperature schemes were tested that had been used successfully for virus or viroid elimination in hops and in other crops, as, for example, by Postman et al. (2005), Matoušek et al. (1995 and 2001), Faltus et al. (2011) and Kazemi et al. (2020). In these tests, either no effect on the elimination of the viruses could be observed, or the regeneration of the meristems into small plants was completely thwarted by excessive stress.

For the size of the prepared meristems, a diameter of 0.3 to 1.0 mm was used. Preparations of about 0.5 mm proved to be optimal in terms of regenerative capacity and the virus elimination rate. In principle, the smaller the initial meristem (0.3 to 0.4 mm), the higher was the virus elimination rate, but only very few of these plants could also be regenerated from the smallest meristem preparations.

Outlook

Work is underway to further increase the virus elimination rate by optimizing the regeneration of meristems. Viroid infestations, in particular, pose a major challenge and truely effective methods are still lacking. Therefore, new approaches to viroid elimination or inactivation are being pursued.

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6.9 Precision breeding of hops: Genome-based precision breeding of future-oriented quality hops

Sponsor:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung *(Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)*
Financing:	Förderung aus Mitteln des Zweckvermögens des Bundes bei der Landwirtschaftlichen Rentenbank *(Funding provided out of the German Federal Government's earmarked deposits at the Landwirtschaftliche Rentenbank)*
Funding Indicator	Landwirtschaftlichen Rentenbank: 837 150; BLE File Number: 28RZ4IP025
Project Management:	Dr. M. H. Hagemann, Universität Hohenheim (*University of Hohenheim*) (overall project) Dr. E. Seigner (LfL)
Team:	AG Züchtungsforschung Hopfen *(WG Hop Breeding Research)* (IPZ 5c): A. Lutz, J. Kneidl, E. Seigner and the breeding team AG Hopfenqualität/Hopfenanalytik *(WG Hop Quality/ Hop Analytics* (IPZ 5d): Dr. K. Kammhuber, C. Petzina, B. Wyschkon, M. Hainzlmaier und S. Weihrauch AG Genomorientierte Züchtung *(WG Genome-Oriented Breeding)* (IPZ 1d), Prof. Dr. V. Mohler AG Züchtungsforschung Hafer und Gerste (*WG Breeding Research Oats and Barley)* (IPZ 2c), Dr. T. Albrecht
Network Partners:	Universität Hohenheim, Institut für Nutzpflanzenwissenschaften, FG Ertragsphysiologie der Sonderkulturen *(University of Hohenheim, Institute for Crop Science, FG Yield Physiology of Speciality Crops)*: Dr. M. H. Hagemann, Prof. Dr. J. Wünsche Institut für Pflanzenzüchtung, Saatgutforschung und Populationsgenetik *(Institute for Plant Breeding, Seed Research and Population Genetics)*: Prof. Dr. G. Weber *emeritus* Gesellschaft für Hopfenforschung e.V. *(Society of Hop Research)*: W. König Hopfenverwertungsgenossenschaft HVG e.G. *(Hop Sales Cooperative)*: Dr. E. Lehmair
Duration:	August 1, 2017 to December 31, 2021

Objectives

The focus of this research project is the development of prerequisites for the use of genome-based selection criteria for parent breeding lines, as well as the evaluation of offsprings from such crosses. Selections based on molecular markers should also allow for the upfront evaluation of the breeding value not only of female hops but also of male hops. This is a crucial step forward, because until now male hops could not be assessed directly regarding yield and brewing quality, simply because they lack cones. Therefore, their potential as crossbreeding partners was always unclear.

Method

The first step is the generation, within an assortment of reference breeding material, of phenotypical data such as resistance, agronomic performance, and cone compounds. Then, all hops are genotyped, that is, their genetic material is sequenced.

Using a bio-statistical process, DNA sections (molecular markers) are mapped for their association with various phenotypical properties to reveal marker-to-feature relationships. The linkages between genetic markers and breeding-relevant traits lead to the development of a predictive model that allows for the forecasting of phenotypical properties solely on the basis of the genetic data of new selection candidates (= their genotype).

Phase 2: August 2017 - December 2021

The following work is being carried in collaboration with the Universität Hohenheim (*University of Hohenheim*) (UHOH) as a research partner, as well as the Gesellschaft für Hopfenforschung (*Society for Hop Research*) (GfH) and the Hopfenverwertungsgenossenschaft *(Hop Sales Cooperative*) (HVG) as additional collaborative partners:

- Continuation of the phenotyping of the reference assortment: Collection of data for resistance, agronomic features, and cone compounds at various locales and for different years; aggregation of historical data, which is partially available back to the 1990s. (LfL)
- Molecular studies on bitter acid synthesis and their processes (UHOH)
- Association mapping: bio-statistical linkage between the phenotypical data (resistances, agronomic performance, cone compounds) and the genotypical data of the reference hop assortment to identify simple and/or complex marker-characteristic relationships (LfL)
- Development of a predictive model to estimate the breeding value (genomic selection) (LfL)

Funding is provided out of the German Federal Government's earmarked deposits at the Landwirtschaftliche Rentenbank.

rentenbank

Results

Phenotyping – generation of agronomic and chemical data

At the beginning of the project, the first task was the assembly of a reference assortment of hops. The eventual selection for phenotyping included 251 hop varieties, breeding lines, and wild hops, representing the entire Hüll gene pool. The following criteria came into play in the selection: broad genetic distribution; prior availability of plenty of agronomic data from different years and locations; genotypes with special compounds (e.g., high beta acids, xanthohumol, or special aroma profiles and substances). In addition, genotype x environmental interactions could be generated specifically for the 52 genotypes of the reference group that are grown repeatedly, whereby repetition is defined as 4 to 24 plants or, in some cases, to 500 plants.

Over a six-year period, a very broad-based and intensive phenotyping effort revealed more than 40 distinct agronomic characteristics in the reference group, as well as extensive chemical data regarding bitter and aroma substances.

Extremely hot and dry weather conditions in the summers of 2017 and 2018 resulted in a significant reduction of alpha acid and oil contents in hops that are known to be less hot- and/or drought-tolerant. Often, there was also a drop in yield, which is not surprising considering that none of the test sites were irrigated. In addition, the relatively long periods of heat and drought in both years led to stress reactions such as loss of leaves, fewer lateral shoots, less or earlier flowering. These factors also contribute to the lower yields.

In 2019 and 2020, after the two extreme years, phenotyping was continued, albeit on a somewhat reduced scale, when material could be collected under "more normal" weather conditions. This increased the amount of additional data for association mapping,

The agronomic surveys documented such characteristics as the start of flowering and ripening, as well as resistances and tolerances to the most important diseases and pests. Resistance data from the powdery mildew and downy mildew leaf test systems were also added. The assessment criteria for this phenotyping are largely based on the protocol of the EU Plant Variety Office for testing for distinctiveness, uniformity, and stability in hops (CPVO-TP / 227/1, 2006), while taking into account the BBCH growth stages (Rossbauer et al., 1995), as well as the evaluation criteria according to Weihrauch et al. (2010).

The female hops were harvested and their yield was determined after kilning. In addition, the dried cones were assayed, which, in addition to the field assays, allow an overall assessment of their resistance to downy mildew, powdery mildew, botrytis, and aphids. In addition, these cone assessments of the harvest generated information about the cone shape, color, and plucking characteristics.

The determination of the cone compounds was particularly important. The chemical analyzes for the quantitative determination of bitter acids were carried out according to the protocols standardized by the European Brewery Convention (EBC) (EBC 7.4 = conductometric method, EBC 7.7 = HPLC technology and near-infrared spectroscopy = NIRS). In addition, aroma-relevant metabolites, mostly from the group of terpenes, were detected by means of GC-MS. This allowed for the quantification of more than 130 compounds. In addition, there was a determination of the total oil content after water distillation (EBC 7.10).

These phenotypical data together with historical phenotype information from more than 30 years of practical breeding experience provide the starting point for association mapping so that these data can be linked to genotype data using biostatistical methods.

Generation of genotype data

A portion of the data from earlier project work had been generated and processed by the Max-Planck-Institute for Developmental Biology. The sequencing data for all genotypes of the reference group could only be provided after a significant delay, in April 2020. This was after the University of Hohenheim (UHOH) had taken over this part of the study, starting in 2019.

A previous analysis of an F_1 mapping population intended to generate a genetic map of hops did not produce the desired result. Therefore, no genetic map, that is, no sequence of markers in the genome, was available for association mapping. Nevertheless, a regression analysis brought to light genetic markers for two genes that transmit resistance to powdery mildew in the F_1 mapping population.

Association mapping

The Max-Planck-Institute had compared the first part of the GBS raw data of 104 varieties/strains to the Teamaker reference genome, which, however, contined considerable gaps. Starting in 2019, the UHOH finally compared the sequencing data of all 242 strains to the newly available reference genome of the Cascade variety (Padgitt-Cobb et al., 2019). These data were made available to the LfL in April 2020. Although more strains were available for the second genome comparison with Cascade, fewer markers with good quality could be filtered out. For an initial association mapping, weighted averages from the Hüll site, from 2014 to 2019, were used to focus on the highly hereditary characteristics of "content of alpha and beta acids, cohumulone, and xanthohumol." Using mathematical models, the genome-wide SNPs from the sequence data were linked with all available phenotypical data (association mapping). In the models, the direction of breeding objectives (high alpha vs. low alpha) served as a correction factor for the population structure and as a covariance for family relationships.

A

the data set based on the comparison to the Teamaker genome produced more markers associated with hop compounds. To compare the results of both analyzes without a genetic map, the number of possible gene locations was calculated based on the correlation between the significant markers. Three to eight correlation clusters could be identified for the characteristics. Also, there was a very high agreement between associated markers identified by both genome alignments. This suggests that the same gene locations were mapped. An in-depth mapping of the hop compounds and other characteristics will be carried out as soon as the UHOH has completed its evaluation of the phenotypical data.

Table 6.4: Overview of the number of strains used and the results of their association mapping. The number of associated markers was determined using a limit value of p = 0.001; the number of possible loci corresponds to the number of clusters found in a correlation analysis between the markers.

	Teamaker genome comparison	Cascade genome comparison
Number of genotyped strains	104	242
Number of phenotyped strains in Hüll	104	147
Number of available markers	532,116	83,243
Number of markers used after sorting	88,207	21,399
Genome-wide association mapping		
Alpha acids		
Number of associated markers	152	53
Number of possible gene locations via correlation	3	2
Beta acids		
Number of associated markers	155	34
Number of possible gene locations via correlation	3	2
Cohumulone		
Number of associated markers	277	35
Number of possible gene locations via correlation	2	4
Xanthohumol		
Number of associated markers	102	29
Number of possible gene locations via correlation	8	3-4

Collaboration with the GfH in evaluating high alpha strains for the quality of their bitterness in beer

The preliminary work for brewing tests as part of the GHop project involved the selection of two high alpha breeding lines (2010/80/728 and 2011/71/19), in November 2019. The selections for the brewing tests were made by the GfH expert panel following an earlier positive aroma assessments. Based on a standardized brewing protocol, the two high alpha strains were used in brewing trials, as was Herkules for comparison. The brewing locations were the research brewery of the Technical University of Munich-Weihenstephan, as well as the pilot breweries at St. Johann and the Bitburger Brewing Group. The beer tastings for the evaluation of the bitter quality took place in Wolnzah, on June 23, 2020. Both high alpha strains received bitter quality ratings that were comparable to those of Herkules.

For several years now, both strains have also been cultivated in commercial plots in the Hallertau, as well as on a trial basis in Tettnang and the Elbe-Saale region. Since the spring of 2020, the 2011/71/19 breeding line, which has the most favorable agronomic properties among the two lines, has also been tested in large-scale trials on commercial farms.

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7 Hop Quality and Analytics

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

7.1 General

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

Hops have three groups of valuable ingredients. In order of importance, these are bitter substances, essential oils and polyphenols (Figure 7.1)

Figure 7.1: Valuable compounds in hops

Alpha acids are considered the primary quality feature of hops, since they are a measure of the bitter potential. In addition, the amounts of hops added to the beer are based on their alpha acid content. Currently, the international average amount of alpha acids added to beer is about 4.3 g per 100 l. Alpha acids are also increasingly important in setting hop prices. Hop growers are either paid directly by the weight of alpha acids (in kilograms), or there are additional clauses in hop contracts for surcharges and discounts if shipments are outside an agreed-upon "neutral" alpha acid range.

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

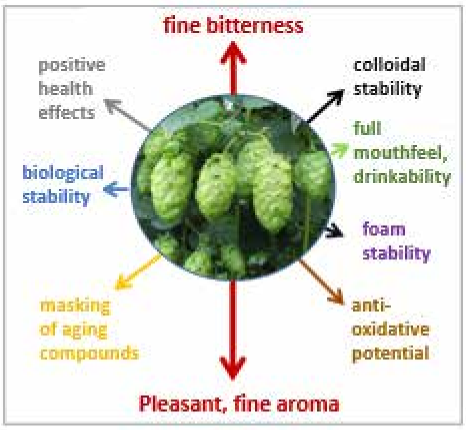


Figure 7.2: The many contributions of hops to beer

7.2 Which requirements should the hops of the future fulfill?

Hops are grown almost exclusively for brewing beer. Some 95% of it is used in breweries and only 5% in other applications. There are now efforts underway to find additional uses for the plant (Figure 7.3).

Figure 7.3: Uses for hops

7.2.1 Demand from the brewing industry

With regard to the use of hops in the brewing industry, there are very different philosophies. Some users are only interested in cheaper alpha acids; others select hops very deliberately according to variety and cultivation terroir (Figure 7.4). Some breweries fall into the middle between these two views.

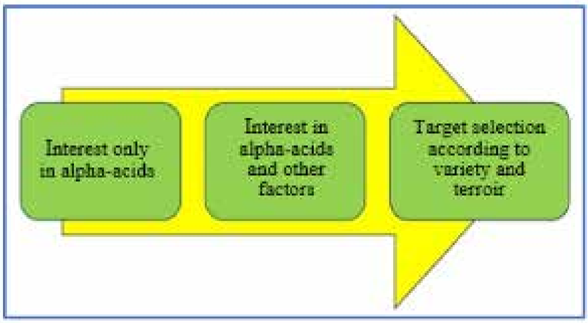


Figure 7.4: Different philosophies regarding the use of hops

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

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

7.2.1.1 Special requirements of craft brewers

Until recently, the craft brew movement has been viewed as the great hope for the hop industry. Meanwhile, as a result of the corona pandemic, craft brewers have suffered disproportionally because their beers are mainly sold on-premise in pubs, restaurants, and tap rooms, where sales have plummeted during the lockdowns.

However, the requirements that craft brewers place on hops remain. They prefer hops with fruity and floral aromas, which differ from the aroma profile of classic varieties. Some producers group these hops under the term "Special Flavor Hops".

7.2.1.2 Dry hopping is experiencing a Renaissance

Craft brewers rediscovered the classic technique of dry-hopping, that is, of adding hops to cold beer. This process was already well known in the nineteenth century and is now being revived. It is a form of cold extraction, whereby hops are added to the finished beer in the bright, lagering, or conditioning tank; and the dosages are calculated based on the hop oil content, not on the amounts of alpha acids. Beer is a polar solvent; and the average beer contains roughly 92% water and 5% ethanol. This means that the compounds released by the hops in the cold area are primarily polar (Figure 7.5).

Figure 7.5: The solubility of hop compounds is based on their polarity

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

The group of polyphenols is also soluble because of their polarity, as are, unfortunately, some undesirable substances, such as nitrate, which is completely absorbed by beer. The average nitrate content of hops is about 0.9%. However, the legal nitrate limit in drinking water (in Germany) is 50 mg/l; and it does not apply to beer. Plant protection products are generally non-polar and therefore not very soluble in water. This means that dry-hopped and non-dry-hopped beers have the same amount of trace elements of these products.

7.2.2 Alternative uses of hops

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

As for cones, the antimicrobial properties of their bitter acids are of special interest for alternative uses. Even in catalytic quantities (0.001 to 0.1% by weight), they reveal their antimicrobial and preservative effectiveness, in ascending strength from iso-alpha acids, to alpha acids, to beta acids polar (Figure 7.6).

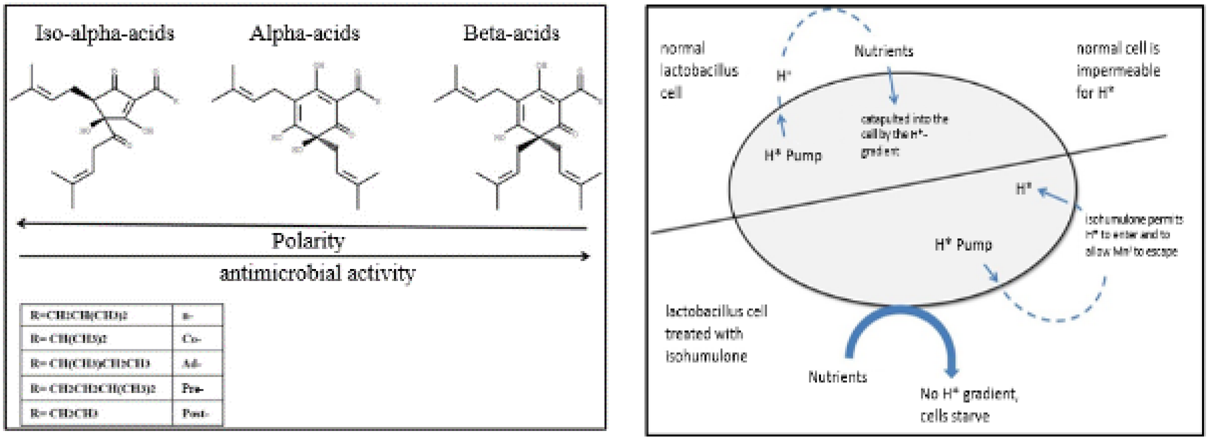


Figure 7.6: Sequence of antimicrobial activity of iso-alpha acids, alpha acids, and beta acids, as well as their effectiveness

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

Other possible uses of the antimicrobial properties of hops are as preservatives in the food industry (fish, meat, and dairy products) or as antibiotics in animal nutrition, as well as for sanitizing biohazardous waste (sewage sludge, compost) and for the elimination of mold infestations. They can also be used as odor and hygiene improvements in litter and for the control of allergens. It is certainly conceivable that the use of hops in these applications will increase in the future. Therefore, developing hops with an increase in beta acids is also a breeding objective in Hüll. The current record in beta-acid is at about 20%. There is even a breeding line that produces only beta and no alpha acids. This variety is used for tea.

Because hops contain a large number of polyphenolic substances, they are also of interest for applications in health, wellness, nutritional supplements and functional foods. Hops can have a polyphenol content of up to 8%, which puts them into the group of very polyphenol-rich plants. Polyphenols are generally considered beneficial because they are antioxidants and can trap free radicals. Substances in hops with very high antioxidative potential include oligomeric proanthocyanidins (up to 1.3%), glycosidically bound quercetin (up to 0.2%), and kaempferol (up to 0.2%). Anti-inflammatory multifidols, too, are significant compounds in hops. Their name derives from the tropical plant *Jatropha multifida*, which exudes a milky latex sap that contains these compounds. Finally, hops contain trace amounts of prenylated flavonoids such as 8-prenylnaringenin, which is one of the strongest phytoestrogens. Therefore, hops have a mild estrogenic effect.

Of all the hop polyphenols, however, xanthohumol has received the most public attention. Scientific work on this polyphenol has exploded, which has led to the European Food Safety Authority (EFSA) of the European Union to recognize the health-promoting effects of xanthohumol. This means that xanthohumol can now be marketed with health claims for applications in food supplements and functional foods. Comprehensive information about the history of xanthohumol and its effects can be found on the homepage of T.A. XAN Development S.A.M. (https://www.xan.com). The benefits of xanthohumol cover a broad spectrum (Figure 7.7), but its most important aspect, no doubt, is its anticarcinogen effect.

During the brewing process, prenylated flavonoid is constantly being transformed (Figure 7.7). During the wort boil, xanthohumol is isomerized to iso-xanthohumol, and dimethyl-xanthohumol, to 8- and 6-prenylnaringenin. Therefore, desmethyl-xanthohumol cannot be found in beer. On the other hand, concentrations of prenylated naringenins are significantly higher in beer than in hops.

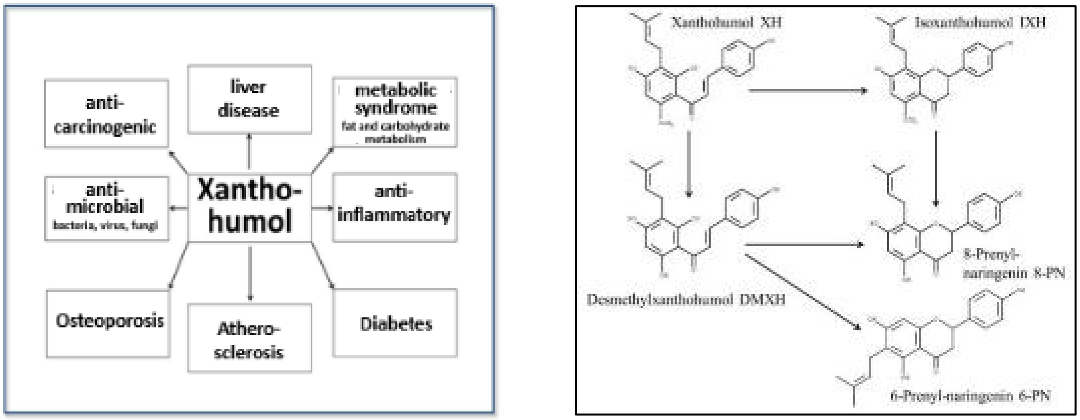


Figure 7.7: Effects of xanthohumol and its transformations in the brewing process

The estrogenic effect of 8-prenylnaringenin (8-PN) stems from the fact that the structure of this substance is similar to that of the female sex hormone 17-beta-estradiol.

7.3 Bitter Intensity and Bitter Quality

It is true that the amount of alpha acids in hops is a measure of their bitter potential. However, the quality of this bitterness depends not only on the concentration of alpha acids but also on many other substances which accompany the acids and certainly contribute to pleasant, well rounded, and harmonious bitterness sensations (Figure 7.8).

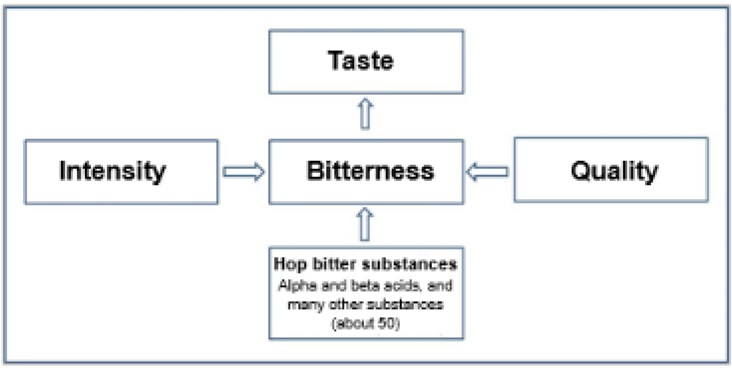


Figure 7.8: The intensity and quality of the bitterness is determined by a variety of substances

In a dissertation at the TUM in 2013, Dr. Dresel used LC-MS to explain many of these substances. Many of them are degradation and transformation products of alpha and beta acids, such as humulinic acids, humulinones, allo-iso-humulones, hulupones, hulupinic acids, tricyclohumens, tricyclolupones, dehydrotricyclolupones, and many other substances (Figure 7.9 and Figure 7.10).

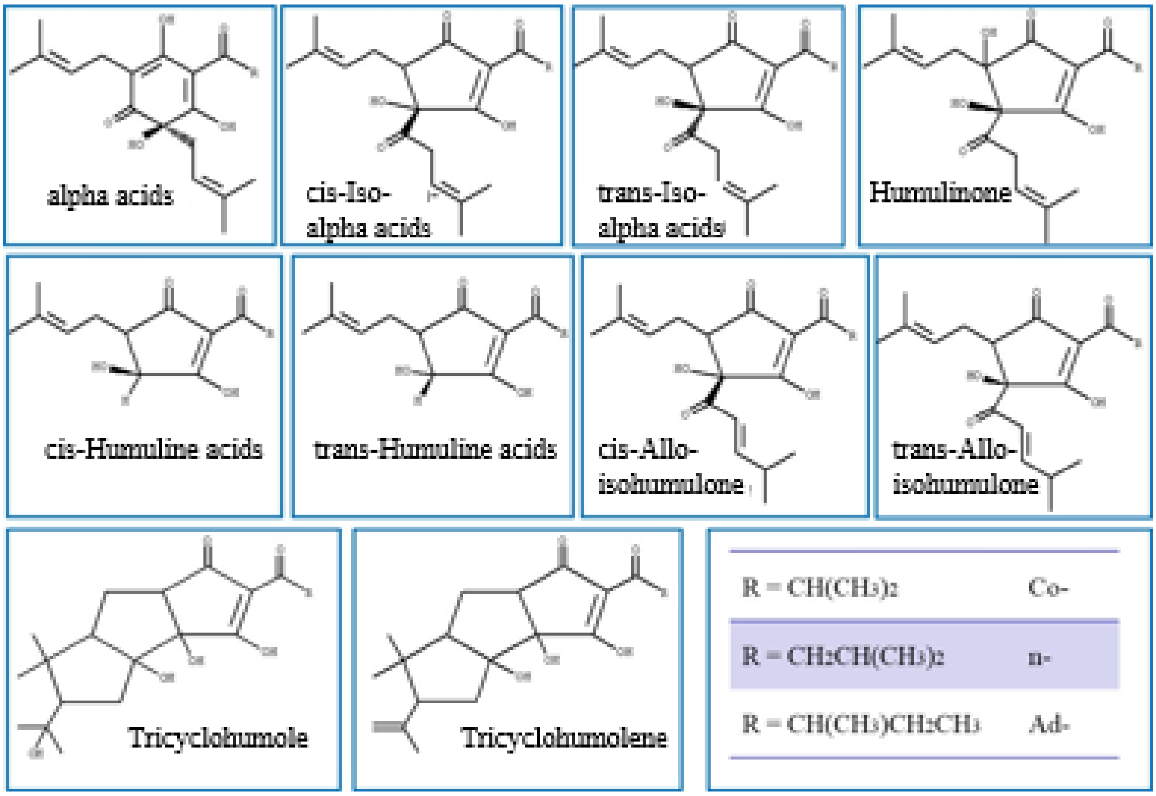
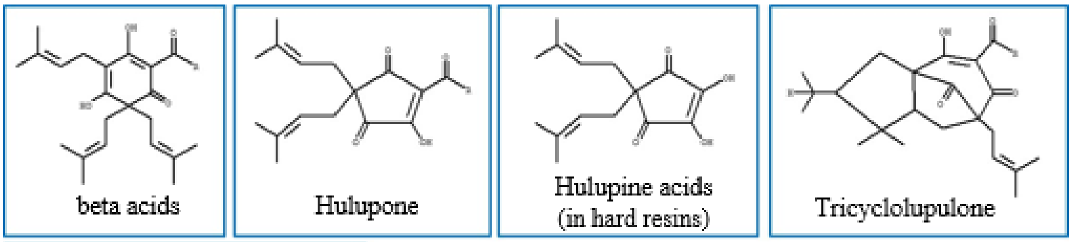


Figure 7.9: Rearrangement and oxidation products of the alpha acids



R = $CH(CH_3)_2$	Co-
R = $CH_2CH(CH3)_2$	n-
R = $CH(CH_3)CH_2CH_3$	Ad-

Figure 7.10: Rearrangement and oxidation products of beta acids

In addition to the primary compound, xanthohumol, many additional compounds that are derived from xanthohumol are also found in hops, but in lower concentrations (Figure 7.11).

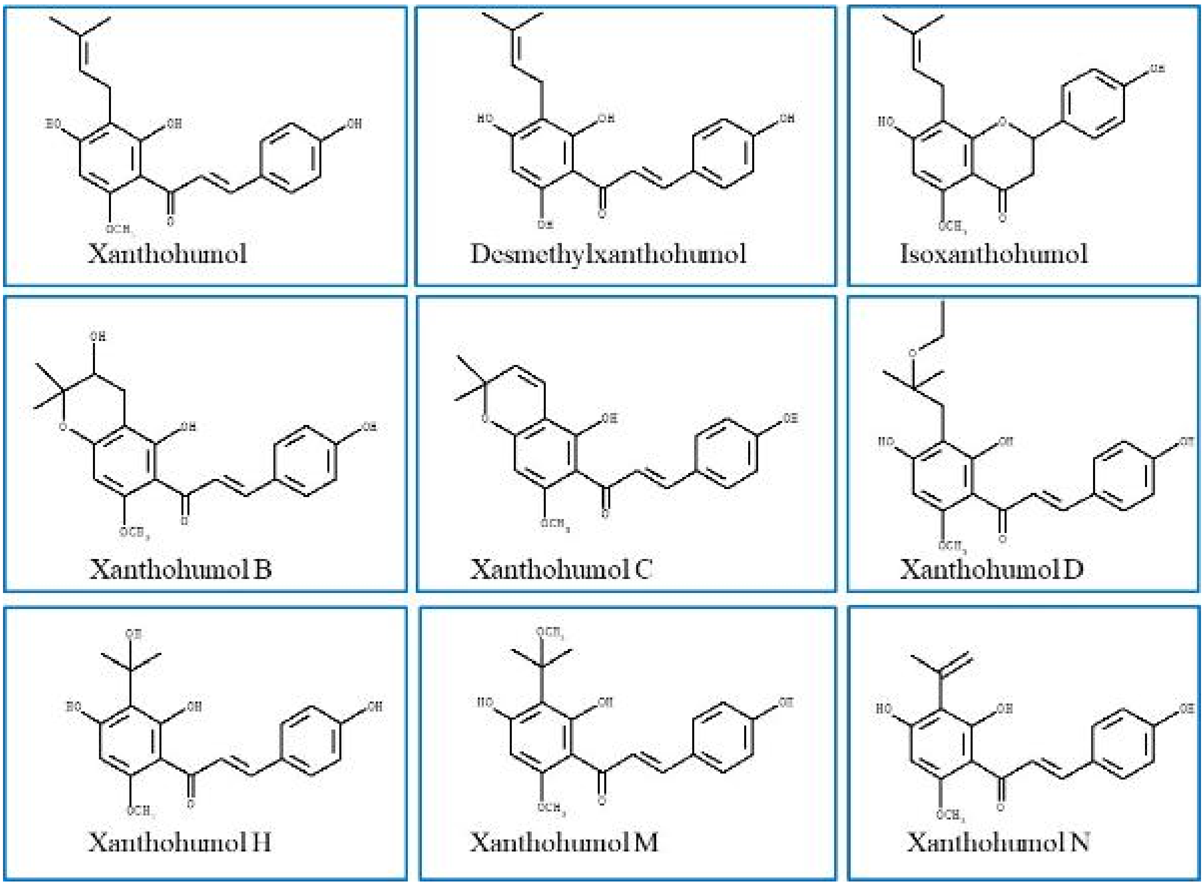


Figure 7.11: Xanthohumol and compounds derived from xanthohumol

The degree to which these substances can be dissolved in beer depends on their polarity. Humulinone, for instance, is very soluble, while the xanthohumol derivatives are not very soluble. Because of their high polarity resulting from the glycosidic bond, quercetin and kaempferol glycosides (Figure 7.12) as well as the multifidol glucosides (Figure 7.13) are readily soluble in wort and are fully transferred into beer. These substances are genetically determined, which makes them suitable for identifying different varieties.

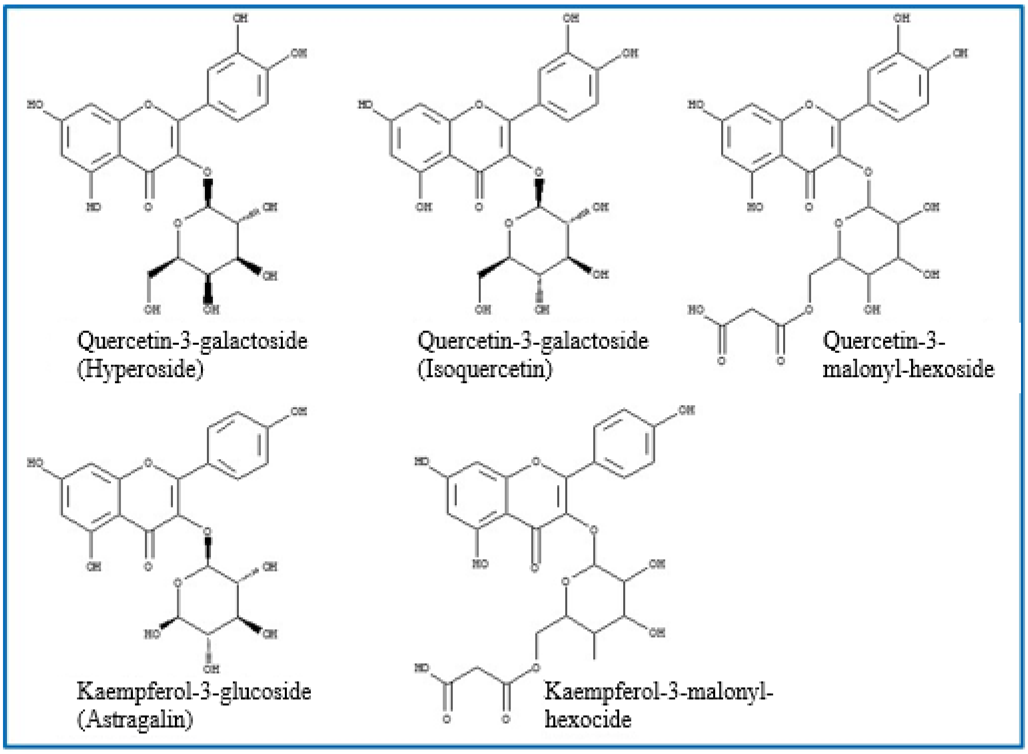


Figure 7.12: Quercetin and kaempferol glycosides

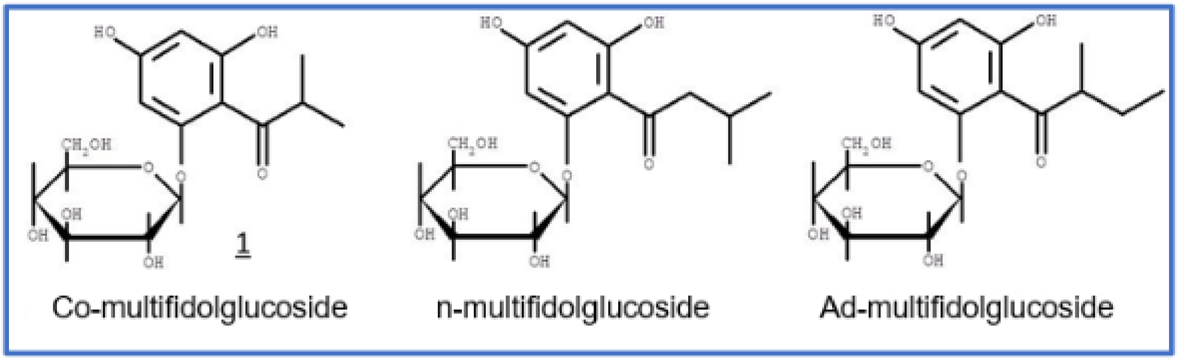


Figure 7.13: Chemical structures of multifidol glucosides

Analogous to Co-, n- and Adhumulon there are Co-, n- and Ad-Multifidolglucosid. These compounds are by-products of the biosynthesis of the bitter substances.

7.3.1. Isolation, identification, and analytics of multifidols in hops

For 2020 and 2021, this research project is funded with a grant of € 10,000 from the Wissenschaftliche Station für Brauerei München e.V. (Scientific Station for Brewery Munich e.V).

Quercetin and kaempferol glycosides, as well as multifidols occur in hops in relatively high concentrations. Because of their polarity, they are easily soluble in water. They also have low taste thresholds. Table 1 shows their taste thresholds according to Dr. M. Biendl and S. Cocuzza (Hartharze, Hopfenrundschau International, 2016/2017, 60-68).

Table 7.1: Taste thresholds of low-molecular-weight polyphenols in hops and the percent of beers in which they transgress these thresholds.

low molecular weight Polyphenols	Taste Threshold in mg/l	Percent of beers exceeding the taste threshold
Quercetin-3-glucoside	0.9	86
Kaempferol-3-glucoside	0.5	95
Kaempferol-3- (malonyl) hexoside	2.7	1
Co-multifidol glucoside	1.8	54

A total of 88 beers were examined. The multifidol glucosides are also of pharmacological interest because they have anti-inflammatory properties (Bohr, G., Gerhäuser, C., Knauft, J., Zapp, J., Becker, H .: “Anti-inflammatory Acylphloroglucinol Derivatives from Hops (Humulus lupulus), J. Nat. Prod. 2005, 68, 1545-1548).

The initial objective of this project was to develop a suitable sample preparation technique and an analysis method for multifidol glucosides. These should then be applied for quantitative analyses of the most important hop varieties.

A mixture of methanol and water (90:10) has proven to be ideal for extracting multifidols. Using an ultrasonic bath with 50 ml of solvent for 15 minutes, 5 g of hops are subjected to an extraction. The resulting liquid is then filtered twice, first with a folded filter and then with a syringe nylon filter made by Roth, with a porosity of 0.23 µm, ø 33 mm. Of this filtrate, 5 ml are placed in a 10 ml volumetric flask. Then 1 ml of a pure reference substance („standard“) is added, after which the overall volume is brought up to 10 ml. For the HPLC analysis, samples are filled into 1.5 ml vials.

The instrument for the HPLC analysis is the tAccela 10000 HPLC system from Thermo Scientific. The selected analytical column is the EC 125/2 Nucleodur 100 3 C18 produced by Macherey-Nagel.

The analysis is conducted with the following gradient program:

Solvent A = H2O:methanol (90:10); solvent B = methanol

Gradient program:

Time in minutes	Solvent A	Solvent B	Flow
0	100	0	900 µl/Min.
30	0	100	900 µl/Min.
31	100	0	900 µl/Min.

The detection wavelength is 280 nm. The co-multifidol glucoside elutes at 6.4 minutes and the flavone at 16.6 minutes (Figure 7.14).

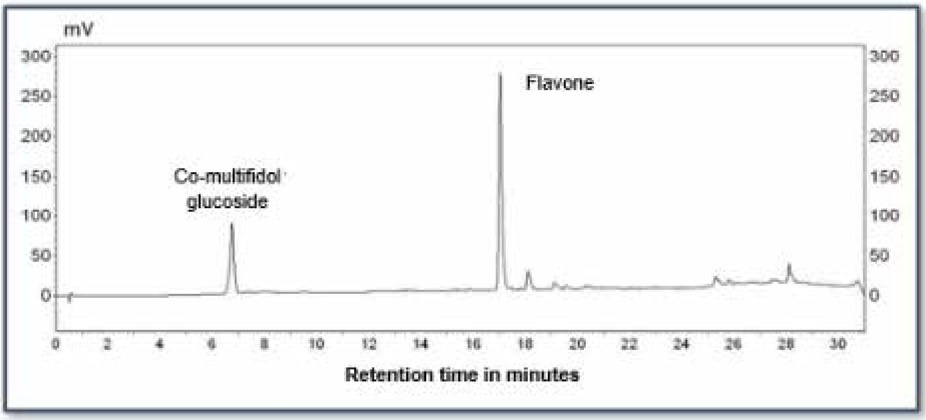


Figure 7.14: Chromatogram of co-multifidol glucoside - flavone

Figure 7.15 shows the UV spectra of the co-multifidol glucoside and the flavone.

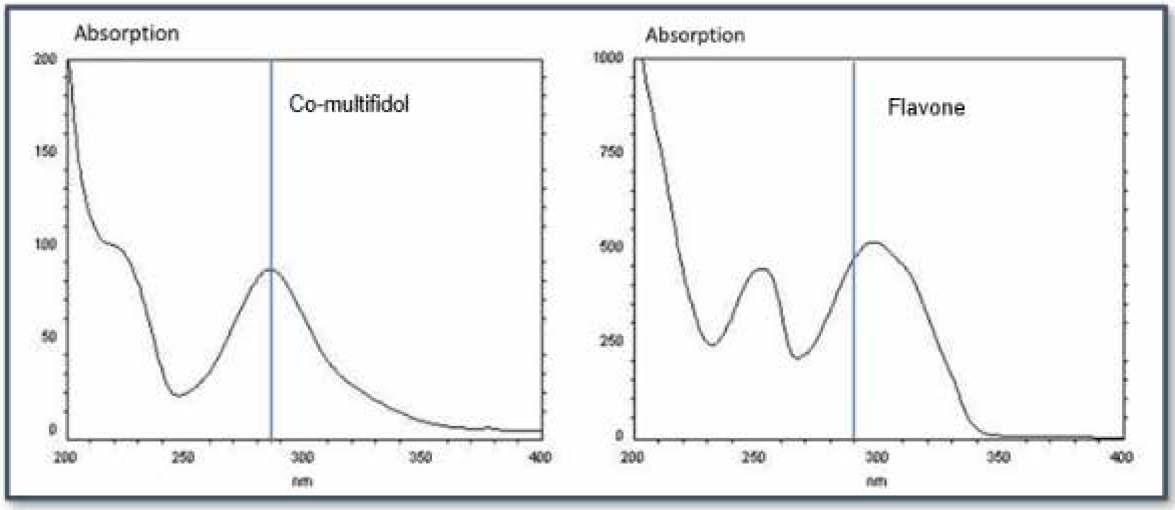


Figure 7.15: UV spectra of the co-multifidol glucoside and of flavone

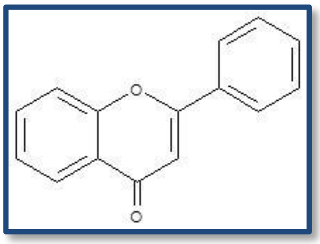


Figure 7.16: Chemical structure of flavone

The co-multifidol glucoside has an absorption maximum at 280 nm; and the flavone, at 300 nm. However, flavone still absorbs very well even at 280 nm and is therefore suitable as a secondary standard. Flavone (Figure 7.16) does not occur naturally in hops and can therefore be used as an internal or external standard.

Dr. Wietstock of the TU Berlin has isolated the co-multifidol glucoside from hops at 96% purity, using preparative HPLC. Then the response factors at the wavelength 280 nm were determined. The ratio of the response factors of co-multifidol glucoside to flavone is almost exactly 1:3.

Response-Factor

Co-multifidol glucoside: Flavone **1:3**

For the analysis, 100 mg of flavone are dissolved in 50 ml of methanol and water at a ration of 90:10. This is then diluted to 1:10 and used as a standard for analysis.

Figure 7.17 shows the results for important hop varieties, which have very different contents. Herkules has the highest co-multifidol glucoside content and Hersbrucker Spät the lowest.

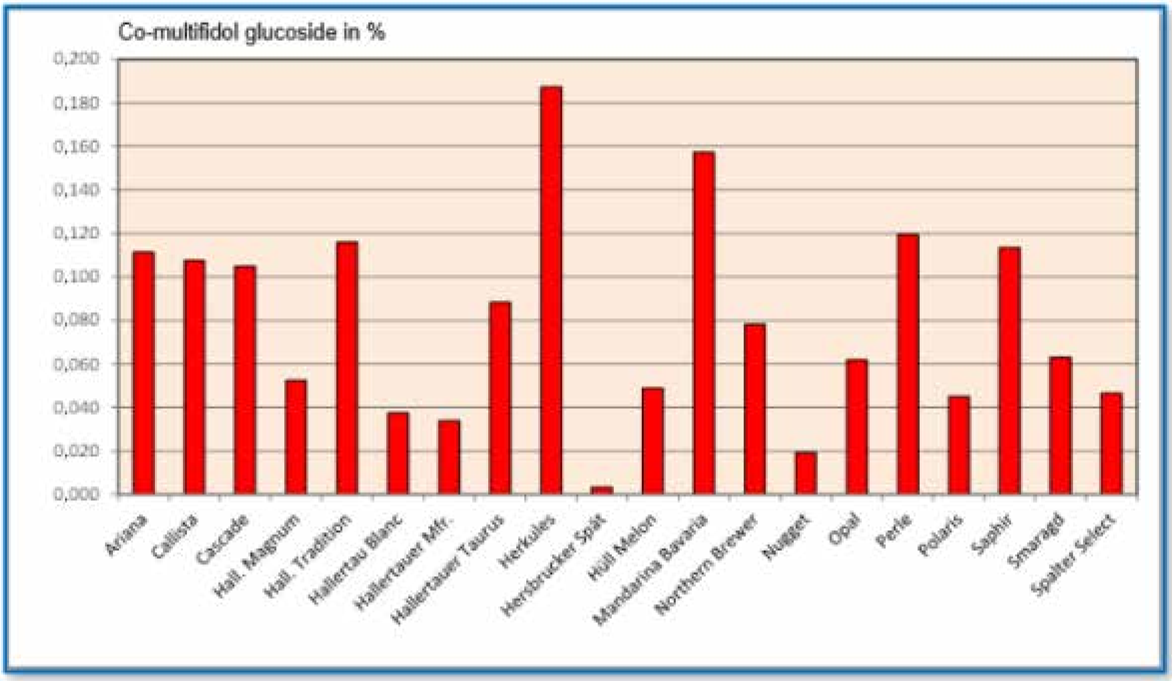


Fig.7.17: Co-multifidol glucoside content of important hop varieties

However, there is no correlation with the alpha acid content. Some varieties with high alpha acid contents, such as Herkules or Polaris, tend to have a fairly low co-multifidol glucoside content, while other varieties, such as the low alpha acid Saphir, have a high co-multifidol glucoside level. Figure 7.18 shows an evaluation of the correlation between alpha acid content and the co-multifidol glucoside content. The illustration demonstrates that there is no correlation.

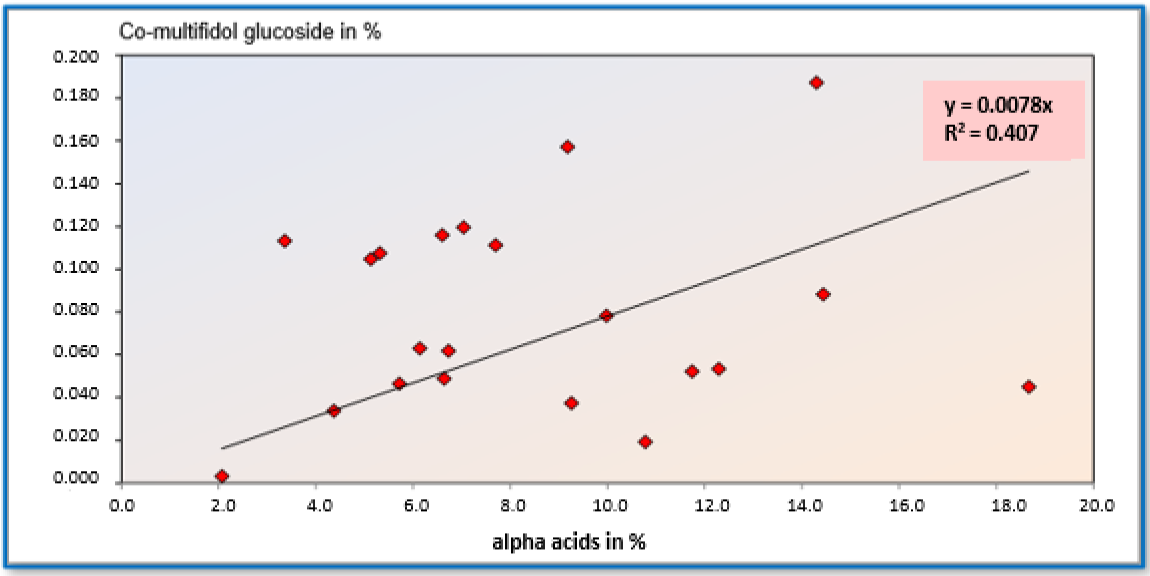


Fig.7.18: Correlation between alpha acid and co-multifidol glucoside levels

In future work, more data needs to be collected to determine if the varietal differences can be confirmed. The entire analysis program needs to be reworked in 2021. This also allows for the detection of differences between growing years. In the end, the results are planned to be published in a specialty journal.

7.4 World hop portfolio (harvest 2019)

Every year, the essential oils are analyzed with headspace gas chromatography; and the bitter substances, with HPLC. Table 7.2 shows the results for the 2019 harvest year. It can be used as an aid to assign unknown hop varieties to a specific variety type.

Hop compounds are identified by their variety-specific DNA, although many external factors also play a role in the development of the morphological appearance and of the metabolome of the compounds (Figure 7.19).

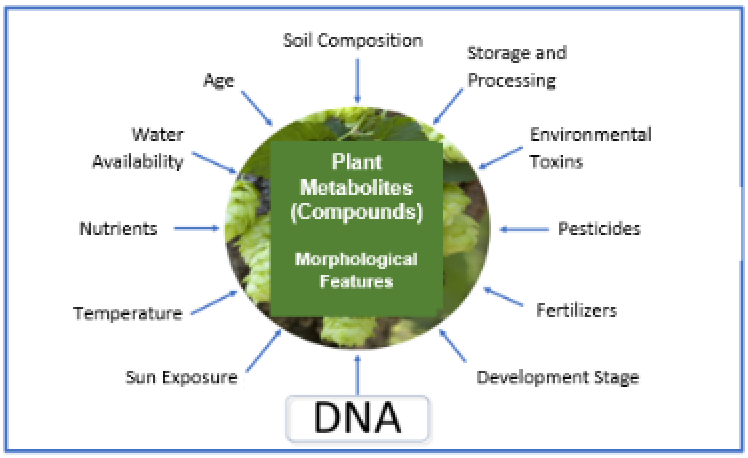


Figure 7.19: The morphology and the metabolome of hops are determined by many factors

Table 7.2: World hop portfolio (Harvest 2019)

Sorte	Myr cene	2-Metyl-butyl-isobutyrat	Methyl-isohep-tanoate	ß-Oci-mene	Lina-lool	Aroma-den-drene	Unde-ca-none	Hu mu-lene	ß-Far-nesene	ɡ-Muu-rolene	ß-Seli-nene	a-Seli-nene	ß/ɡ-Ca-dinene	3.7-Seli-nadiene	Gera-niol	a-acids	ß-acids	ß/a	Co-humo-lone	Co-lupu-lone
Admiral	5476	1828	1	259	94	0	1	688	0	20	2	5	44	0	0	14.2	5.5	0.38	43.5	71.5
Agnus	812	113	0	24	20	0	8	161	0	23	4	8	45	0	11	9.8	4.6	0.47	32.9	58.1
Ahil	5932	1167	111	41	54	0	14	134	64	17	7	14	38	1	17	7.5	3.6	0.47	35.9	59.2
Alliance	1649	318	0	11	37	0	13	439	0	19	2	3	47	0	0	3.1	2.1	0.66	29.4	45.0
Aquila	4390	424	1	677	48	37	30	54	2	28	45	93	28	145	9	5.3	3.8	0.73	49.0	60.6
Ariana	3795	656	292	481	34	0	44	548	0	24	30	57	37	0	2	8.0	5.1	0.64	40.3	58.0
Atlas	4948	1227	76	57	45	0	0	164	94	17	6	13	38	1	26	6.3	3.6	0.57	38.2	58.0
Aurora	3903	564	1	395	97	0	82	108	49	17	2	3	41	1	3	7.8	3.3	0.42	23.9	51.1
Backa	3540	1167	1	177	57	0	17	192	18	20	2	3	43	0	0	7.2	4.5	0.62	47.8	63.5
Belgisch Spalter	2262	420	0	101	53	9	34	342	0	22	19	41	32	77	0	4.6	3.2	0.69	19.2	44.1
Blisk	2884	550	59	51	48	0	3	74	93	19	5	9	48	0	18	5.6	3.1	0.56	33.1	54.5
Bobek	7577	835	38	708	158	0	69	176	13	19	2	4	44	0	11	4.4	4.4	1.01	26.3	47.9
Bor	2822	382	1	439	23	0	19	501	0	16	2	3	40	0	3	6.8	3.9	0.58	27.6	49.2
Bramling Cross	4808	768	0	29	71	0	30	660	0	15	2	3	35	0	0	3.2	3.2	1.00	40.5	52.7
Braustern	1514	237	0	234	15	0	11	320	0	18	2	3	44	0	1	5.6	3.8	0.68	25.5	49.3
Brewers Gold	1736	317	54	157	27	0	3	267	0	17	4	8	41	0	15	7.5	4.5	0.60	40.0	66.2
Buket	2804	476	1	470	71	0	50	81	36	20	2	3	47	0	3	7.1	3.9	0.54	20.1	49.3
Bullion	2089	412	64	126	29	0	1	320	0	18	5	11	36	0	2	7.3	5.4	0.74	45.5	61.3
Callista	3855	507	208	30	146	0	28	555	0	31	43	81	54	2	2	3.6	7.4	2.04	19.4	38.9
Cascade	4192	677	94	99	51	0	11	266	28	28	11	23	46	0	10	4.7	4.4	0.94	34.9	52.1
Centennial	2766	547	181	15	56	0	4	388	0	30	2	3	56	0	33	6.5	2.7	0.42	30.5	54.2
Challenger	4511	930	1	198	56	0	34	635	0	18	31	69	35	0	0	4.4	3.6	0.81	28.5	50.5
Chang bei 1	4329	634	2	12	69	0	30	192	15	28	17	37	56	34	5	2.2	3.8	1.77	12.4	38.8
Chang bei 2	3981	2	9	8	67	0	34	148	11	21	13	27	36	46	2	2.0	3.7	1.79	8.0	36.8
Chinook	1497	359	48	24	17	0	5	284	0	61	8	15	123	26	8	9.7	3.2	0.33	31.7	55.7
Columbus	2654	415	75	73	22	0	2	305	0	45	8	14	74	26	2	12.1	3.9	0.32	36.5	60.1

Sorte	Myrcene	2-Metylbutyl-isobutyrat	Methylisoheptanoate	ß-Ocimene	Linalool	Aromadendrene	Undecanone	Humulene	ß-Farnesene	γ-Muurolene	ß-Selinene	α-Selinene	ß/γ-Cadinene	3.7-Selinadiene	Geraniol	α-acids	ß-acids	ß/α	Cohumolone	Colupulone
Comet	1879	259	22	146	24	0	4	9	0	5	31	65	7	21	4	8.7	4.1	0.46	39.1	61.3
Crystal	2978	397	4	199	86	42	18	483	0	31	25	52	46	83	2	2.1	4.5	2.10	22.0	36.3
Density	4978	816	0	33	76	0	30	652	0	15	2	3	35	0	0	3.0	3.2	1.07	39.1	52.5
Diva	2883	622	4	152	112	0	79	495	0	26	83	170	55	0	7	6.1	4.9	0.81	26.3	49.2
Early Choice	1720	318	1	64	13	0	12	439	0	16	28	59	40	0	1	2.1	1.4	0.67	24.7	44.2
Eastwell Golding	1930	341	1	73	32	0	15	471	0	18	2	3	39	0	0	4.3	3.1	0.72	30.1	51.7
Emerald	1626	234	15	120	12	0	19	469	0	17	2	4	43	0	1	5.0	4.1	0.82	32.8	48.9
Estera	1932	405	0	29	42	0	15	223	21	18	2	3	47	0	1	2.1	2.4	1.13	22.3	46.3
First Gold	2129	623	0	82	59	0	31	410	0	21	82	174	54	0	2	8.0	4.0	0.49	30.8	54.1
Fuggle	2483	410	1	26	42	0	15	125	7	19	1	3	45	0	1	3.2	2.3	0.72	30.4	50.9
Galena	4277	1183	237	657	8	0	2	476	0	16	6	12	39	1	1	10.5	7.8	0.74	41.1	63.4
Ging Dao Do Hua	4622	1217	0	24	45	0	3	543	0	46	29	61	86	4	11	5.4	4.4	0.81	50.2	60.9
Glacier	3856	287	7	25	77	0	26	635	0	20	2	4	45	0	2	2.9	5.6	1.93	9.3	39.2
Golden Star	4306	1252	0	18	43	0	21	559	0	50	31	64	108	0	8	5.2	3.7	0.70	52.0	65.4
Granit	2823	448	20	167	17	0	40	436	0	18	5	10	40	2	2	7.0	4.1	0.58	24.7	48.2
Hallertau Blanc	11404	2815	847	32	182	0	37	112	0	40	592	1223	61	3	13	8.9	5.7	0.64	24.4	40.4
Hallertauer Gold	2503	231	53	51	50	0	19	487	0	18	2	3	42	0	1	5.9	5.3	0.90	22.3	42.8
Hall. Magnum	2013	335	139	135	20	0	12	353	0	17	2	3	40	0	2	11.4	6.3	0.55	27.4	44.6
Hall. Merkur	1826	368	74	38	50	0	15	351	0	21	2	4	52	0	1	10.9	5.2	0.48	19.5	42.8
Hallertauer Mfr.	1606	287	45	20	50	0	26	417	0	23	2	4	53	0	1	3.7	3.7	0.98	24.7	41.1
Hall. Taurus	3872	449	101	173	109	0	37	464	0	18	42	84	43	0	2	14.1	4.5	0.32	22.5	43.7
Hall. Tradition	2075	305	45	48	61	0	23	467	0	21	2	3	45	0	1	5.5	3.9	0.72	26.6	47.1
Harmony	2865	260	3	73	67	0	30	433	0	20	53	113	46	0	3	6.7	5.4	0.80	22.6	42.0
Herald	2410	677	1	361	35	0	103	328	0	16	18	37	41	0	7	9.4	3.8	0.40	38.9	62.1
Herkules	3324	665	311	443	27	0	25	494	0	17	2	3	41	0	7	16.9	4.8	0.29	33.5	55.3
Hersbrucker Pure	4804	700	22	182	80	12	35	560	0	29	16	34	50	65	2	3.6	2.1	0.58	26.7	49.1
Hersbrucker Spät	2184	270	7	51	77	36	12	368	0	28	27	51	37	73	2	2.6	5.2	1.97	19.0	35.0

Sorte	Myrcene	2-Metyl-butyl-isobutyrat	Methyl-isoheptanoate	ß-Ocimene	Linalool	Aromadendrene	Undecanone	Humulene	ß-Farnesene	γ-Muurolene	ß-Selinene	α-Selinene	ß/γ-Cadinene	3.7-Selinadiene	Geraniol	α-acids	ß-acids	ß/α	Cohumolone	Colupulone
Huell Melon	7663	2940	1	258	68	0	57	75	121	61	254	491	122	152	29	5.7	7.5	1.32	30.0	49.3
Hüller Anfang	2061	410	27	15	46	0	21	531	0	23	4	7	50	0	0	1.9	3.3	1.71	20.3	41.8
Hüller Aroma	2477	434	14	35	65	0	27	551	0	25	7	15	50	0	1	3.8	3.6	0.95	27.2	46.2
Hüller Fortschritt	1984	173	13	7	51	0	23	539	0	20	2	4	46	0	0	2.0	3.4	1.74	32.8	46.4
Hüller Start	1188	149	0	13	24	0	33	424	0	25	2	4	48	0	1	2.0	3.2	1.65	15.5	44.6
Kazbek	2258	447	86	131	31	0	5	312	0	19	6	12	31	1	3	6.4	4.9	0.77	39.2	57.0
Kirin 1	3947	1014	0	19	40	0	19	501	0	46	28	60	105	0	9	5.3	4.1	0.77	51.0	63.4
Kirin 2	4198	1057	0	36	36	0	21	518	0	48	31	65	95	0	7	6.0	4.2	0.70	49.2	65.3
Kitamidori	1900	209	25	211	12	0	9	143	17	22	4	7	51	1	2	9.0	5.7	0.63	23.8	43.5
Kumir	2222	298	2	147	54	0	23	429	4	18	2	4	50	0	1	9.0	4.5	0.50	19.5	43.9
Late Cluster	9441	2583	154	99	159	37	7	127	0	209	69	138	371	234	14	6.8	4.2	0.62	29.6	49.1
Lubelski	3518	20	3	32	49	0	34	185	28	18	3	6	45	0	2	4.0	4.7	1.18	30.3	46.9
Mandarina Bavaria	4459	312	71	147	42	0	23	164	2	28	66	37	65	0	17	6.7	4.1	0.62	32.0	53.0
Mt. Hood	2318	595	73	44	45	0	9	493	0	31	11	22	63	0	3	4.8	4.0	0.84	30.6	47.4
Neoplanta	1609	317	0	200	13	0	12	88	18	19	2	3	44	0	1	6.9	3.4	0.49	36.3	62.0
Neptun	1199	285	133	33	51	0	8	241	0	23	2	3	51	0	1	13.3	4.4	0.33	21.9	44.5
Northdown	1906	336	0	212	21	0	11	372	0	18	2	3	45	0	1	6.0	4.3	0.72	29.4	50.9
Northern Brewer	1444	222	0	205	19	0	12	272	0	17	2	3	42	0	1	7.1	4.1	0.58	28.4	50.1
Nugget	1728	257	3	125	33	0	11	293	0	13	5	10	31	0	1	10.1	3.9	0.38	29.0	54.3
Opal	2338	238	48	208	65	0	20	372	0	17	1	1	40	0	3	6.0	4.7	0.79	15.5	35.5
Orion	1464	278	10	81	32	0	16	325	0	20	1	2	46	0	0	5.3	3.5	0.66	33.0	52.5
Perle	1199	212	4	180	13	0	11	288	0	17	2	3	42	0	2	5.1	2.9	0.56	32.6	60.9
Pioneer	1720	514	2	369	24	0	81	288	0	18	19	41	45	0	11	8.9	3.5	0.39	35.7	61.2
Polaris	1458	355	86	226	13	0	15	268	0	19	1	3	47	0	2	18.0	4.7	0.26	25.9	45.3
Premiant	2611	345	0	116	53	0	28	489	0	19	2	3	46	0	1	7.6	3.8	0.50	23.0	50.1
Progress	10347	2213	276	275	152	36	65	83	0	183	66	137	313	226	16	6.9	3.8	0.56	23.4	45.1
Record	2561	149	3	7	48	0	26	573	0	20	2	4	44	0	0	2.6	6.2	2.37	28.2	41.4

Sorte	Myrcene	2-Metyl-butyl-isobutyrat	Methyl-isoheptanoate	ß-Ocimene	Linalool	Aromadendrene	Undecanone	Humulene	ß-Farnesene	γ-Muurolene	ß-Selinene	α-Selinene	ß/γ-Cadinene	3.7-Selinadiene	Geraniol	α-acids	ß-acids	ß/α	Cohumolone	Colupulone
Relax	1870	391	54	7	27	0	35	521	0	36	3	5	64	0	15	0.3	8.2	28.93	44.7	/
Rottenburger	2750	118	1	9	49	0	24	608	0	19	2	4	46	0	0	1.7	5.1	2.93	25.9	40.0
Rubin	2116	330	113	108	31	0	9	344	0	25	51	101	48	0	9	11.7	3.7	0.32	35.6	54.9
Saazer	2879	4	5	2	64	0	70	639	11	25	2	4	58	0	4	4.8	4.0	0.84	24.8	41.0
Saphir	2967	237	6	185	83	8	114	422	0	19	12	23	34	40	3	2.7	4.2	1.58	17.1	48.1
Serebrianker	1552	279	8	16	62	0	13	315	0	30	20	39	58	0	6	1.7	5.0	2.92	17.5	40.8
Sladek	2224	301	3	163	56	0	24	433	7	19	2	4	45	0	2	8.1	4.6	0.57	19.5	42.9
Smaragd	2388	70	35	143	68	0	15	397	0	19	3	1	42	0	7	4.6	4.2	0.92	16.4	33.4
Sorachi Ace	2787	340	0	195	25	0	16	161	8	23	2	4	47	0	4	9.5	6.3	0.66	29.1	50.5
Spalter	2217	0	6	9	82	0	82	139	14	25	2	4	45	0	11	5.0	4.3	0.86	26.6	46.7
Spalter Select	4308	447	49	50	155	22	54	174	69	26	22	43	38	75	1	3.4	3.7	1.09	23.4	42.2
Strisselspalter	2282	332	3	115	81	38	17	398	0	31	28	55	43	89	2	2.9	4.5	1.57	19.1	36.8
Talisman	2273	368	1	294	17	0	11	394	0	18	2	3	39	0	1	7.5	4.4	0.59	26.3	50.0
Target	2186	538	1	197	54	0	37	308	0	34	6	12	81	13	2	10.4	4.6	0.44	34.2	58.5
Tettnanger	3349	10	11	43	86	0	68	240	51	22	2	4	48	0	14	3.3	4.0	1.20	26.0	43.2
Viking	4408	477	3	370	52	0	50	102	102	16	21	43	39	0	6	8.0	4.6	0.58	21.7	42.0
Vojvodina	3840	595	0	315	25	0	22	535	0	15	1	3	39	0	2	4.0	2.9	0.73	30.6	50.7
WFG	4840	48	4	30	80	0	63	153	22	21	2	5	48	1	4	3.5	3.6	1.04	22.5	42.5
Willamette	1630	301	1	51	38	0	7	80	16	20	2	5	46	1	2	2.9	2.8	0.97	34.9	54.6
Yeoman	1877	507	51	91	21	0	14	359	0	16	28	60	42	0	5	11.3	4.3	0.38	26.5	50.0
Zatecki	1622	341	2	75	34	0	13	212	6	17	5	10	39	0	1	2.5	2.4	0.98	30.9	47.9
Zenith	2970	366	0	223	63	0	27	485	0	18	51	116	47	0	1	6.1	2.7	0.45	19.9	48.0
Zeus	2425	400	73	86	20	0	3	307	0	45	8	14	72	25	2	12.2	4.1	0.33	35.6	59.5
Zitic	2565	14	1	108	23	0	30	494	6	18	2	4	44	0	11	4.1	4.1	1.01	26.8	46.6

Essential oils = relative values; beta caryophyllene = 100; alpha and beta acids in % liter; analogs in % of alpha and beta acids, respectively

7.5 Quality assurance in alpha acid analytics for hop supply contracts

7.5.1 Chain analyses for the 2020 harvest

Since 2000, hop supply contracts have contained a clause covering the alpha acid content of shipments. The farm price agreed upon in a contract applies if the alpha acid content is in the so-called neutral zone. If it exceeds or falls below the specified value, a surcharge or a discount applies. The instructions for the Hop Anaytics Working Group specify precisely how samples for alpha acid tests are to be handled (sample taking, storage), which laboratories are allowed to conduct follow-up examinations, and which tolerance ranges are permitted for the results of the analyses. In 2020 once again, the Working Group IPZ 5d was tasked with organizing and evaluating chain tests to ensure the quality of the alpha acid analytics.

The following laboratories took part in the chain tests, in 2020.

- Hallertauer Hopfenveredelungsgesellschaft *(Hallertau Hop Processing Society)* (HHV), Au/Hallertau plant
- Hopfenveredlung *(Hop Processing)* St. Johann GmbH & Co. KG, St. Johann
- Hallertauer Hopfenveredelungsgesellschaft (*Hop Processing Society*) (HHV), Mainburg plant
- Hallertauer Hopfenverwertungsgenossenschaft *(Hop Sales Cooperative)* (HVG), Mainburg
- AGROLAB Boden-und Pflanzenberatungsdienst *(Soil and Plant Advisory Service*) GmbH
- Bayerische Landesanstalt für Landwirtschaft, Arbeitsbereich Hopfen, *(Bavarian State Research Center for Agriculture, Hops Department)*, Hüll
- BayWa AG Tettnang

In 2020, the chain laboratory tests started on September 7 and ended on November 6, during which time most of the hop plots were examined in the laboratories. Overall, the chain tests were conducted nine times (in 9 weeks). The sample material was kindly provided by the Hallertau Hop Circle. All samples were taken from a single bale to ensure the greatest possible homogeneity. Every Monday, in Hüll, the samples were ground up with a hammer mill, divided (Figure 7.20), vacuum-packed, and taken to the individual laboratories. During the following days, one sample was analyzed per day. The results of the analyses were returned to Hüll a week later and evaluated there. A total of 36 samples were analyzed in 2020.

Figure 7.20: Hammer mill (Hammermühle) and sample divider (Probenteiler)

The evaluations were then passed on to the individual laboratories as quickly as possible. Figure 7.21 shows an example of an ideal evaluation chain. Note: The numbering of the laboratories (1-7) does not correspond to the above list.

Nr. 26: HEB (21.10.2020)

Laboratory	Measured Value		Mean	s	cvr
1	3.68	3.70	3.69	0.014	0.4
2	3.66	3.71	3.69	0.035	1.0
3	3.79	3.80	3.80	0.007	0.2
4	3.65	3.64	3.65	0.007	0.2
5	3.65	3.67	3.66	0.014	0.4
6	3.69	3.71	3.70	0.014	0.4
7	3.70	3.73	3.72	0.021	0.6

mean	3,70
sr	0,019
sL	0,047
sR	0,050
vkr	0,50
vkR	1,36
r	0,05
R	0,14
Min	3,64
Max	3,80

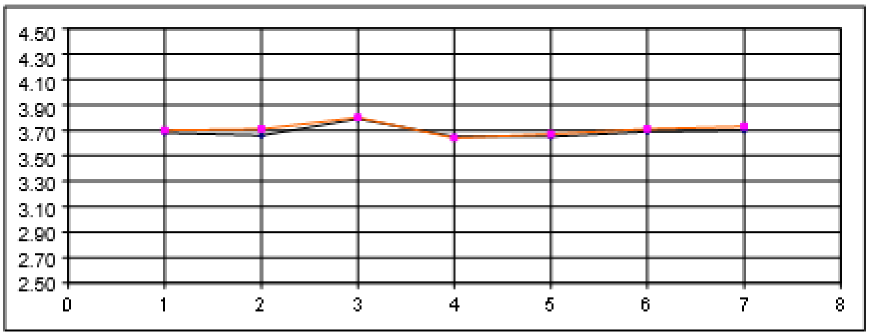


Figure 7.21: Example of an evaluation analysis chain (21.10.2020 = October 10, 2020)

7.5.2 Evaluation of the efficiency test

Here is a brief exlanation of the key variables in Figure 7.21.

7.5.2.1 Statistical definitions

The arithmetic mean is the sum of all measurements divided by the number of measurements.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

The standard deviation is a measure of the spread of the individual values around the mean. The variance is the square of the standard deviation.

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2 \longrightarrow s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Variance Standard Deviation

$$s_r = \frac{\sum_{i=1}^{p} s_i}{p}$$

P = number of laboratories

$$s_L^2 = \frac{1}{\bar{n}}\left[\frac{1}{p-1}\sum_{i=1}^{p} n_i(x_i - \bar{x})^2 - s_r^2\right] \quad \text{mit} \quad \bar{n} = \frac{1}{p-1}\left(N - \frac{\sum_{i=1}^{p} n_i^2}{N}\right)$$

$$s_L = \sqrt{s_L^2}$$

$$N = \sum_{i=1}^{p} n_i$$

p = number of laboratories

n_i = repeated measurements per laboratory

$$s_R^2 = s_r^2 + s_L^2 \longrightarrow s_R = \sqrt{s_r^2 + s_L^2}$$

The repeatability r indicates the value below which two measurements under the same conditions, with the same personnel, the same test material, and the same equipment should be expected with a probability of 95%.

The reproducibility R indicates the value below which two measurements under different conditions, such as different personnel, different devices, and different laboratories should be expected with a probability of 95%.

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

Repeatability Reproducibility

These formulae for r and R are designed to apply only to a large number of laboratories. Therefore, for a smaller number of laboratories, they need to be adapted.

In the evaluation of the round robin tests, the coefficients of variation vkr and vkR are also provided. These are the sr and sR as a % of the mean. For a good analysis, the variation coefficients should be smaller than 4%.

$$vkr = \frac{sr}{\bar{x}} \qquad vkR = \frac{sR}{\bar{x}}$$

Formulas for vkr and vkR

7.5.2.2 Comparison of measured values under repeatability conditions (same laboratory)

If a duplicate determination is conducted under repeatability conditions in a laboratory, then d_{krit} is calculated. This value indicates the difference, within which measurements cannot be distinguished. The formula for this is as follows:

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

7.5.2.2.1 Comparison of measured values under repeatability conditions (different laboratories)

If a double determination has been conducted in two different laboratories, then the following formula applies for d_{krit}.

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

7.5.2.3 Determination of outliers in ring analyzes

The ISO 5725-2 2002 standard outlines various statistical tests for the determination of outliers in ring analyzes. A graphic test, the Mandel k-statistic, and a numerical process called the Cochran test, assess the repeat error of the individual participants. In terms of comparability, the graphical variant is the Mandel h-statistic; and the numerical calculation is based on the Grubbs test.

7.5.2.3.1. Verifying the repeatability standard deviation according to the Mandel k-statistics

The test variable k is calculated for each laboratory according to the following scheme.

1. Calculation of the repeatability standard deviations for each laboratory (assuming at least duplicate determination)

2. Calculation of the combined standard deviation s_{komb} (n = number of laboratories)

3. Calculation of the individual k for each laboratory

$$s_{\text{komb}} = \sqrt{\frac{\sum s^2}{n}} \qquad k = s/s_{\text{komb}} = \frac{s\sqrt{n}}{\sqrt{\sum s^2}}$$

Formulas for s_{komb} and k

The k-values are shown graphically as bar charts. The Mandel's k-table with indicators for the compatibility test at the 5% and 1% level is used for this assessment. These depend on the number of repeat determinations and the number of laboratories. The tables can be found in ISO 5725-2002. With 7 laboratories and a duplicate determination, k is 1.87 at a = 0.05 and 2.20 at a = 0.01.

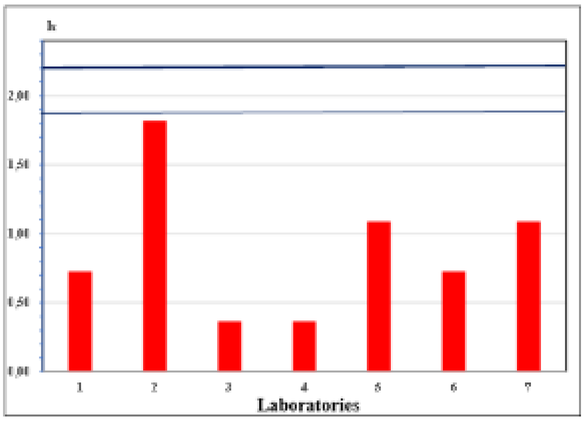


Figure 7.22: Mandel's k-values

Figure 7.22 shows the evaluation for the example in Figure 7.21. The figure shows the k-values for a = 0.05 (thin line) and for a = 0.01 (thick line). Since the bars are both smaller than the thinner and thicker line, there are no repeat outliers.

7.5.2.3.2. Using the Cochran test to check for the repeatability standard deviation

Another numerical method for testing the repeatability standard deviation is the Cochran test. It is calculated in accordance with ISO 5725-2 2002, using the following formula:

$$C = \frac{s_{max}^2}{\sum s_i^2}$$

With 7 laboratories and a double determination, a value is considered an outlier, unless C is smaller than 0.838 at a = 0.01; and C is smaller than 0.727 at a = 0.05.

7.5.2.3.3. Testing laboratory mean values according to Mandel's h-statistics

The size of the compatibility test variable h between laboratories is calculated as follows:

$$h = \frac{\bar{x} - \bar{\bar{x}}}{\sqrt{\frac{1}{(n-1)} \sum(\bar{x} - \bar{\bar{x}})^2}}$$

$\bar{x}$ = Mean value laboratory $\bar{\bar{x}}$ = Overall mean n – Number of laboratories

Unlike k values, h values can be negative. Figure 7.23 shows the representation of h-values for the example in Figure 7.21.

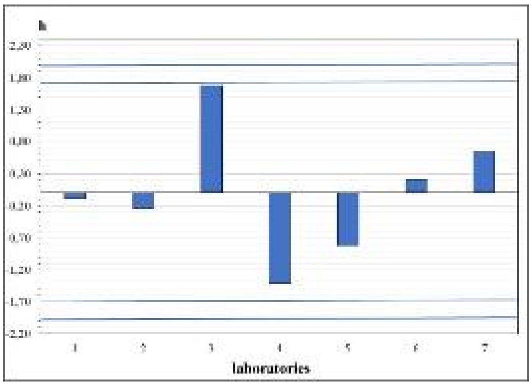


Figure 7.23: Mandel‘s h-values

In 7 laboratories the critical h-value is 1.71 for a= 0.05 and 1.98 for a = 0.01. These values are shown in Figure 7.23 as thin and thick lines, respectively. Because the bars are smaller than these critical limit values, there are no outliers in the laboratory mean values.

7.5.2.3.4 Testing laboratory mean values using the Grubbs test

The Grubbs test is calculated using the following formula.

$$G = \frac{|x_{max} - \bar{x}|}{s}$$

With 7 laboratories and a double determination, G must be smaller than 2.139 for a = 0.01 and smaller than 2.020 for a = 0.05, otherwise the value is an outlier.

The outliers for 2020 are summarized in Table 7.3.

Table 7.3: Outliers in harvest year 2020

	Cochran		**Grubbs**	
Sample	a = 0.01	a = 0.05	a = 0.01	a = 0.05
36		Laboratory 3		
Total:	**0**	**1**	**0**	**0**

Since 2013, there have been five alpha classes and new tolerance limits. Table 7.4 shows the new classification and the transgressions for 2020.

Table 7.4: Updated alpha acid classes and tolerance limits, as well as their transgressions in 2020

	< 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
Transgressons in 2020	0	0	0	0	0

In 2020, there were no values exceeding permitted tolerance ranges.

In Figure 7.24, the results of all analyses are summarized, for each laboratory, in the form of

lues that are too high or too low.

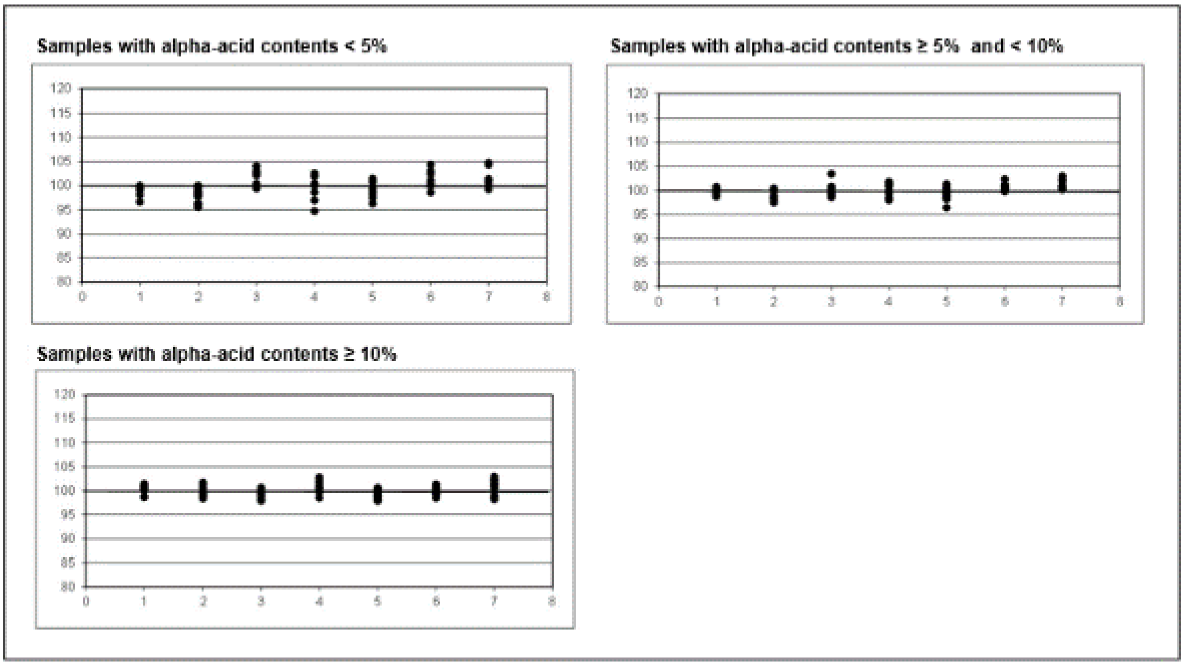


Figure 7.24: The results of the laboratory analyses relative to the mean

The Hüll laboratory is number 5.

7.5.3 Evaluation of control examinations

In addition to the chain tests, control examinations have been conducted since 2005, which the Working Group IPZ 5d evaluated before passing the results on to the participating laboratories, as well as to the hop growers and hop industry associations. For an initial examination, a laboratory selects three samples per week, which are then analyzed by three different laboratories in accordance with AHA specifications. The first examination value applies if the mean value of the follow-up examinations and the value from the initial examination fall within the tolerance limits (Table 7.4).

Table 7.5 shows the results for 2020. In all cases, the first investigation value was confirmed. The BayWa Tettnang laboratory has also been a follow-up laboratory since the 2020 harvest.

Table 7.5: Control evaluation in 2020

Sample name	Initial test laboraory	Initial test value	Follow-up tests			Mean	Results confirmed
			1	2	3		
10939 HAL	Agrolab	3.9	3.8	3.8	3.9	3.83	yes
10659 HTR	Agrolab	6.0	5.8	5.8	6.0	5.87	yes
11141 HKS	Agrolab	17.5	17.4	17.6	17.8	17.60	yes
239 Spalter Select	BayWa	4.7	4.4	4.5	4.5	4.47	yes
253 Hallertauer	BayWa	6.5	6.4	6.4	6.5	6.43	yes
255 Perle	BayWa	9.3	9.1	9.2	9.2	9.17	yes
HNBR KW 39 - 10731	HVG Mainburg	8.6	9.0	9.0	9.10	9.03	yes
HPER KW 39 - 11016	HVG Mainburg	7.2	7.1	7.2	7.4	7.23	yes
HHTR KW 39 - 10335	HVG Mainburg	6.5	6.6	6.6	6.7	6.63	yes
KW 40 – PER Agrolab No. 16294	HV St. Johann	6.0	5.7	5.9	6.1	5.90	yes
KW 40 – HMG Agrolab No. 17706	HV St. Johann	12.5	12.2	12.3	12.8	12.43	yes
KW 40 – PER Agrolab No. 16294	HV St. Johann	14.8	14.6	14.7	15.2	14.83	yes
KW 41 – HMG	HHV Au	14.9	14.5	14.5	14.9	14.63	yes
KW 41 – NUG	HHV Au	12.8	12.6	12.7	12.9	12.73	yes
KW 41 – HKS	HHV Au	17.1	16.8	17.0	17.2	17.00	yes
KW 42 – 21658 Herkules	Agrolab	17.0	16.7	16.8	17.0	16.83	yes
KW 42 – 21457 Mandarina Bavaria	Agrolab	8.8	9.5	9.5	9.7	9.57	yes
KW 42 – 21137 Hall. Tradition	Agrolab	6.0	5.7	5.8	5.9	5.80	yes
KW 43 – SSE Sample No. 667	BayWa	5.7	5.3	5.3	5.7	5.43	yes
KW 43 – SGD Sample No. 638	BayWa	7.0	6.6	6.7	6.9	6.73	yes
KW 43 – HKS Sample No. 675	BayWa	18.4	17.7	17.9	18.0	17.87	yes
KW 44 – HNUG 19696	HVG Mainburg	12.5	12.4	12.4	12.7	12.50	yes
KW 44 – HPLA 10731	HVG Mainburg	22.1	21.9	22.0	22.1	22.00	yes
KW 44 – HHKS 16392	HVG Mainburg	17.1	17.1	17.2	17.2	17.17	yes
HPER KW 45 21836	HV St. Johann	6.9	6.7	6.8	7.0	6.83	yes
HHMG KW 45 13947	HV St. Johann	12.6	12.1	12.3	12.4	12.27	yes
HHKS KW 45 19691	HV St. Johann	14.8	14.5	14.6	14.7	14.60	yes
KW 46 - NUG	HHV Au	12.6	12.1	12.5	12.5	12.37	yes
KW 46 - HMG	HHV Au	14.2	13.9	13.9	14.1	13.97	yes
KW 46 - HTU	HHV Au	15.0	14.6	14.8	14.8	14.73	yes

KW = Calendar week

7.5.4 Follow-up examinations of the 2020 harvest

The laboratory in Hüll has functioned as a follow-up laboratory since 2019. Its task is to evaluate the results of the other laboratories. Starting with the 2020 harvest, the BayWa laboratory in Tettnang has also been approved as a test laboratory (Table 7.6).

Table 7.6: 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 tests is transmitted as an LfL follow-up report to the initial test laboratory within three working days after receipt of the follow-up test results. The initial test laboratory immediately forwards the report to the client who commissioned the follow-up tests. In 2020, a total of 42 follow-up tests had been requested; and in only one case was the initial test result not confirmed. Table 7.7 shows the follow-up test results in ascending chronological order.

Table 7.7: Follow-up tests in 2020

Sample name	Initial test laboratory	Initial test results	Follow-up tests			Mean	Results confirmed
			1	2	3		
HPER Agrolab No. 10999	HV St. Johann	6.9	6.8	6.8	7.0	6.87	yes
HHTR Analysis No. Agrolab 10647	HVG Mainburg	5.6	5.7	5.7	5.8	5.73	yes
HPER Analysis No. Agrolab 12014	HVG Mainburg	6.8	6.9	7.1	7.2	7.07	yes
15253 HKS	Agrolab	14.4	14.6	14.6	14.7	14.63	yes
16616 HEB	Agrolab	2.0	1.9	2.0	2.2	2.03	yes
HPER Analysis No. Agrolab 14115	HV St. Johann	5.5	5.5	5.6	5.7	5.60	yes
HHTR Analysis No. Agrolab 15031	HVG Mainburg	5.6	5.5	5.6	5.6	5.57	yes
HHTR Analysis No. Agrolab 12695	HVG Mainburg	14.7	14.6	14.6	15.0	14.73	yes
H DE HTU Analysis No. Agrolab 16103	HV St. Johann	15.4	15.4	15.4	15.9	15.57	yes
H DE HKS Analysis No. Agrolab 17371	HV St. Johann	15.9	15.8	15.8	16.0	15.87	yes

Sample name	Initial test laboratory	Initial test results	Follow-up tests			Mean	Results confirmed
			1	2	3		
HKS Agrolab Analysis No. 16330	HHV Au	15.4	15.2	15.3	15.3	15.27	yes
HKS Agrolab Analysis No. 17915	Agrolab	18.7	18.9	18.9	19.0	18.93	yes
PLA Agrolab Analysis No. 15805	Agrolab	14.9	15.0	15.2	15.2	15.13	yes
HKS Agrolab Analysis No. 18875	Agrolab	6.9	6.8	6.8	7.0	6.87	yes
HKS Agrolab Analysis No. 17097	HHV Au	14.9	14.6	14.7	15.0	14.77	yes
H DE HKS Analysis No. Agrolab 17252	HV St. Johann	14.8	14.9	14.9	15.0	14.93	yes
H DE HKS Analysis No. Agrolab 17135	HV St. Johann	16.5	16.7	16.7	16.9	16.77	yes
H DE HKS Analysis No. Agrolab 16421	HV St. Johann	17.3	17.4	17.6	17.9	17.63	yes
H DE HKS Analysis No. Agrolab 18254	HV St. Johann	15.5	15.8	15.8	16.1	15.90	yes
HMG Analysis No. Agrolab 14971	Agrolab	12.2	12.0	12.1	12.1	12.07	yes
PER Sample No. 436 Siegelnr. 2376931	BayWa	6.5	6.4	6.4	6.6	6.47	yes
H DE HKS Analysis No. Agrolab 18771	HV St. Johann	14.2	13.8	13.8	14.1	13.90	yes
HKS Agrolab No. 15017	HHV Au	15.7	15.6	15.6	15.7	15.63	yes
HHMG Analysis No. Agrolab 14229	HVG Mainburg	14.9	14.9	14.9	14.9	14.90	yes
HHKS Analysis No. Agrolab 17436	HVG Mainburg	13.5	13.6	13.7	13.7	13.67	yes
HHKS Analysis No. Agrolab 18574	HVG Mainburg	15.8	15.8	15.9	16.1	15.93	yes
HHKS Agrolab No. 15751	HV St. Johann	17.1	17.7	17.9	18.0	17.87	no
HHKS Agrolab No. 20567	HV St. Johann	14.2	14.0	14.1	14.2	14.10	yes
HHKS Analysis No. Agrolab 20444	HVG Mainburg	13.8	14.0	14.0	14.2	14.07	yes
HKS Agrolab Nr. 17068	Agrolab	14.9	14.7	14.7	14.9	14.77	yes
Sample No. 769 HKS	BayWa	16.7	15.9	16.1	16.2	16.07	yes
Sample No. 602 HKS	BayWa	16.8	16.3	16.3	16.4	16.33	yes
H DE HKS Analysis No. Agrolab 20969	HV St. Johann	14.4	14.9	14.7	14.7	14.77	yes

Sample name	Initial test laboratory	Initial test results	Follow-up tests			Mean	Results confirmed
			1	2	3		
THKS Plot No. 83044	HHV Au	14.4	14.2	14.4	14.4	14.33	yes
H DE HKS Analysis No. Agrolab 17084	HV St. Johann	15.4	15.6	15.6	15.6	15.60	yes
HKS Agrolab. Nr. 21106	Agrolab	13.7	13.2	13.2	13.3	13.23	yes
THKS Analysis No. Tettnang 1011	HVG Mainburg	14.8	14.6	14.7	15.0	14.77	yes
THKS Analysis No. Tettnang 1012	HVG Mainburg	14.7	14.7	14.9	15.3	14.97	yes
19520 Herkules	Agrolab	14.8	14.4	14.4	14.5	14.43	yes
HKS Sample No. 863	BayWa	15.2	14.6	14.9	15.2	14.90	yes
H DE HMG Agrolab No. 13947	HV St. Johann	12.6	12.1	12.3	12.4	12.27	yes
PER Analysen Nr. 2796083	HHV Au	6.3	6.0	6.1	6.1	6.07	yes

The results of the controls and follow-up tests are published annually in July or August in Hopfenrundschau (Hop Review).

7.6 Studies of the biogenesis of bitter compounds and oils in new breeding lines

With newer breeding lines, extensive biogenesis tests for essential oils and bitter compounds are conducted every year to determine the optimum harvest dates. Table 7.8 shows the harvest dates. Note that the harvest dates may shift slightly from one harvest year to the next.

Table 7.8: Harvest dates as determined by biogenesis experiments

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

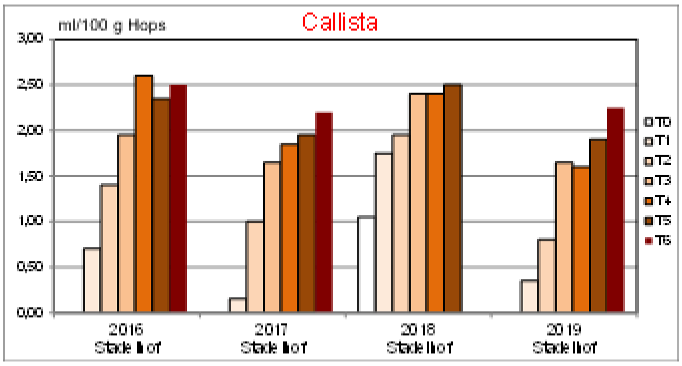


Figure 7.25: Biogenesis of oils in Callista

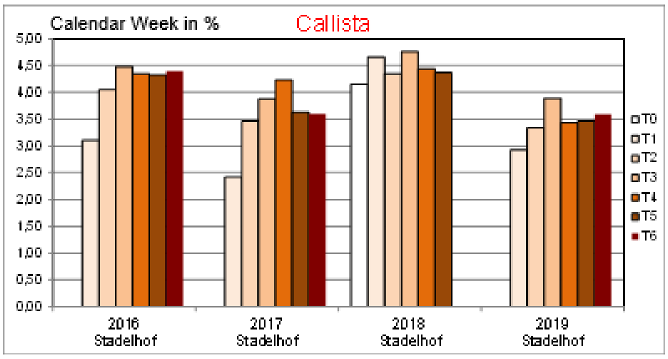


Figure 7.26: Biogenesis of bitter compounds in Callista

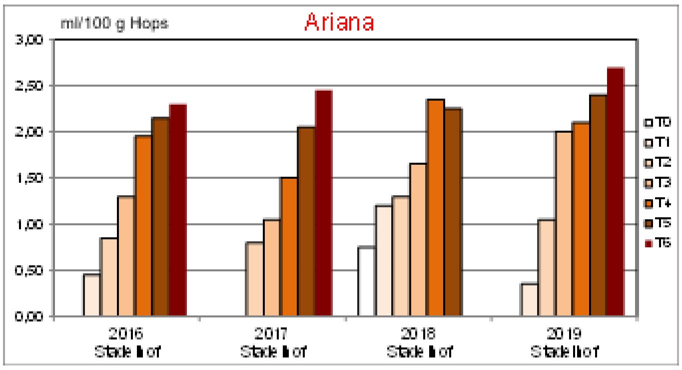


Figure 7.27: Biogenesis of oils in Ariana

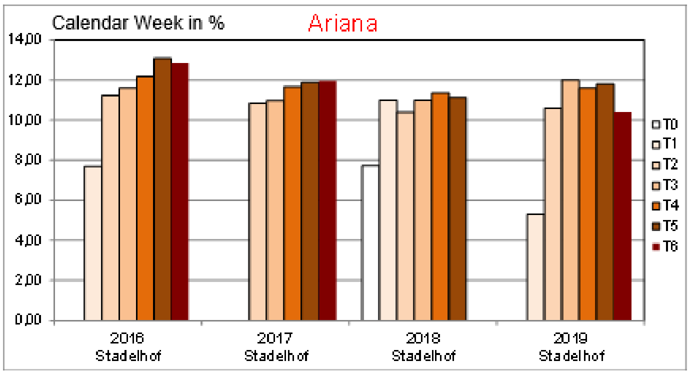


Figure 7.28: Biogenesis of bitter compounds in Ariana

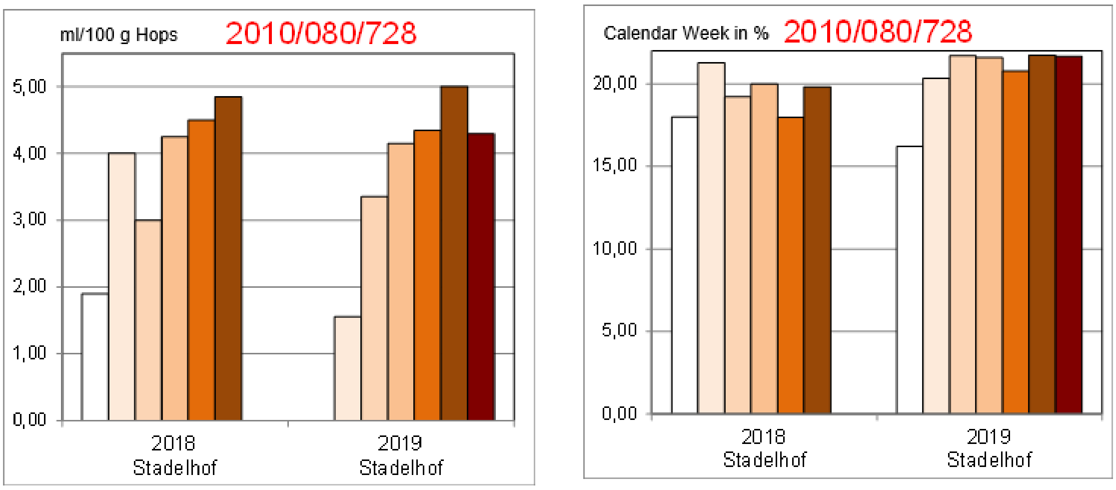


Figure 7.29: Biogenesis of oils and bitter compounds in breeding line 2010/080/728

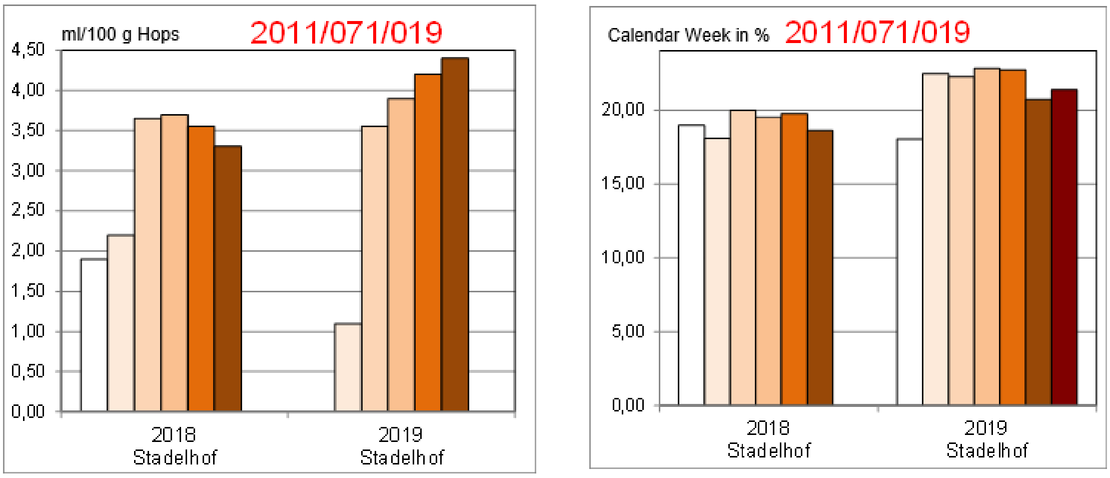


Figure 7.30: Biogenesis of oils and bitter compounds in breeding line 2011/071/019

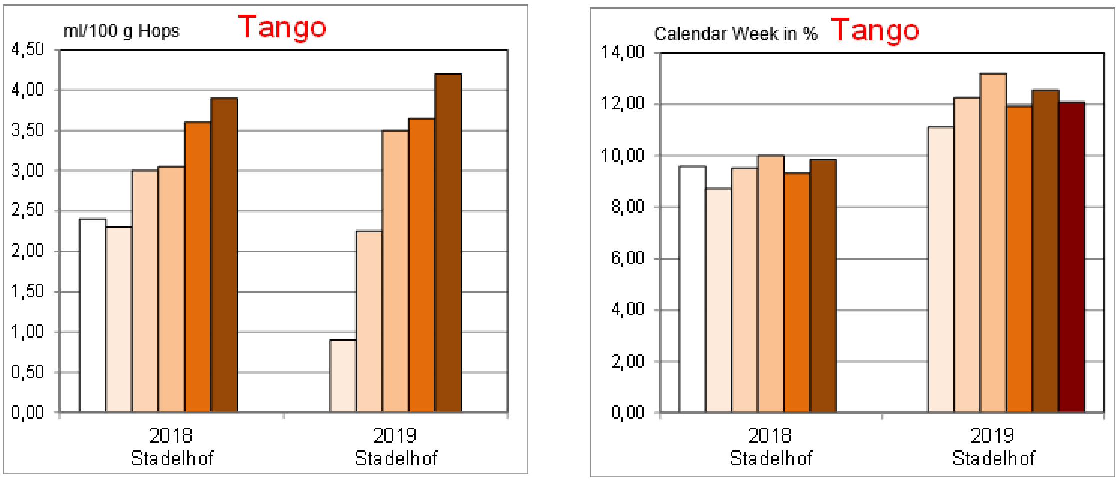


Figure 7.31: Biogenesis of oils and bitter compounds in 2011/071/019 = Tango

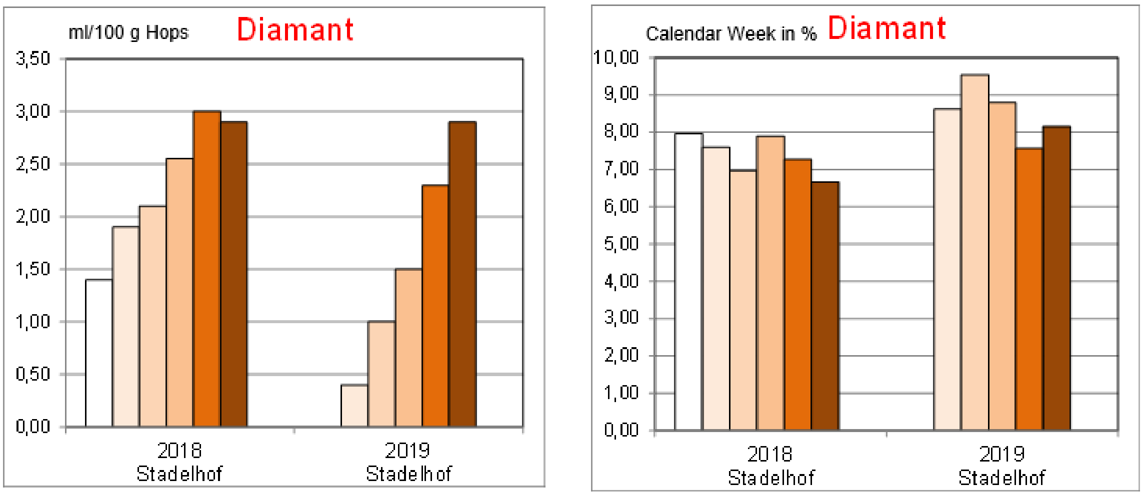


Figure 7.32: Biogenesis of oils and bitter compounds in Diamant

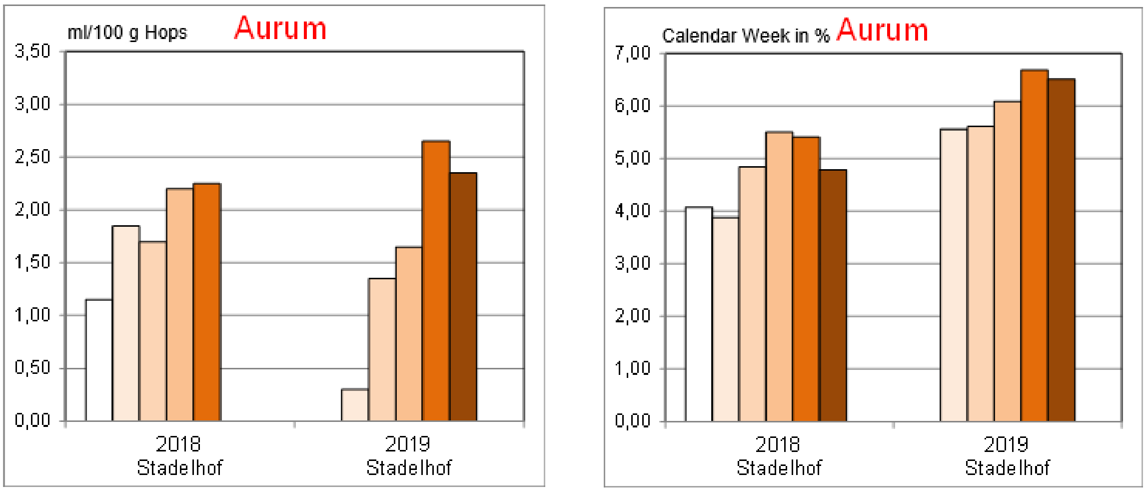


Figure 7.33: Biogenesis of oils and bitter compounds in Aurum

The graphics clearly show that the oil content is much more dependent on the harvest date than is the bitter content. If a distinctive aroma is desired, it is better to harvest later. The new variety Tango has a remarkably high oil content of 2.4 to 4.0 ml/100g, in addition to its alpha acid content of 7.5 to 11.0%.

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

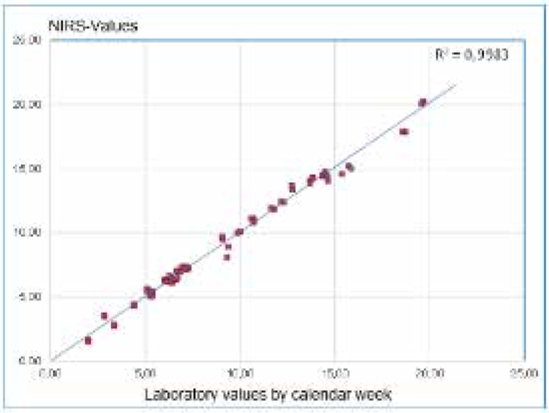
Since the spring of 2017, the laboratory in Hüll has used a new NIRS device that was developed and fully funded by the Society for Hop Research (Figure 7.34).

Figure 7.34: NIRS device from Unity Scientific

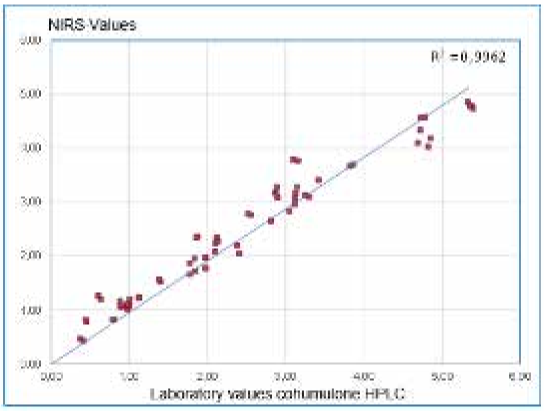
The device is compatible with the devices at AQU in Freising. The old calibration of the Foss device could be adapted to the new device with the help of a mathematical transformation.

However, we also started to develop our own calibration based on conductometer and HPLC data. Figure 7.35 shows the correlations of the individual parameters between laboratory values and NIRS values.

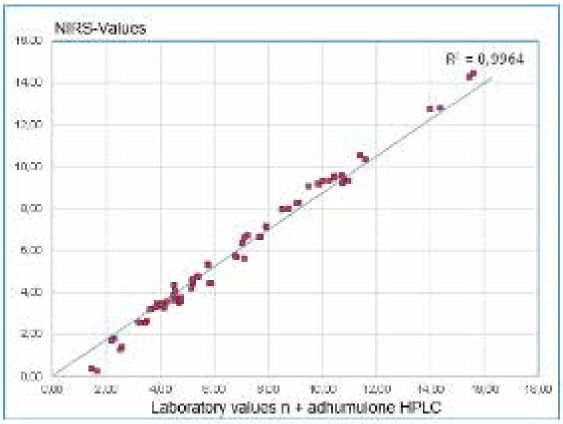
Conductometer values in %



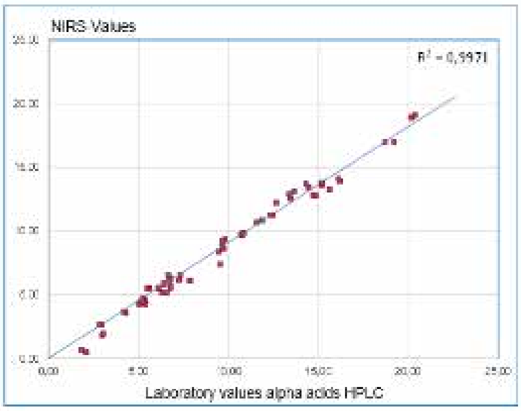
Cohumulone in %



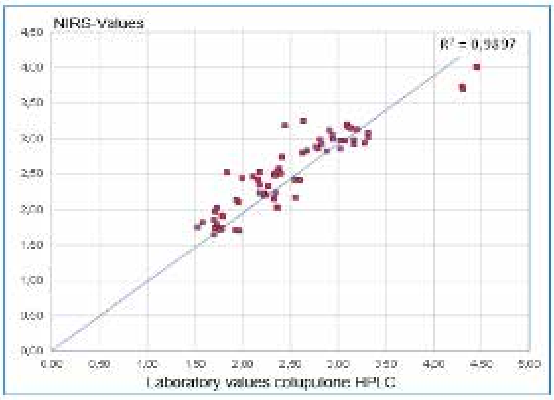
n + Adhumulone in %



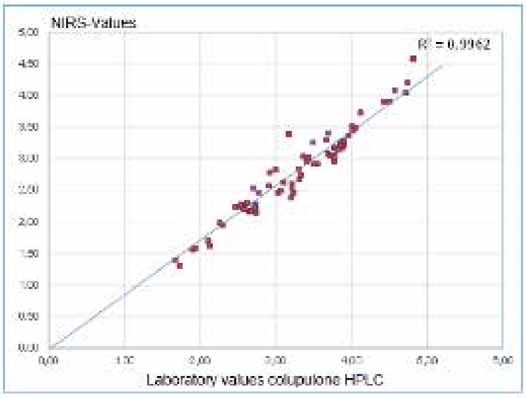
Alpha acids in %



Colupulone in %



n + Adlupulone



Beta acids in %

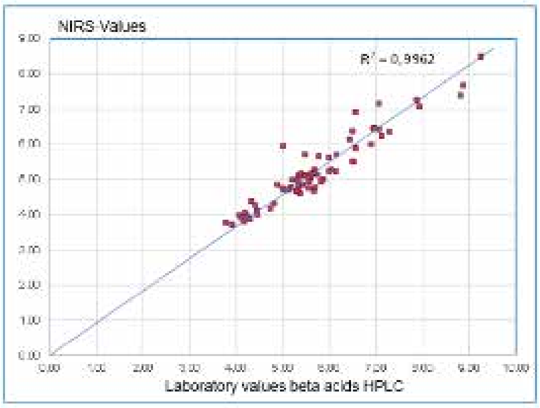


Figure 7.35: Correlations between laboratory values and NIRS values

Table 7.9: Comparison of the repeatability standard deviations between the standard methods (reference methods) and the NIRS methods

Methode	Sr – Reference Method	Sr – NIRS-Method	Sr– NIRS/ Reference
Conductometer values	0.0593	0.1007	1.70
Cohumulone (HPLC)	0.0275	0.0437	1.59
n + Adhumulone (HPLC)	0.0761	0.1009	1.33
Alpha acids (HPLC)	0.1040	0.1191	1.15
Colupulone (HPLC)	0.0393	0.0314	0.80
n + Adlupulone (HPLC)	0.0437	0.0547	1.25
Beta acids	0.0813	0.0753	0.93

The comparison of the repeatability standard deviation shows that, for alpha acids, the NIRS method performs slightly worse than the reference method. For beta acids, on the other hand, the NIRS method is more precise.

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

By now, alpha acid data the new Hüll cultivars are available for the years 2012 to 2020. They can be visualized conveniently using a box plot display. The evaluation of a box-plot display is explained in Figure 7.36.

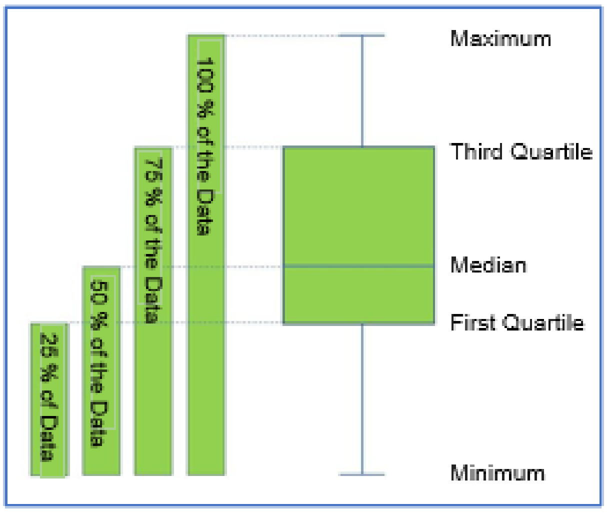


Figure 7.36: Explanation of a box plot display

Figures 7.37 and 7.38 show box-plot evaluations of the official AHA results. The illustrations clearly show that the new Hüll cultivars are much more stable than, for instance, Perle and Northern Brewer.

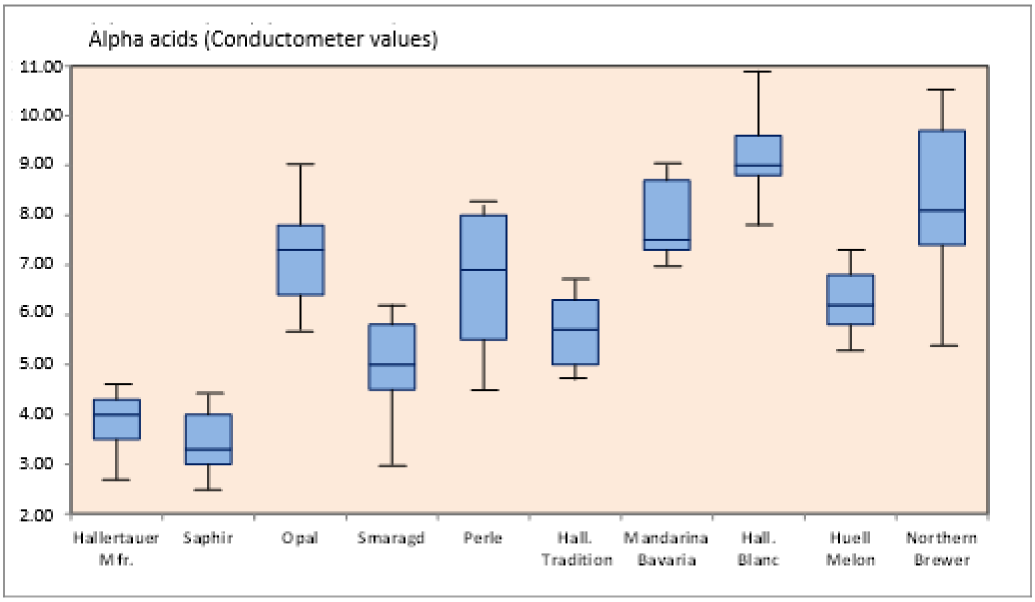


Figure 7.37: Box plot evaluation of aroma varieties

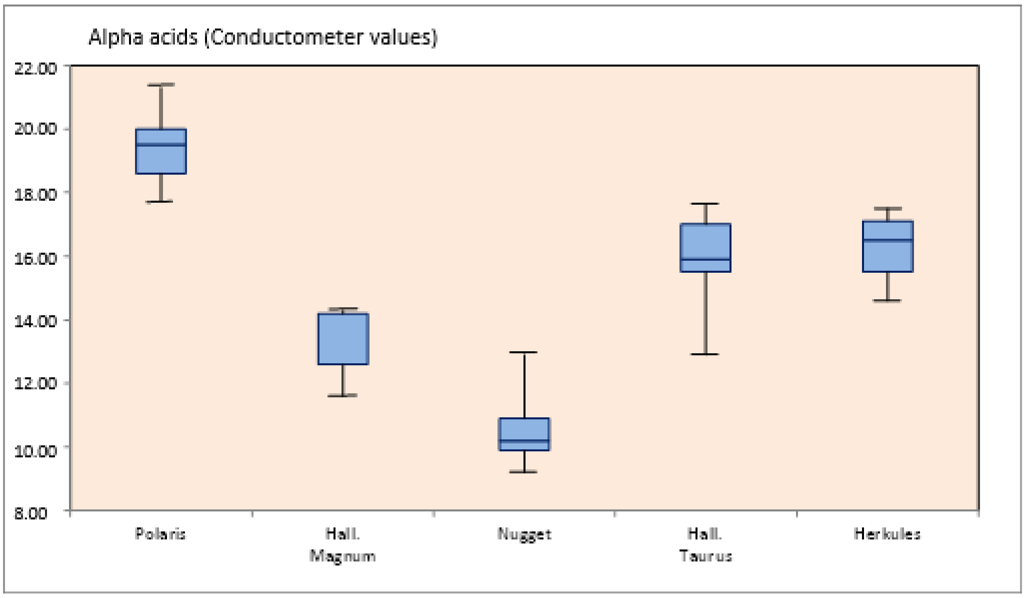
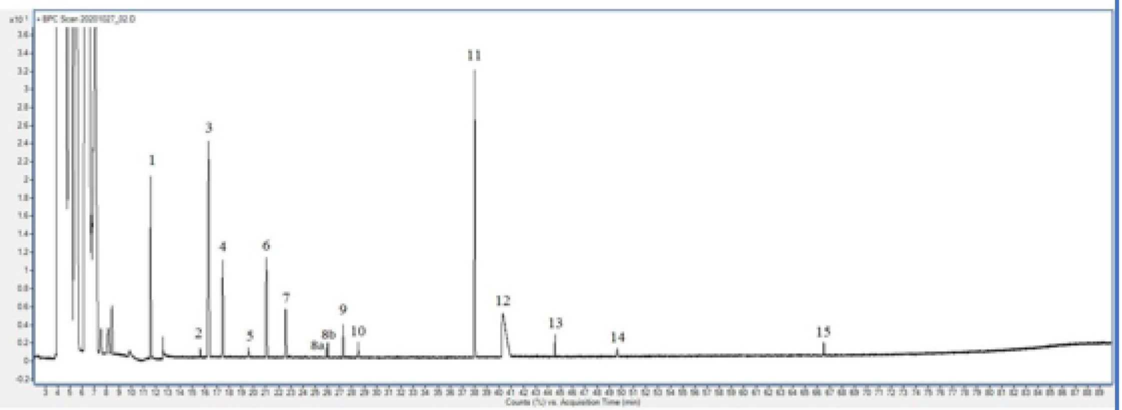


Fig. 7.38: Box plot evaluation of bitter varieties

7.9 Project of Working Group IPZ 6 - Determination of volatile substances in broad beans

Mr. Huber of Working Group IPZ 6 requested a project for the identification and measurement of volatile compounds in broad beans. The samples were first freeze-dried and then analyzed using headspace gas chromatography. Figure 7.39 shows a chromatogram and the identified compounds.



1 = 6-methyloctadecane	2 = beta-pinene	3 = 1-penten-3-ol	4 = n-dodecane	5 = isopenthyl alcohol	6 = n-pentylfuran
7= beta-ocimene	8a = tridecane	8b = acetone	9 = acetoin	10 = penten-1-ol	11 = 1-octen-3-ol
12 = acidic acid	13 = linalool	14 = butyrolactone	15 = phenylethyl alcohol		

Fig.7.39: Chromatogram of volatile compounds in broad beans and other identified substances

7.10 Control of the stability of hop varieties in 2020

Testing for the continued authenticity of a variety is a compulsory administrative task, which the Working Group IPZ 5d must perform on behalf of food safety authorities.

Variety checks for food safety authorities (district offices) in 2020: 27 of which 3 were complaints.

8 Ecological Issues in Hop Production

Dr. Florian Weihrauch, Dipl.-Biol.

The task of this Working Group is to update the state of knowledge and applied research regarding environmentally friendly and organic hop production. This includes diagnoses, observations, and monitoring of the occurrence of hop pests and their enemies, while considering the progression of climate change and the resulting effects on affected biocoenoses. It also involves the development and evaluation of biological and other eco-compatible crop protection methods. The Working Group is mainly supported by research funds for ecological issues in hop cultivation.

8.1 Minimizing the use of copper-containing crop protection agents in ecological and integrated 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:	Erzeugergemeinschaft Hopfen HVG e. G. *(HVG Hop Producer Group)*
Project Management:	Dr. F. Weihrauch
Team:	M. Obermaier, A. Baumgartner, M. Felsl, K. Kaindl, M. Mühlbauer, R. Obster, J. Weiher, A. Roßmeier, Dr. F. Weihrauch
Collaboration:	Betrieb (*Hop Farm*) Robert Drexler, Riedhof Agrolytix GmbH, Erlangen Forschungsinstitut für Biologischen Landbau *(The Research Institute of Organic Agriculture)* (FiBL), Frick Boku Wien, IFA-Tulln Institut für Umweltbiotechnologie *(University of Natural Resources and Life Sciences,* Vienna BOKU *Institute of Environmental Biotechnology)*
Duration:	March 1, 2014 to December 31, 2022 (project extension)

Objectives

After an environmental and toxicological assessment of plant protection products containing copper, the German Federal Environment Agency and other authorities have concluded that these products should no longer be used. At the EU level, too, this active ingredient has received an unfavorable classification in recent years (listing on Annex I) and has been permitted for use in crop protection only as an exceptional, short-term remedy. A new extension of the approval of copper was granted in December 2018, although only for a maximum "grace period" not exceeding seven years, until January 31, 2026. During this period, pesticides containing copper should disappear entirely from the market as soon as there are equivalent or better active ingredients available; and the member states are, therefore, obligated to work intensely on concepts that allow for the further reduction of the amount of copper in use.

Organic farms, however, still cannot do without copper as an active ingredient regardless of the cultivated crop. A four-year test program that lasted from 2010 to 2013 and was sponsored by the German Federal Organic Farming Program (BÖLN), produced information about the degree to which copper could be reduced in hop gardens before crop losses ensued. The program concluded that the currently permissible amount of 4 kg/ha/year can be reduced by at least one quarter to 3 kg/ha/year. After the successful completion of the first project, this follow-up project is tasked with critically evaluating if the current 3 kg Cu/ha/year can be reduced further and by how much.

Approach and results

In the trial year 2020, as in the year before, 14 trial sections were created. All copper test variations were based on Funguran® Progress as the currently approved, copper-based plant protection product. The variations consisted of different application rates with different mixing partners as synergists, some of which were also tested as solo variations (Table 8.1). As in 2019, the trial was carried out on the susceptible Hercules variety, but this time at the new Riedhof location. As is customary in practice, all of the treatments in 2020 were split into six applications (June 22, July 7, July 14, July 28, August 13, and August 25), whereby for one of the variations, which received only 1 kg of copper per hectare, the amount was divided into only two 0.5-kg applications, on July 14 and July 28. The key consideration for the timing was to protect the plants from fungal attacks during the sensitive flowering and cone development stages.

In 2019, the trials showed significant differences between individual test variations, especially for the new plant extract FiBL ('R2-D2'), for a Chitosan formulation from IFA Tulln, and for the Czech product 'Polyversum' (a parasitic soil fungus). These showed good to very good control results. Unfortunately, these favorable results could not be replicated satisfactorily in 2020. In addition to a generally high pressure of powdery mildew in all plots, the downy mildew pressure was also very high in the test gardens shortly before the harvest, as well as in all copper-free trial variations, which had the same degree of infestation as the untreated control plots. Also, the trial plants treated 1 kg of R2-D2, Chitosan, or Polyversum were significantly more infected at harvest time, in 2020, than they were in the previous year. They also differed negatively from the standard treated with 3 kg of copper (Fig.8.1).

Table 8.1: Trial variations of the 2020 copper minimization test in the Riedhof test gardens with varying amounts of pure copper applied per hectare and year

No.	Trial variation	Pure Copper per ha
1	Untreated	0 kg
2	Funguran® Progress	3 kg
3	Funguran® Progress	2 kg
4	Funguran® Progress + Kumar	2 kg
5	Funguran® Progress + Biplantol® H forte NT	2 kg
6	Funguran® Progress	1 kg
7	Licorice extract (*Glycyrrhiza glabra*)	0 kg
8	Panamin + Regenerative Microorganisms	0 kg
9	Funguran® Progress + COV17-01 (plant extract)	1 kg
10	Funguran® Progress + R2-D2 (plant extract)	1 kg
11	Polyversum® (fungus *Pythium oligandrum*)	0 kg
12	Funguran® Progress + Polyversum®	1 kg
13	Chitosan hydrochloride (biopolymer, elicitor)	0 kg
14	Funguran® Progress + Chitosan	1 kg

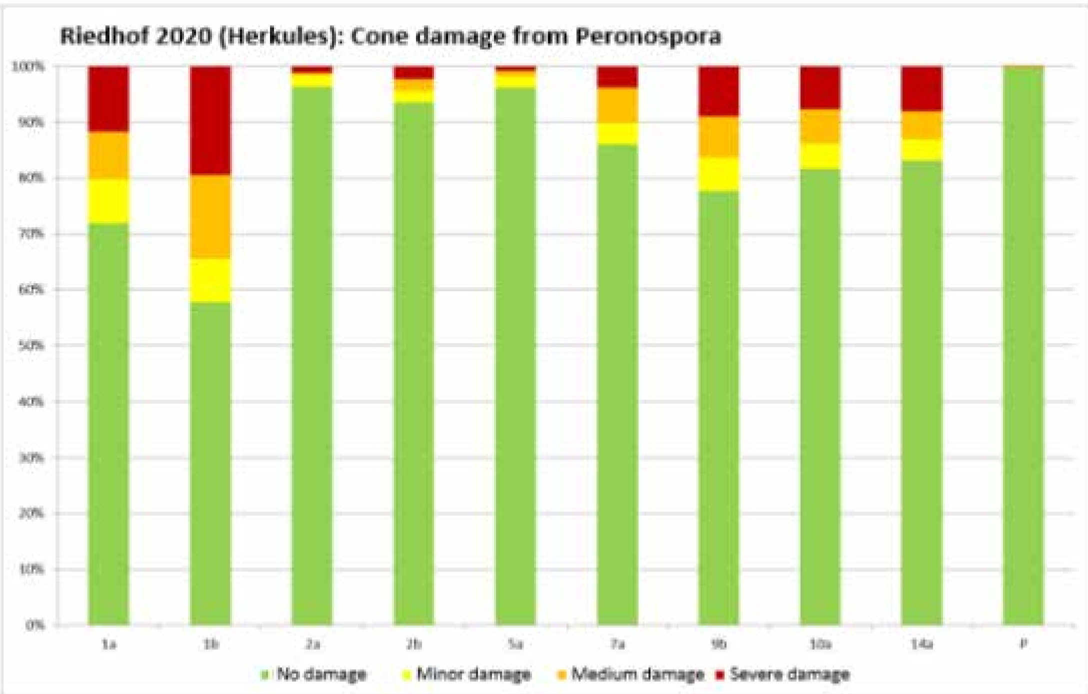


Figure 8.1: Laboratory assay of dried cones from the trial harvest 2020 in the Riedhof test gardens. For the numbering of the variations, see Table 8.1 and Figure 8.2

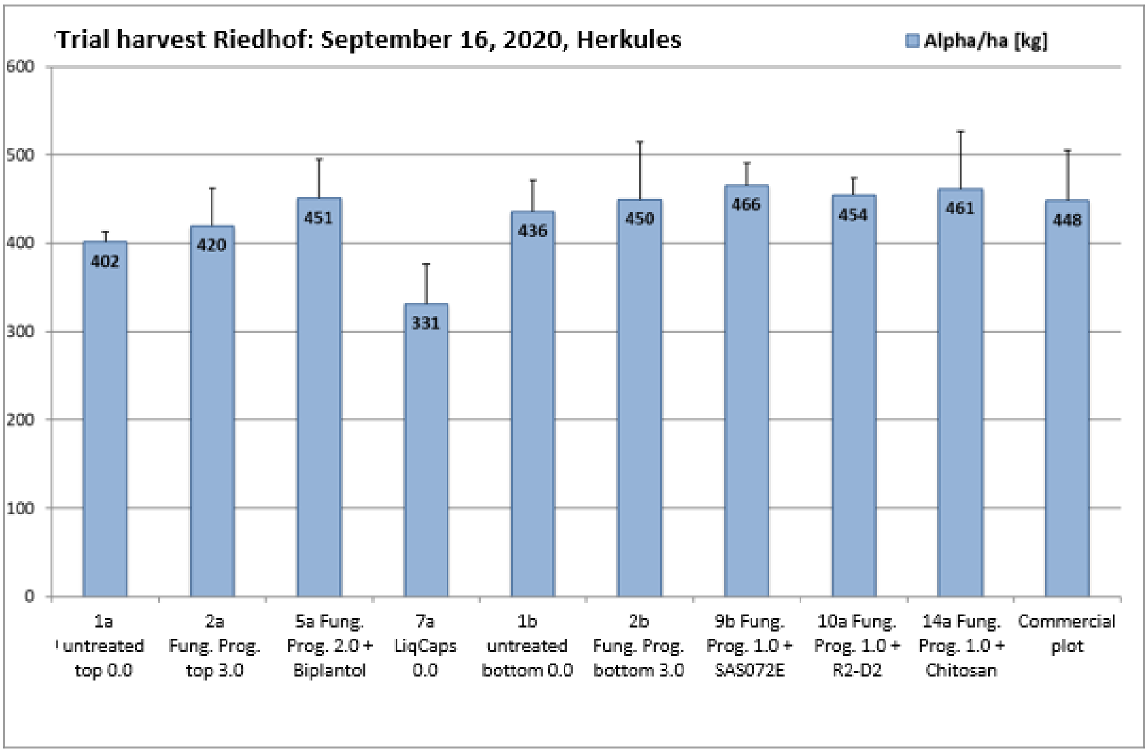


Fig. 8.2: During the trial harvest on September 16, 2020, the alpha yields of individual trial plots were determined nd compared to those of the other plots under commercial cultivation in the same hop farm, which were treated conventionally

It is noteworthy that, just as in 2019, the widely differing infestation rates had no significant influence on yields or alpha acid levels (Fig. 8.2). Except for the encapsulated licorice extract, which obviously created problems with plant tolerance this time, all harvested test variations showed statistically uniform values in the vicinity of 450 kg of alpha yield/ha. The tests will be repeated at the same location in 2021 and it will be interesting to see whether these results can be reproduced.

8.2 Further development of crop-specific strategies for ecological plant protection with the help of sector-specific networks in the hop industry

Sponsor:	Bund Ökologische Lebensmittelwirtschaft (BÖLW e.V.) und Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) *[Organic Food Production Alliance (BÖLW e.V.) and Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Ecology (IPZ 5e)]*
Financing:	Bundesanstalt für Landwirtschaft und Ernährung (BLE) über Bundesprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft (BÖLN-Projekt 2815OE095) (*Federal Agency for Agriculture and Food (BLE) through Federal Organic Farming Program including other forms of sustainable agriculture) (BÖLN Project 2815OE095)*
Project Management:	Dr. F. Weihrauch
Team:	Dr. F. Weihrauch, M. Obermaier
Collaboration:	Bund Ökologische Lebensmittelwirtschaft (BÖLW e.V.) *[Organic Food Production Alliance (BÖLW)]*
Duration:	August 15, 2017 to December 31, 2022 (Project extension)

Objectives

The aim of this research project is to set up six cultivation-specific networks (arable farming, vegetables, hops, potatoes, fruit, and viticulture) that deal with the subject of plant health in organic farming, whereby each sector has its own coordinator serving as the central point of contact. The overall coordination of the project is in the hands of BÖLW, whereas the hop sector is coordinated by IPZ 5e in Hüll.

The tasks of the coordinator include building up a durable, cultivation-specific network with commercial companies as participants; offering advice to companies interested in a change-over; keeping track of issues relating to plant health in their respective area; capturing and disseminating innovation; communicating research needs; and formulating strategies for each cultivation sector.

Within the organic hop network, communication takes place primarily during two to three annual meetings of the participants, whereby one of the meetings is a special workshop open to all companies. The exchange between the cultivation networks and the overall coordination should also take the form of at least one workshop per year.

From the perspective of hop growers, the most important events in 2020 were a hop-growing day as part of the Bioland week in the Plankstetten Abbey (February 4, 2020), a workshop and network meeting with the BÖLW in Fulda (March 10, 2020), and especially a two-day summer excursion of the Working Group Organic Hops in the Hallertau (July 21/22). This excursion attracted a cap of 45 participants because of the pandemic. Unfortunately, a planned round table in Hüll about current plant protection problems in organic hop growing had to be canceled twice, in April and in November 2020, also because of the pandemic.

The main goals of the research project are to pursue targeted management strategies and to rely less on inputs of phytomedical substances into the cultivation system. The expectations of the program clients, BLE and BMEL, in such areas of progress and innovation are, ideally, the development of new management or cultivation systems and a working program for getting results. A "strategy paper," most likely to be published in the first quarter of 2021, will serve as the conclusion of the first part of the research project. In December 2020, the BLE approved a two-year extension of the project for a second stage, which is expected to deliver a comparative evaluation of various strategies supported with concrete data from organic farms.

8.3 Development of a catalog of measures that promote biodiversity in hop growing

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)

Financing: Erzeugergemeinschaft Hopfen HVG e.G.
(HVG Hop Producer Group)

Project Management: Dr. F. Weihrauch

Team: Dr. F. Weihrauch, M. Obermaier

Collaboration: Interessengemeinschaft Niederlauterbach (IGN) e.V.
(Interest Group Niederlauterbach)

AELF Pfaffenhofen, FZ Agrarökologie
(Centre of Expertise for Agroecology)

TU München, Lehrstuhl für terrestrische Ökologie Landesbund für Vogelschutz
(Munich Technical University, Chair of Terrestrial Ecology)

Landesbund für Vogelschutz KG, Pfaffenhofen (LBV)
(The State Association for Bird Protection in Bavaria eV)

Duration: March 1, 2018 to December 31, 2023 (Project extension)

Background and objectives

The term biodiversity is on everyone's lips these days; and the Bavarian state government declared 2019 and 2020 to be "Years of Biodiversity." At the beginning of 2018, the EG HVG and the LfL initiated measures to stop the loss of species and to promote biodiversity in hop cultivation. This includes, for example, the evaluation of possible measures to promote biodiversity in and around hop gardens, the creation of a working concept, the formulation and evaluation of individual topics, and the initiation and development of follow-up projects, as well as coordinating their implementation in commercial practice in hop cultivation.

Method

The first step was to set up a cooperating network of as many associations, organizations, and facilities as possible come to a joint and constructive approach and solution. In addition to the LfL and TUM (Technical University Munich), the BBV (Bavarian Farmers Association), the AELF Pfaffenhofen (*specialist center for agroecology*), the LBV (Landesbund für Vogelschutz in Bayern e.V; *Bavarian state association for the protection of birds*), the UNB (Unteren Naturschutzbehörde; *Nature Protection Office*) at the Pfaffenhofen district office, the IGN (Interessen Gemeinschaft Qualitätshopfen; *Interest Group for Quality Hops*) in Niederlauterbach and all organizations headquartered in the Haus des Hopfens (*House of Hops* in Wolnzach) have been involved to date.

The range of measures to be introduced includes, for example, not cultivating marginal, unproductive, or critical areas (especially in the immediate vicinity of bodies of water); the targeted ecological upgrading of existing, landscape-defining small structures, such as the borders of fields; the creation of buffer strips to bodies of water, surround structures, flower strips, or flower areas; the rededication of such areas as roadsides and road embankments; the preservation of fallow land for several years; and the preservation or creation of untouched ground areas, such as the edges around demolitions. Basically, the aim is not to interfere with productivity or with productive spaces.

A master's thesis at the TUM (Stiglmaier 2020) was the first concrete sub-project. In 2019, it examined whether there are qualitative or quantitative differences in insect colonization between organically and conventionally managed hop gardens. The evaluation was not completed until 2020; and it showed that there were more individuals of many insect orders in organic than conventional hop gardens. In this context, the cover crops planted between the rows of hops seem to have played an important role. In ecological hop cultivation, flowering plants are much more frequently used for this purpose than in conventional gardens.

Stiglmaier V. 2020. Untersuchung des Insektenvorkommens in biologisch und konventionell bewirtschafteten Hopfengärten (*Investigation of the occurrence of insects in organically and conventionally managed hop gardens.*) M.Sc. Thesis, TU München (*Technical University Munich*), Weihenstephan Science Center, Chair for Terrestrial Ecology. 69 pp.

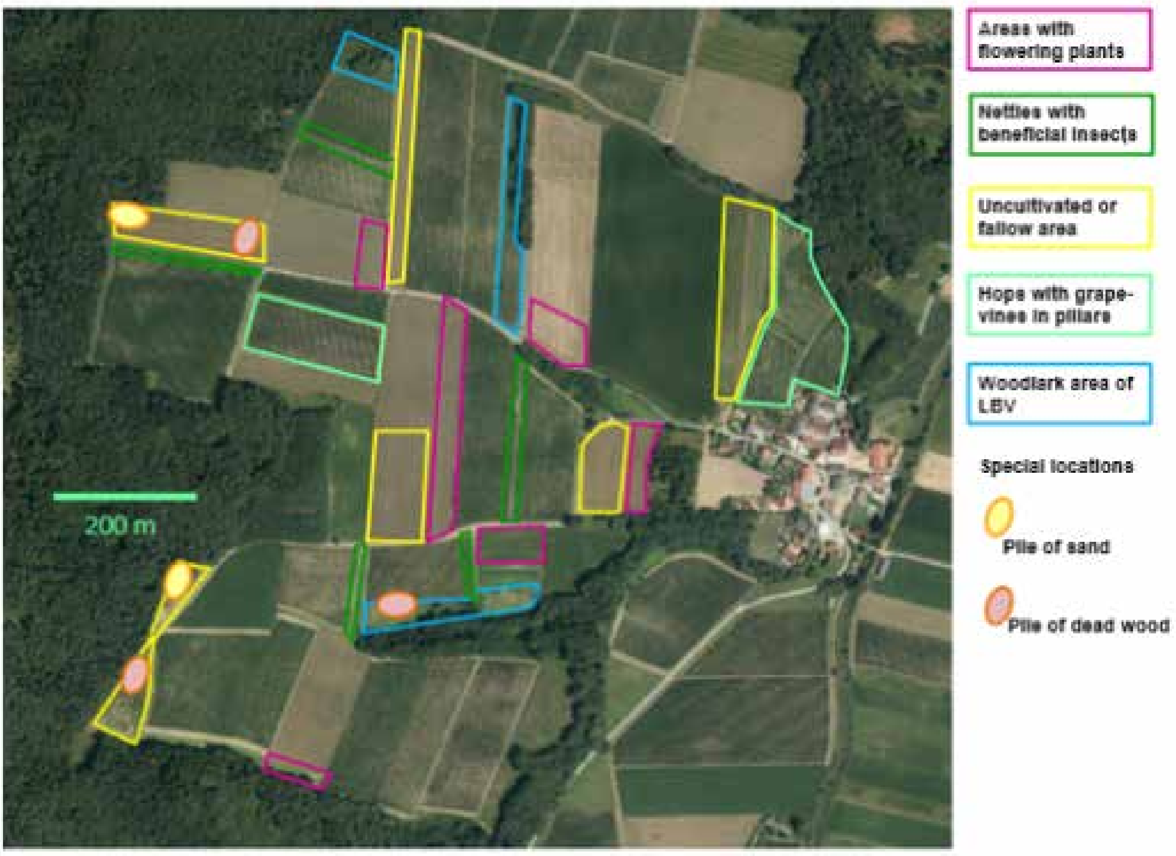


Fig. 8.3 Aerial photo of the “'Eichelberg biodiversity backdrop” with provisionally planned measures for the promotion of biodiversity and biological plant protection methods.

Concept of the "Eichelberg biodiversity backdrop"

The most significant step thus far in the project resulted from the constructive collaboration with IGN Niederlauterbach. Within the landscape of the traditional hop-growing village of Eichelberg, on the edge of the Ilm Valley, there is an almost contiguous 85-ha basin, most of which belongs to and is managed by three IGN farms. Of this area, 34 ha (40%) are planted with hops, 28 ha (33%) is arable land, and the rest is divided into wooded areas, grasslands, flowering meadows, as well as other special-use or no-function spaces. Thanks to the small number of committed landowners and farmers who are interested in biodiversity, the setting in Eichelberg offers exceptional opportunities to develop an example for demonstrating how hop growing and biodiversity do not have to be mutually exclusive but can coexist without problems. In the fall of 2020, a preliminary action plan with an outline of planned measures was introduced (Fig.8.3). The starting date for the implementation of these measures is the spring of 2021.

Fig. 8.4: Flowering meadows next to a hop garden in the Eichelberg biodiversity setting, in August 2020

8.4 Combating the hop flea beetle in organic hop cultivation with gypsum, pulverized rock, and diatomaceous earth (DME)

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: A. Ruß (Bachelor's Thesis), M. Obermaier, Dr. F. Weihrauch

Collaboration: Naturland-Betrieb (*Naturland eV*) Georg Pichlmaier, Haushausen

Dr. Alexander Höldrich, TUM, Campus Straubing für Biotechnologie und Nachhaltigkeit

(Technical University Munich, Straubing Campus for Biotechnology and Sustainability)

Duration: March 1, 2020 to May 31, 2020

Background and objectives

In discussions with organic hop growers, one of the key questions raised is whether pulverized rock can sufficiently prevent flea beetles for damaging leaf surfaces, or if other measures are more suitable. Specifically, gypsum (anhydrite) as an alternative has been considered in discussions at the "Round Table for Plant Protection" and at the Bioland-Hop-Growing day, in the winter of 2019/2020. Another alternative, DME, was proposed by the JKI (Julius Kühn-Institut/Bundesforschungsinstitut für Kulturpflanzen; *Julius Kühn Institute/Federal Research Center for Cultivated Plants*). This substance is also used to protect goods in storage from beetle damage. From these discussions emerged the goal of comparing the effectiveness of these substances at a location with flea beetle infestations, in the spring of 2020. This work took on the form of a bachelor's thesis by Antonia Ruß (TUM, Campus Straubing), who is pursuing a B.Sc. in renewable raw materials.

Results

In April, as soon as the flea beetles were visible on the hop shoots, a preliminary assessment was conducted. At this stage, on April 20, the damage from feeding flea beetles was still considered very small. It was evenly distributed in all test sections and amounted to around 20 to 23% of the leaf area. On April 24, different sections were treated with different agents. Gypsum and pulverized rock were spread mechanically, while DME, which has a tendency to clump, was spread by hand. Because of subsequent rains, application of the different agents was repeated on May 5 between the second and third assay (Fig. 8.5).

Fig.8.5: Leaf damage from hop flea beetles in an untreated control row (left) and a row treated with DME in a test hop garden in Haushausen, on April 24, 2020

At the first assay date, all three treated test variations were significantly different from the untreated control. For each assay, a one-way ANOVA with a significance level $p < 0.05$ was conducted. The loss of leaf area on the new growth of hops was only 10 to 12%. In the untreated control, the loss of leaf area remained unchanged for the first two assays; and for the third assay it had risen to only 20%. On the fourth assay date, however, there was very little new feeding damage on the new leaf growth because, by that time, the hops had "outgrown" the beetles, meaning that the increase in plant matter had exceeded the beetles' ability to keep up. In addition, the life cycle of the beetles neared its natural end. On the second and third assay dates, DME (B2) and pulverized rock (B3) were determined to have significantly reduced leaf damage, if compared to the untreated control. However, we cannot conclude from these tests that one of the remedies perform better than others in fighting damage from hop leaf beetles. At the final assay, there was no statistically significant difference between the overall outcomes of the three treatment agents (Fig. 8.6).

At the beginning of the growing season, pulverized rock, DME, and gypsum were all effective defenses against leaf damage from hop flea beetles, but only parts of the plant are covered with the agents and thus protected. As the hops continued to grow (or after a rainfall), the agents disappeared and needed to be reapplied. Overall, there were no demonstrable differences in effectiveness of the three agents. However, DME is probably less relevant in practice because it needs to be spread by hand, whereas pulverized rock and gypsum can be applied using a mechanical spreader.

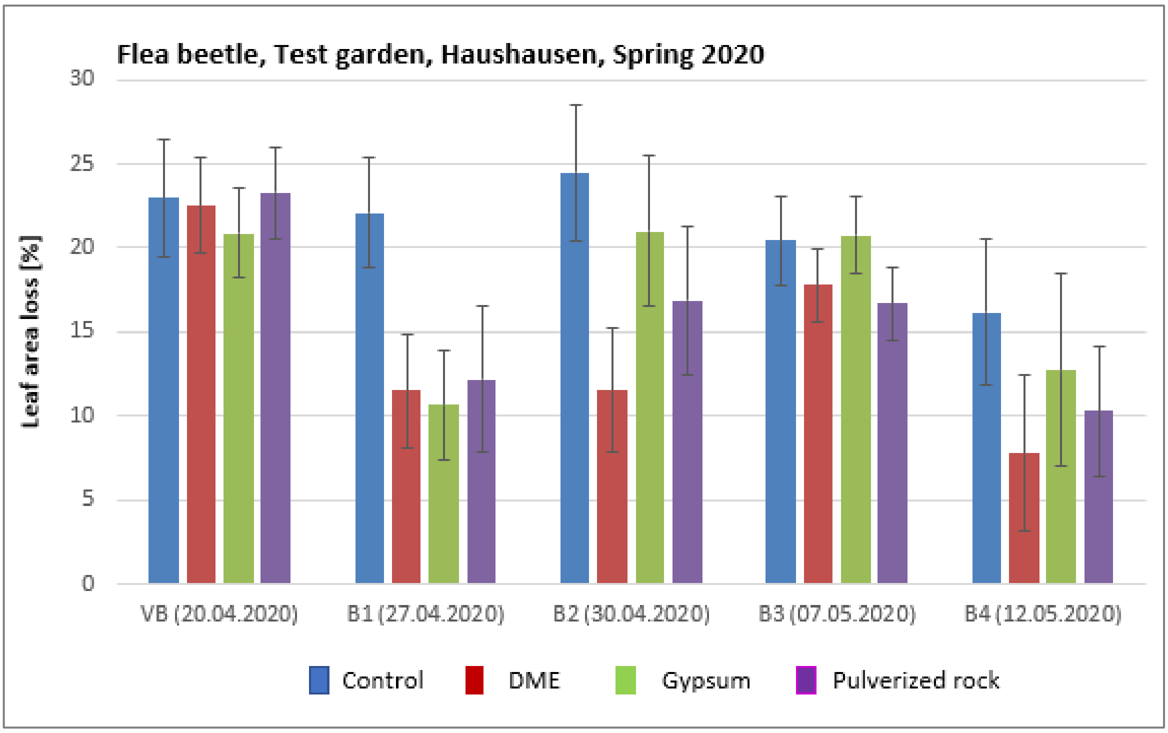


Fig. 8.6: Assay of damage from hop flea beetles in the Haushausen organic test garden planted with Hallertauer Tradition: After the preliminary assay on April 20, 2020, the rows of hops were treated with DME, gypsum, and pulverized rock. This application was repeated on May 5 after several rainfalls. The greatest effect of the treatment was evident at the assay on April 27, when all three test variations showed significant differences from the untreated control (one-way ANOVA, p <0.05).

8.5 Establishment of predatory mites in commercial hop plots via undersowing of cover crops

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:	Bundesanstalt für Landwirtschaft und Ernährung (BLE) über Bundesprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft (*Federal Agency for Agriculture and Food (BLE) through Federal Organic Farming Programme including other forms of sustainable agriculture) (BÖLN Project 2815NA131)* Gesellschaft für Hopfenforschung (GfH) e.V. *(Society for Hop Research)*
Project Management:	Dr. F. Weihrauch
Team:	M. Obermaier
Collaboration:	Various companies practicing ecological and integrated hop production
Duration:	May 1, 2018 to May 31, 2021

Objectives

The main goal of this project is to establish the autochthonous (native) predatory mite species *Typhlodromus pyri*. This predatory mite is widespread in German viticulture and fruit groves. It is able to use various food sources, including harmful mite species (spider mites, grape rust mites, grapevine blister mites), as well as grass pollen.

Because of this low degree of alimentary specialization, *T. pyri* can build stable, long-term populations. The permanent establishment of *T. pyri* is considered capable of bringing about a continuous reduction in spider mites to the point of preventing serious damage of hops from infestations.

Background

The common spider mite *Tetranychus urticae* is one of the main pests in hop cultivation. Infestation can lead to severe yield and quality losses or even to total crop failures. The possibility of effective, sustainable, biological spider mite management is particularly important in organic hop growing, because past methods involving the preventive use of whey and sulfur endanger other, beneficial insects.

Effective biological controls of the common spider mite are becoming increasingly interesting also for conventionally managed hop farms. Integrated pest management strategies have become part of the discussions about pesticide approvals, environmental pollution, and the risk to bees from conventional pesticides in agriculture. A look at other specialty crops shows that successful spider mite management with populations of predatory mites is definitely possible in German fruit and wine growing regions.

Method

Domestic predatory mites are collected in vineyards (provided by the LWG, Veitshöchheim) using pieces of vine that are collected both during winter culling and in May, when frost damage is trimmed. These vines are spread in the hop gardens. In May, the frost-damaged vines can be hung directly on the hop wires, while material from winter culling, based on previous experience, are best spread in February directly into the cover crop between the rows of hops. In the spring, the predatory mites migrate to the hop plants.

*Fig. 8.7: Piece of frost-damaged vine from a vineyard with predatory mites (*T. pyri*) placed on the wire for "inoculating" the hop garden.*

Fig. 8.8: Bean leaves with a mix of predatory mites at the hop wire

In cases of extreme infestations of common spider mites, the use of a mix of specially bred allochthonous (non-native) predatory mites, *Phytoseiulus persimilis* and *Neoseiulus californicus*, are also under consideration as a supplementary mitigation. This mix has shown promising results in previous experiments. What remains to be determined is the best method of introduction, as well as the optimum timing and quantities.

The winter-hardy, tall fescue (*Festuca arundinacea*) is a suitable cover crop in hop gardens, as is a grass mixture that includes meadow foxtail (*Alopecurus pratensis*), Kentucky bluegrass (*Poa pratensis*), and meadow fescue (*Festuca pratensis*). This selection is favorable to predatory mites because it allows them to feed alternately on grass pollen and spider mites, and thus ensures their survival in the spring, between their winter dormancy and the onset of spider mite infestations in hops. In addition, this cover crop should have a positive, year-round effect on the microclimate in the hop gardens.

Also of interest is the experimental planting of strawberries as a woody plant. This strategy is based on experiences in vineyards and fruit orchards. It would allow predatory mites to survive winters between the hop rows instead of in the cover crop.

Fig. 8.9: Strawberries between rows of hops

Fig. 8.10: Grass mix between rows of hops offers a retreat for predatory mites after the hop harvest

Results

Compared to the first two project years, an only moderate spider mite infestation developed in the third project year. In the two organically managed test sites in the Hersbruck area, the infestation pressure from the common spider mite remained at a low level in the summer of 2020. This prevented us from drawing firm and reliable conclusions about the effectiveness of predatory mites. A similar picture emerged at the project's third organic trial hop garden in Ursbach, where the infestation remained at a very low level until mid-August (fewer than 1 spider mite per leaf, on average). Infestation pressure increased only during harvest week, when it was too late for additional damage to occur.

Two conventionally managed experimental hop gardens in Oberulrain and Starzhausen, on the other hand, showed spider mite infestations that required control measures during the 2020 growing season. As was the case in 2018, an initially large spider mite infestation developed in the experimental hop garden, which, however, collapsed in August without any external influence. In Starzhausen, early in the growing season, only domestic predatory mites were brought from vineyards into the hop garden. Vines from winter culling or frost-damaged vines were spread in May. They were intended to support the domestic predatory mites that had survived through the winter.

Table 8.2: Test plots (VGL) at the Starzhausen site, in 2020

VGL	Treatment	Cover crop	Type of predatory mite application
1	Control	---	---
2		Fescue	Frost-damaged vines
3		Grass mix	Vines from winter culling
4	+ predatory mite mix	Strawberries	Frost-damaged vines + bean leaves
P	Commercial plot	Standard strategies	(Integrated pest management)

It was known from previous years that two parcels in a test hop garden planted with strawberries were particularly vulnerable to spider mite infestation. This is because of the sunny hillside location of the parcels in combination with their sandy-gravelly soil. As some of these parcels showed particularly strong infestations in mid-June, additional predatory mites (a mix of *Phytoseiulus persimilis* and *Neoseiulus californicus* on bean leaves) were brought in at the end of June. During subsequent weeks, the number of spider mites in this test section decreased continuously, even though, at this time of year, it would have been normal to see an increase in spider mite infestations. Such an increase did indeed occur in neighboring plots. This demonstrates two facts: A targeted application of predatory mites brought in from the outside at critical points of a spider mite infestation can, indeed, successfully combat infestations. Secondly, it can also prevent the spread of the infection to the rest of the plot. At the end of the growing season, right before the harvest, this test section even showed the lowest spider mite infestation. All plots with predatory mites, regardless of type, showed a significantly lower infestation level of spider mites than did the untreated control.

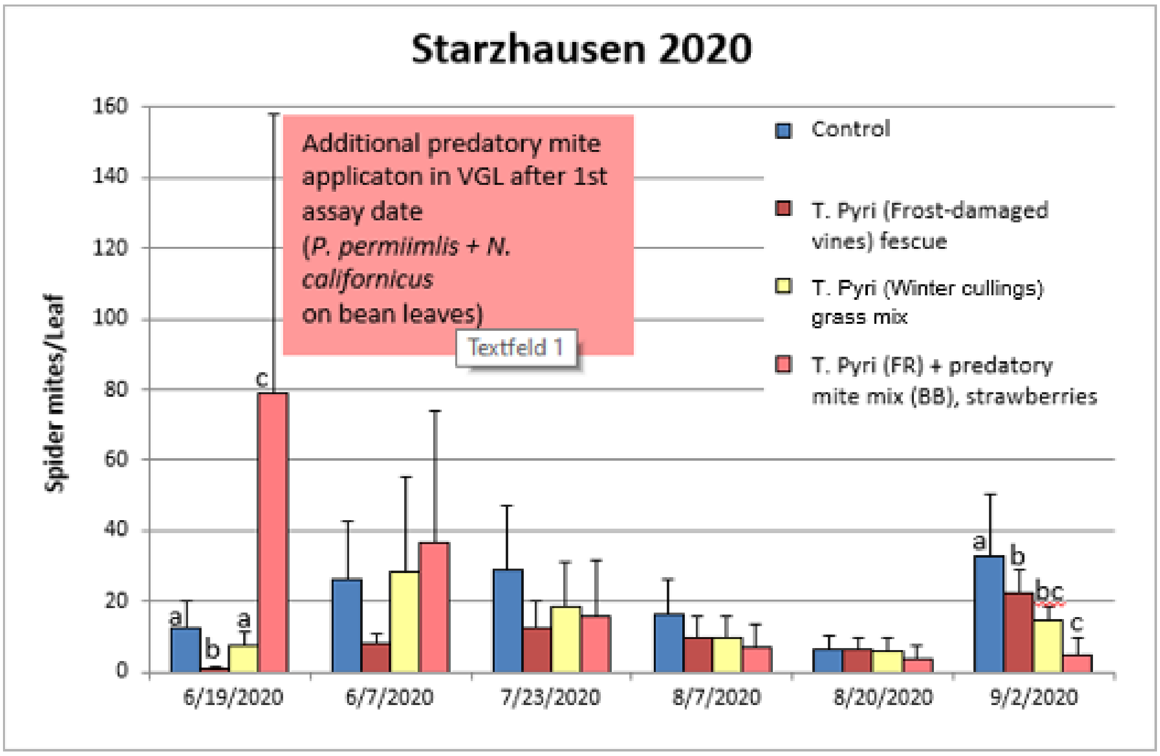


Fig.8.11: Leaf assay at the Starzhausen trial site (Herkules, integrated Plant protection with the exception of chemical treatment against the common spider mite): Spider mites/leaf, 120 leaves were counted per test element (VGL); the VGL elements differ to a statistically significant extent only for the first and last assay date (one-way ANOVA, p <0.05), as denoted by letters

In addition to the positive effects of predatory mites, an increase in the occurrence of other beneficial insects was also observed across all plots at the Starzhausen site. Because a beneficial insect experiment had never been carried out in these test plots before, and because they had always been under conventional hop cultivation, this increase over the three project years can be attributed exclusively to the natural immigration and propagation of beneficial insects. In the third year of the project, black lady beetles and their larvae, as well as other flower bugs (including juvenile stages) and spiders were found rather frequently. These beneficial insects are predators, which, depending on their stage of development, not only eat adult spider mites but also a considerable amount of their eggs. This is an essential mitigation counteracting the build-up of spider mite infestations to a level that is dangerous for the quality of the harvested crop.

Fig.8.12: Beneficial insects that eat spider mites and/or spider mite eggs: predatory mite, larva and adults of Stethorus punctillum *from the black lady beetle family*

Cone assays from the test plots also confirm the performance of predatory mites in combating damage caused by spider mites. While the cones from the untreated control plot showed the greatest damage from spider mites, the two test plots with domestic predatory mites showed significantly less damage. Test section 4, for instance, which was originally heavily infested in June, shows only slight cone damage after treatment with predatory mites. The acaricide-treated commercial plot showed the least damage. In this plot, however, the damage level had a wide range, which demonstrates that even chemical pest controls cannot always guarantee uniform protection. None of the cone damage outlined above, however, had a noticeable effect on cone quality. The variations in quality could be detected only during particularly strict evaluation methods.

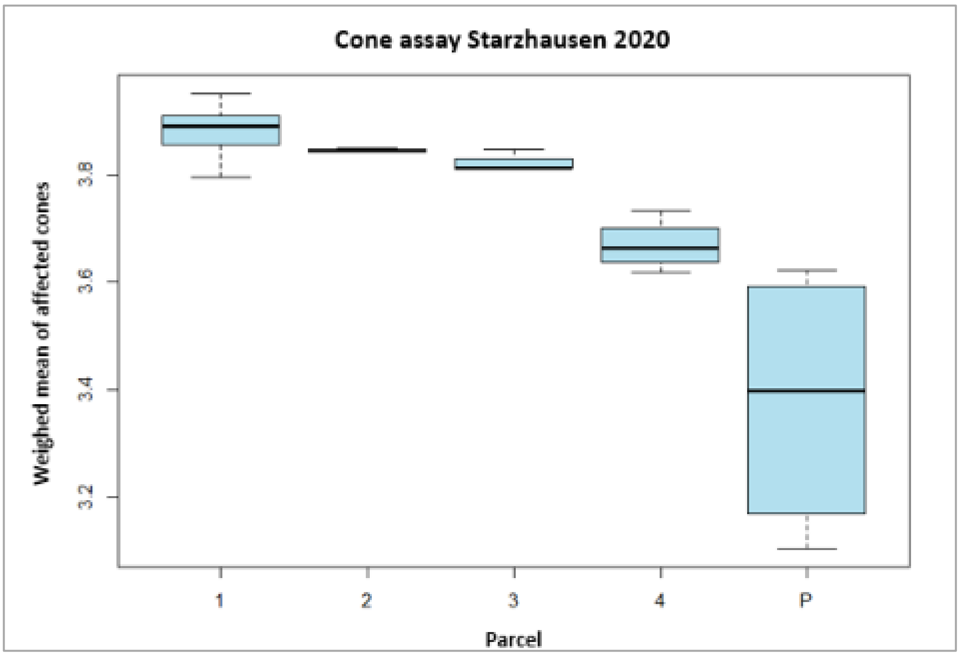


Figure 8.13: Cone damage in the Starzhausen trial in the form of the weighted mean of the severity of the damage sustained by the infected cones at harvest time. Statistically significant differences between the VGL plots are indicated by different letters (Kruskal-Wallis test, p <0.05)

In terms of alpha acid yield, two of the predatory mite test plots are at the level of the commercial plot, although there are no statistically significant differences among the test variations, including the untreated control.

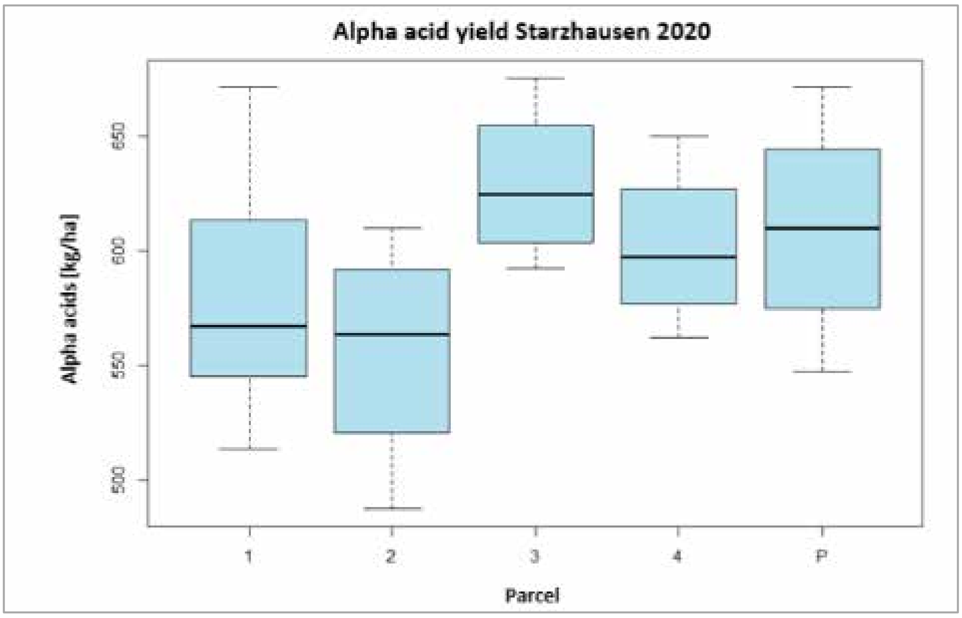


Figure 8.14: Alpha acid yields from the Starzhausen 2020 trial harvest show no statistically significant differences (one-way ANOVA, p <0.05) between the untreated control (1); the VGL plots with predatory mites 2, 3, and 4; and the commercial plot. Noticeably, VGL 3 and 4 were at roughly the same level as the commercial plot

In terms of alpha acid yield, two of the predatory mite test plots are at the level of the commercial plot, although there are no statistically significant differences among the test variations, including the untreated control.

A repeated side observation of the leaf assays was the lower temperature of hop plots with well-developed cover crops. To confirm this observation, data loggers for measuring air humidity and temperature were attached at three different heights (approx. 1.8 m, 4 m, and 7 m above the ground) to individual hop bines in the assay area.

The evaluation revealed a tendency towards smaller temperature fluctuations and higher air humidity, which, in turn, improves the microclimate. Compared to the plot without cover crops, even strong temperature outliers were attenuated in the crown of the hop plant, which is relatively distant from the cover crop.

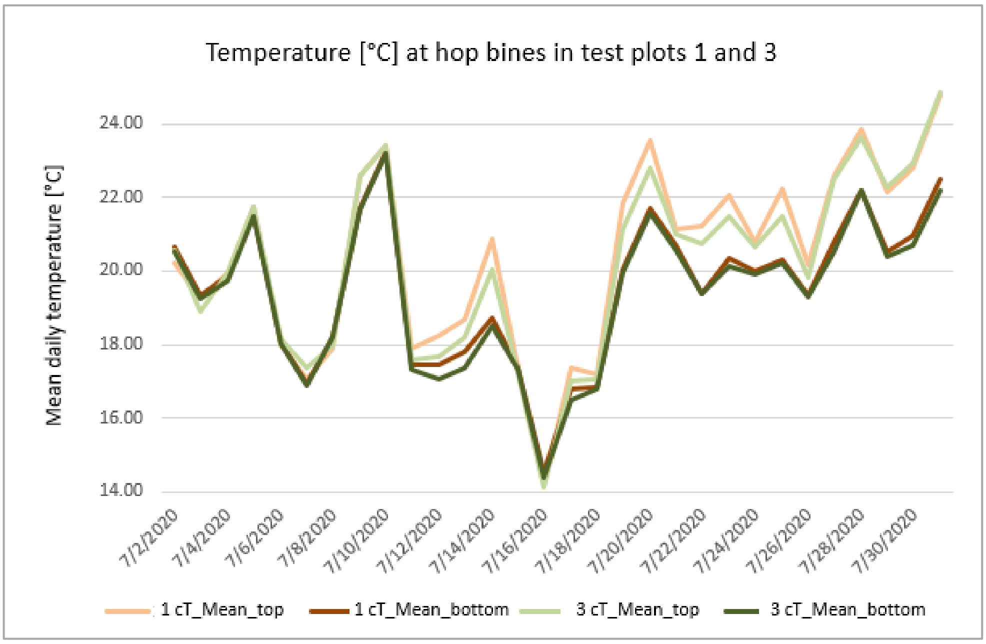


Fig. 8.15: The daily mean temperature as reported by a data logger placed on one hop plant each in plot 1c (control) and plot 3a (grass mix cover crop): Even in the sun-exposed crown area, the temperature in the plot with a well-developed cover crop sowing rises less extremely than it does in the control without a cover crop.

Conclusion

As a summary of the current state of knowledge, the project confirms that the use of predatory mites can limit spider mite infestations in hop gardens to a level that prevents alpha yield losses and cone damage, with the latter being less important as a quality criterion in contracts that have an alpha clause. Targeted use at critical spots in a hop garden, the locations of which a farmer generally knows from experience, can prevent the spread of infestations to the entire plot, while also reducing the infestation level at the application site. Furthermore, by foregoing the use of acaricide treatments, natural opponents of the spider mite can settle long-term in a hop garden. These advantages can be amplified by planting suitable cover crops, which also create microclimates with lower temperatures and increased humidity. This also inhibits spider mite growth and reproduction because the pests prefer drier and warmer environments. Finally, covers can also provide a winter retreat and serve as an alternative food source (pollen) for beneficial insects.

9 Publications and Technical Information

9.1 Overview of public relations

Activity	Number	Activity	Number
Practice-relevant information and scientific papers	43	Guided tours	20
LfL publications	2	Exhibitions/shows and posters	-
Specialist information	14	Expert assessments and opinions	25
Radio and TV broadcasts	-	Internships	4
Internet contributions	12	Participation in working groups	38
Internal events	14	Participation in seminars, congresses, workshops	1
Seminars, symposia, trade conferences, workshops	5	Lectures and Talks	75

9.2 Publications

9.2.1 Practice-relevant information and scientific papers

Doleschel, P.; Euringer, S. (2020): Auftreten des Citrus Bark Cracking Viroid in der Hallertau beschäftigt Hopfenexperten. BrauIndustrie, 1/2020, 28 - 29

Euringer S. (2020): Keine Zitrusreste in den Hopfen. Donaukurier, Pfaffenhofener Kurier, Publisher: Donaukurier GmbH

Euringer, S. (2020): Hopfen 2020 - Grünes Heft, Pflanzenschutz. LfL-Information, Publisher: Bayerische Landesanstalt für Landwirtschaft (LfL)

Euringer, S. (2020): Keine Zitrusreste in den Hopfen. Hopfen-Rundschau, 02/2020, Hopfen-Rundschau, Publisher: Verband dt. Hopfenpflanzer, 58 - 59

Fuß, S. (2020): Pflanzenstandsbericht April 2020. Hopfen-Rundschau, 71. Jahrgang, 05/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 180

Fuß, S. (2020): Pflanzenstandsbericht August 2020. Hopfen-Rundschau, 71. Jahrgang, 09/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 348

Fuß, S. (2020): Pflanzenstandsbericht Juli 2020. Hopfen-Rundschau, 71. Jahrgang, 08/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 320

Fuß, S. (2020): Pflanzenstandsbericht Juni 2020. Hopfen-Rundschau, 71. Jahrgang, 07/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 277

Fuß, S. (2020): Pflanzenstandsbericht Mai 2020. Hopfen-Rundschau, 71. Jahrgang, 06/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 233

Kaemmerer, D., Euringer, S. (2020): Das Hopfen-Viroid im Visier. Bayerisches Landwirtschaftliches Wochenblatt (BLW), Heft 5/2020, Publisher: BBV, 40 - 41

Kaemmerer, D.; Euringer, S. (2020): Das Hopfen-Viroid im Visier. Bayerisches Landwirtschaftliches Wochenblatt (BLW), 1/2020, Bayer. Landw. Wochenblatt, Publisher: Deutscher Landwirtschaftsverlag GmbH, 40 - 41

Kammhuber, K. (2020): Ergebnisse von Kontroll- und Nachuntersuchungen für Alphaverträge der Ernte 2019. Hopfen-Rundschau, 08, Hopfen-Rundschau, Publisher: Verband Deutscher Hopfenpflanzer e.V., 313 - 315

Kammhuber, K. (2020): Time of harvest and its influence on sulphur compounds of hops. Brewing and Beverage Industry - International, 38, Brauwelt International, Publisher: Fachverlag Hans Carl, 86 - 89

Kammhuber, K. (2020): Wöllmeranalysen der neuen Hüller Zuchtsorten. Brauwelt, 51-52/20, Brauwelt, Publisher: Fachverlag Hans Carl, 1384 - 1387

Lutz, A.; Kammhuber, K., Hainzlmaier, M.; Kneidl., J.; Neuhof-Buckl, E.; Petzina, C.; Wyschkon, B. (2020): Bonitierung und Ergebnisse der Deutschen Hopfenausstellung. Hopfen-Rundschau, 15. Nov. 2020 - 71. Jahrgang, Publisher: Verband Deutscher Hopfenpflanzer e.V., 416 - 419

Münsterer, J. (2020): Neue LfL-Informationsschrift Trocknung und Konditionierung von Hopfen. Hopfenrundschau International, 2020/2021, Publisher: Verband Deutscher Hopfenpflanzer e. V., 60 - 61

Münsterer, J. (2020): Trocknung und Konditionierung von Hopfen. LfL-Information, Publisher: Bayerische Landesanstalt für Landwirtschaft (LfL)

Obermaier M., Weihrauch F. (2020): Etablierung von Raubmilben in der Hopfenbau-Praxis über Untersaaten. LfL-Schriftenreihe, 4/2020, Angewandte Forschung und Entwicklung für den ökologischen Landbau in Bayern Öko-Landbautag 2020, Publisher: Bayerische Landesanstalt für Landwirtschaft (LfL), 119 - 122

Obermaier, M., Weihrauch, F. (2020): Etablierung von Raubmilben in der Hopfenbau-Praxis über Untersaaten. Mitteilung der Deutschen Gesellschaft für allgemeine und angewandte Entomologie, 22, Publisher: Deutsche Gesellschaft für allgemeine und angewandte Entomologie, 121 - 124

Portner, J. (2020): Abschlusstreffen der Demonstrationsbetriebe integrierter Pflanzenschutz am Bundesforschungsinstitut (JKI) in Berlin-Kleinmachnow. Hopfen-Rundschau, 71. Jahrgang, 03/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 95

Portner, J. (2020): Ermittlung des Stickstoffdüngebedarfs von Hopfen in Bayern. Hopfen-Rundschau, 71. Jahrgang, 04/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 129

Portner, J. (2020): Hopfen 2020, Publisher: LfL

Portner, J. (2020): Kostenfreie Rücknahme von Pflanzenschutzverpackungen PAMIRA 2020. Hopfen-Rundschau, 71. Jahrgang, 08/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 316

Portner, J. (2020): Leitlinien zum integrierten Pflanzenschutz im Hopfenanbau. Hopfen-Rundschau, 71. Jahrgang, 06/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 213 - 232

Portner, J. (2020): Leitlinien zum integrierten Pflanzenschutz im Hopfenanbau. Hopfenrundschau International, 2020/2021, Publisher: Verband Deutscher Hopfenpflanzer e. V., 46 – 54

Portner, J. (2020): Nährstoffvergleich bis 31. März erstellen! Hopfen-Rundschau, 71. Jahrgang, 03/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V. , 96

Portner, J. (2020): Peronosporabekämpfung - Planen Sie Ihren Mitteleinsatz. Hopfen-Rundschau, 71. Jahrgang, 06/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 210

Portner, J. (2020): Rebenhäcksel baldmöglichst ausbringen! - Sperrfristverschiebung in Bayern bis zum 15. Oktober. Hopfen-Rundschau, 71. Jahrgang, 08/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 317

Portner, J. (2020): Rebenhäckseluntersuchung als zusätzliche Anforderung in den "Roten Gebieten"! Hopfen-Rundschau, 71. Jahrgang, 08/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 318

Portner, J. (2020): Zwischenfruchteinsaat im Hopfen planen. Hopfen-Rundschau, 71. Jahrgang, 06/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 212

Portner, J. (2020): Übermittlung von Angaben im Hopfensektor. Hopfen-Rundschau, 71. Jahrgang, 05/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 176 - 177

Portner, J., Brummer, A. (2020): N_{min}-Untersuchung 2020 und endgültige N_{min}-Werte in Bayern. Hopfen-Rundschau, 71. Jahrgang, 05/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 178 - 179

Portner, J., Kammhuber, K. (2020): Fachkritik zur Moosburger Hopfenbonitierung 2020. Hopfen-Rundschau, 71. Jahrgang, 10/2020, Publisher: Verband Deutscher Hopfenpflanzer e. V., 384 - 390

Schlagenhaufer, A., Lohr, D. (2020): Umweltgerechte Rückführung der Hopfenrebenhäcksel. Hopfenrundschau International, 2020/2021, Publisher: Verband Deutscher Hopfenpflanzer e. V., 84 - 87

Seigner, E., Lutz, A., Kammhuber, K.; König, W. (2020): Aurum – Grünes Gold für klassische Bierstile. Brauwelt Wissen, 46/47, Publisher: Fachverlag Hans Carl, 1232 - 1235

Seigner, E., Doleschel, P. (2020): Nachruf für Ltd. LD a.D. Franz Gmelch. Hopfen-Rundschau, 15. Oktober 2020 - 71. Jahrgang, Publisher: Verband Deutscher Hopfenpflanzer, 409 - 409

Seigner, E.; Lutz, A. (2020): Der neue Schlepper für die Hüller Hopfenforschung ist da. Hopfen-Rundschau, 04-15. April 2020, 71. Jahrgang, Publisher: Verband Deutscher Hopfenpflanzer e.V, 150 - 150

Seigner, E.; Lutz, A. (2020): Zukunftsweisende Züchtungskooperation zwischen Bayern und den Elbe-Saale-Hopfenbauländern - Leistungsstarke, robuste Hüller Hochalphasorten für die Elbe-Saale-Hopfenpflanzer. Hopfenrundschau International, Jahresausgabe 2020/2021, Publisher: Verband Deutscher Hopfenpflanzer, 28 - 31

Seigner, E.; Lutz, A., Kammhuber, K.; König, W. (2020): Aurum - Feinwürziger Hüller Aromahopfen der Extraklasse. Hopfenrundschau International, Jahresausgabe 2020/2021, Publisher: Verband Deutscher Hopfenpflanzer, 82 - 83

Stampfl, J. (2020): Bewässerung und Fertigation von Hopfen. Hopfenrundschau International, 2020/2021, Publisher: Verband Deutscher Hopfenpflanzer e. V., 92 - 98

Weihrauch, F. (2020): Rosy rustic moth as a hop pest in the Hallertau: History and current situation. Mitteilung der Deutschen Gesellschaft für allgemeine und angewandte Entomologie, 22, Publisher: Deutsche Gesellschaft für allgemeine und angewandte Entomologie, 125 - 128

Weihrauch, F. (2020): Sind 30 Prozent Öko-Hopfen bis 2030 realistisch? Brauwelt, 160 (33-34), Publisher: Fachverlag Hans Carl, 854 - 854

Weihrauch, F. (2020): Sortenliste 2019 des Internationalen Hopfenbaubüros (IHB). Hopfen-Rundschau, 71(01), Publisher: Verband Deutscher Hopfenpflanzer e.V., 18 - 27

9.2.2 LfL-Publications

Name(s)	Working Group	LfL Publication	Title
Hop Department	IPZ 5	LfL-Information	Annual Report 2019 – Specialty Crop Hop
Portner, J.	IPZ 5a	LfL-Information	Hop 2020 - Grünes Heft *(Green Pamphlet)*
Euringer S.	IPZ 5b	LfL-Information	Hop 2020 - Grünes Heft *(Green Pamphlet)* Pflanzenschutz *(Plant Protection)*

9.2.3 Internet contributions

Author(s)	Title	Target Group
Euringer, S.	Arbeiten zum Citrus Bark Cracking Viroid *(Work on the Citrus Bark Cracking Viroid)*	Hop growers
Lutz, K.	Forschungs- und Innovationsprojekt zur *Verticillium*-Problematik bei Hopfen *(Research and innovation project on the* Verticillium *problem in hops)*	Hop growers
Portner, J.	Aktuelle Hopfenbauhinweise und Warndienst-meldungen *(Current hop growing instructions and warning service messages)*	Hop growers
Portner, J.	Aktuelles zum Pflanzenschutz und Termine *(Current information on crop protection and dates)*	Hop growers
Portner, J.	Veranstaltungen und Hinweise *(Events and notices)*	Hop growers
Seigner, E.	Die Hüller Zuchtsorten - Top-Qualität im Aroma- und Alphabereich *(The Hüll cultivars - top quality in the aroma and alpha range)*	Hop and brewng industries, and all those interested in hops
Seigner, E.	Entwicklung von leistungsstarken Hoch-Alpha-Sorten mit besonderer Eignung für den Anbau im Elbe-Saale-Gebiet *(Development of high-performance high-alpha varieties with particular suitability for cultivation in the Elbe-Saale area)*	Hop and brewing industries
Seigner, E.; Lutz, A.	Aurum – Hüller Grünes Gold für Hopfenpflanzer und Brauer *(Aurum - Hüll Green Gold for hop growers and brewers)*	Hop and brewing industries
Seigner, E.; Lutz, A.	Die Hochalphasorten Herkules und Polaris *(The high alpha varieties Hercules and Polaris)*	Hop and brewing industries
Seigner, E.; Lutz, A.	Die neuen, modernen Hüller Aromasorten – Fit für die Zukunft *(New, modern Hüll aroma varieties - Fit for the future)*	Hop and brewing industries, and all those interested in hops
Seigner, E.; Lutz, A.	Klassische Aromasorten mit dem Aromaprofil der feinen Landsorten *(Classic aroma varieties with the aroma profile of the fine landraces)*	Hop and brewing industries, and all those interested in hops
Seigner, E.; Lutz, A.	Diamant – die neue hochfeine Hüller Aromasorte mit Spalter Mutter *(Diamant - the new, extremely fine Hüll aroma variety with Spalter mother)*	Hop and brewing industries

9.3 Conferences, talks and lectures, guided tours, exhibitions/shows

9.3.1 Seminars, symposia, trade conferences, workshops

Date	Speakers(s)	Event	Venue	Target Group
January 29, 2019	Münsterer, J	Seminar: Optimizing hop drying	Hüll	Hop growers
January 14, 2020	Münsterer, J.	Seminar: Optimizing hop drying	Hüll	Hop growers
January 16, 2020	Münsterer, J.	Seminar: Optimal conditioning of hops	Hüll	Hop growers
January 24, 2020	Münsterer, J.	Seminar: Basics of irrigation	Hüll	Hop growers
February 18, 2020	Münsterer, J.	Seminar: Test results for nitrogen fertilization	Hüll	Hop growers
February 28, 2020	Stampfl, J.; Fuß, S:	Workshop: Belt dryers	Hüll	Hop growers
March 3, 2020	Stampfl, J.; Fuß, S.	Workshop: Irriga tion and fertigation	Hüll	Hop growers
March 3, 2020	Portner, J.; Schlagen-haufer, A.	Seminar: Optimizing hop drying	Hüll	Hop growers

9.3.2 Attendance at seminars, symposia, conferences, workshops IPZ 2020

Date	Event	Place	Target Group
September 24, 2020	Honoring the winners of the Moosburger hop assay	Moosburg	Prize winners and guests

9.3.3 Internal events

Date	Event	Place	Target group
January 14, 2020	Seminar: Optimizing hop kilning	Seminar	Hüll
January 16, 2020	Seminar: Optimizing hop kilning	Seminar	Hüll
January 24, 2020	Seminar:Optimal conditioning of hops	Seminar	Hüll
January 29, 2020	Project meeting: N-dynamics in hops	Working Group meeting	Wolnzach
February 2, 2020	Evaluations of drying performance, energy consumption, and shredded hop bines	Working Group meeting	Haunsbach
February 17, 2020	Roundtable: Hops	Working Group meeting	Wolnzach
February 18, 2020	Workshop: Belt dryers	Workshop	Hüll
February 28, 2020	Workshop: Irrigation and fertigation	Workshop	Hüll

Date	Event	Place	Target group
March 3, 2020	Seminar: Basics of irrigation	Seminar	Hüll
March 3, 2020	Seminar: Test results for nitrogen fertilization	Seminar	Hüll
March 4 18, 2020	Meeting: "Grünes Heft" *(Green pamphlet on hops)*	Working Group meeting	Hüll
March 5, 2020	News and innovation in crop protection	Working Group meeting	Mitterstetten
August 18, 2020	News in hop growing	Working Group meeting	Oberpindhart
September 29, 2020	Hop assay in Moosburg	Working Group meeting	Moosburg

9.3.4 Education, training, continuing education

Date	Event/Partner	Type	Place	Target Group
January 1, 2020	Administation of the oral part of the master craftsman's examination Euringer, S.	Final exam	Hüll	Farmers
January 30, 2020	Dealing with CBCVd when giving advice in hop gardens Euringer, S.	Other training	Hüll	Others
June 18, 2020	Training on the procedure and correct sampling for CBCVd monitoring Euringer, S.	Other training	Hüll	Others
June 19, 2020	Training on the procedure and correct sampling for CBCVd monitoring Euringer, S.	Other training	Hüll	Others
November 17, 2020	Continuing education in hops - Doemens World Brewing Academy Lutz, A.	Other training	Hüll	Students

9.3.5 Expert opinions and assessments

Date	Expert	Title	Client
April 29, 2020	Doleschel, P.	Plant breeding research at the LfL	LfL
January 22, 2020	Euringer, S.	Assessment of effects of Revus® & Revus Top® on plant diseases in hops in 2019	AELF
February 10, 2020	Euringer, S.	Fact sheet: Art. 53 Hop aphid - Movento SC 100	Association of German Hop Growers e.V.
March 2, 2020	Euringer, S.	Fact sheet: Art. 53 Soil pests - Exirel	Association of German Hop Growers e.V.

Date	Expert	Title	Client
April 8, 2020	Euringer, S.	Danger of the spread of the Citrus Bark Cracking Viroid with shredded hop bines or fermentation residues	StMELF
May 12,2020	Offenberger, K. Portner, J	Results of the research project: composting and recycling of shredded hop bines	StMELF
April 23, 2020	Portner, J.	EU harvest report hops 2019	BMEL und StMELF
May 29, 2020	Portner, J.	Position paper on the irrigation needs of hops	AELF
June 24, 2020	Portner, J.	Use of calcium cyanamide in hop gardens	StMELF
September 11, 2020	Portner, J.	Use of copper preparations in plant protection in conventional hop cultivation	StMELF
September 11, 2020	Portner, J.	Questionnaire regarding follow-up activities in hop cultivation	BVL
April 16, 2020	Seigner, E.	Peer review	Czech Journal of Genetics and Plant Breeding
May 20 2020	Seigner, E.	Peer review	Czech Academy of Agricultural Sciences
September 16, 2020	Seigner, E.	Peer review	Journal *BrewingScience*
October 22, 2020	Seigner, E.	Peer review	Journal *BrewingScience*
January 13, 2929	Weihrauch, F.	Assessment of conference contributions	International Society for Horticultural Science
January29, 2020	Weihrauch, F.	Supervision, assessment and grading of a master's thesis	TUM
February 26, 2020	Weihrauch, F.	Position paper on emergency application according to §53	BVL
August 4, 2020	Weihrauch, F.	Peer review	Journal Plant, Soil and Environment
August 12, 2020	Weihrauch, F.	Peer review	International Society for Horticultural Science
November 6, 020	Weihrauch, F.	Peer review	International Society for Horticultural Science

Date	Expert	Title	Client
November 9, 2020	Weihrauch, F.	Peer review	International Society for Horticultural Science
November 26, 2020	Weihrauch, F.	Position paper on the area structure of the Hallertau hop growing region	Association of German Hop Growers e.V.
October 14, 2020	Weihrauch, F.; Obermaier, M.	Peer review	Journal 'Arthropod-Plant Interactions'
December 18, 2020	Weihrauch, F.; Obermaier, M.	Peer review	Journal 'Environmental Entomology'

9.3.6 Specialist information

Euringer, S., Lutz, K.: 'Arbeiten zum Citrus Bark Cracking Viroid' (Internet contribution)

Lutz, K., Euringer, S.; Seigner, E.: 'Forschungs- und Innovationsprojekt zur *Verticillium*-Problematik bei Hopfen' (Internet contribution)

Portner, J.: 'Aktuelle Hopfenbauhinweise und Warndienstmeldungen', Wolnzach (Internet-Beitrag)

Portner, J.: 'Aktuelles zum Pflanzenschutz und Termine', Wolnzach, 06.08.2020 (Internet-Beitrag)

Portner, J.: 'Veranstaltungen und Hinweise', Wolnzach, 24.11.2020 (Internet contribution)

Seigner, E., Lutz, A.: 'Die Hüller Zuchtsorten - Top-Qualität im Aroma- und Alphabereich' (Internet contribution)

Seigner, E., Lutz, A.: 'Entwicklung von leistungsstarken Hoch-Alpha-Sorten mit besonderer Eignung für den Anbau im Elbe-Saale-Gebiet' (Internet contribution)

Seigner, E., Lutz, A.: 'Entwicklung von leistungsstarken, gesunden Hopfen mit hohen Alphasäuregehalten und besonderer Eignung für den Anbau im Elbe-Saale-Gebiet - 4. Sachbericht'; (intermediate project status report)

Seigner, E.: 'Kompetenz der LfL-Hopfenzüchtung in allen deutschen Hopfenanbaugebieten gefragt', 17.06.2020 (MAP-contribution)

Seigner, E.; Lutz, A., Kammhuber, K.: 'Die Hochalphasorten Herkules und Polaris' (Internet contribution)

Seigner, E.; Lutz, A., Kammhuber, K.: 'Die neuen, modernen Hüller Aromasorten – Fit für die Zukunft' (Internet contribution)

Seigner, E.; Lutz, A., Kammhuber, K.: 'Klassische Aromasorten mit dem Aromaprofil der feinen Landsorten' (Internet contribution)

Seigner, E.; Lutz, A., Kammhuber, K.: 'Diamant – die neue hochfeine Hüller Aromasorte mit Spalter Mutter' (Internet contribution)

Seigner, E.; Lutz, A.: 'Aurum – Hüller Grünes Gold für Hopfenpflanzer und Brauer' (Internet contribution)

9.3.7 Lectures

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Doleschel, P.	Current issues in plant protection in hop cultivation	LKP-HR	Members and employees of the Hopfenring, consultants, representatives of local organizations	Aiglsbach, March 17, 2020
Doleschel, P.	Overview of the Institut für Pflanzenbau und Pflanzenzüchtung *(Institute for Plant Production and Plant Breeding)*	LfL	Lawyers-in-training	WebEx, July 14, 2020
Euringer, S.	Plant protection in hop growing 2020	Federal Environmental Agency (UBA)	Employees of the Federal Environment Agency (UBA)	Berlin, January 28, 2020
Euringer, S.	Plant protection in hop growing 2020	BayWa Bruckbach	Advisers and warehouse employees	Bruckbach, January 29, 2020
Euringer, S.	Plant protection in hop growing 2020	LfL + AELF Roth	Hop growers	Hedersdorf February 5, 2020
Euringer, S.	Plant protection in hop growing 2020	LfL + AELF Roth	Hop growers	Spalt, February 5, 2020
Euringer, S.	Plant protection in hop growing 2020	LfL + AELF PAF	Hop growers	Unter-pindhart, February 6, 2020
Euringer, S.	Plant protection in hop growing 2020	LfL + AELF AB	Hop growers	Marching, February 7, 2020
Euringer, S.	Plant protection in hop growing 2020	LfL + AELF Erding	Hop growers	Osselts-hausen, February 10, 2020
Euringer, S.	Plant protection in hop growing 2020	LfL + AELF Landshut	Hop growers	Oberhatz-kofen February 11, 2020
Euringer, S.	Plant protection in hop growing 2020	LfL + AELF PAF	Hop growers	Lindach, February 12, 2020
Euringer, S.	Plant protection in hop growing 2020	LfL + AELF AB	Hop growers	Mainburg, February 12, 2020
Euringer, S.	Plant protection in hop growing 2020	LfL + AELF AB	Hop growers	Biburg, February 20, 2020

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Euringer, S.	General information on plant protection in hop growing	BMEL	Staff of the Federal Ministry of Food and Agriculture	Online event, March 26, 2020
Euringer, S.	Current information on the Citrus Bark Cracking Viroid (CBCVd)	Deutscher Brauer-Bund *(German Brewers Association)*	Agricultural Committee of the German Brewers Association	Wolnzach, September 1, 2020
Euringer, S.	Hop week: *Verticillium*	AELF	1st semester students of the winter school Pfaffenhofen a.d. Ilm	Pfaffenhofen an der Ilm, October 16, 2020
Euringer, S.	Hop week: Viroses and Viroids	AELF	1st semester students of the winter school Pfaffenhofen a.d. Ilm	Pfaffenhofen an der Ilm, October 16, 2020
Euringer, S.	Current pesticide situation in Germany	LfL	Members of the Commodity Expert Group (CEG)	Online-event, November 4, 2021
Euringer, S.	Evaluation of the Citrus Bark Cracking Viroid (CBCVd)	LfL	RNQP hops	Online-event, November 25, 2021
Euringer, S.	Report from the research project for *Verticillium* wilt on hops	Gesellschaft für Hopfen-forschung (GfH) *(Society for Hop Research, e.V.)*	GfH-Board of Directors	Hüll, December 2, 2020
Euringer, S.; Seigner, L.; Seigner, E., Mühlbauer, M.	Healthy seedlings for German hop cultivation	Gesellschaft für Hopfen-forschung (GfH) *(Society for Hop Research, e.V.)*	Members of the technical-scientific committee of the Society for Hop Research	Wolnzach, October 21, 2020
Fuß, S., Stampfl, J.	Irrigation and fertigation	LfL	Hop growers	Hüll, February 28, 2020
Fuß, S., Stampfl, J.	Seminar on the basics of irrigation	LfL	Hop growers	Hüll, March 3, 2020
Kammhuber, K.	Isolation, identification and analysis of multifidoles in hops	GfH	GfH Board of Directors	Hüll, December 2, 2020
Lutz, A.	Hüll breeding lines and varieties before the harvest	LfL	Hopfenring	Trial garden, Stadelhof, August 17, 2020

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Lutz, A., Euringer, S.; Kämmerer, D.	Information on CBCVd monitoring in Bavaria	Ministry for Rural Areas and Consumer Protection, Baden-Württemberg	Hop experts from the hops team at the Ministry for Rural Areas and Consumer Protection, Baden-Württemberg	Straß, Tettnang, August 19, 2020
Lutz, A., Kneidl, J.; Ismann, D.; Seigner, E.; Stampfl, J.; Schlagen-haufer, A.	Breeding progress: Low input - high output	Gesellschaft für Hopfen-forschung (GfH) *(Society for Hop Research, e.V.)*	GfH-Vorstandschaft *(GfH Management)*	Hüll, December 2, 2020
Lutz, A., Seigner, E.	Breeding progress: climate tolerance and Powdery mildew resistance	Gesellschaft für Hopfen-forschung (GfH) *(Society for Hop Research, e.V.)*	Members of the technical-scientific committee of the Society for Hop Research	Wolnzach, October 21, 2020
Lutz, A., Seigner, E.; Kneidl, J.; Ismann, D.; Stampfl, J.; Schlagen-haufer, A.	Züchtungsfortschritt: Low Input - High Output	IPZ 5	Working Groups on hops	Hüll, December 14, 2020
Münsterer, J.	Control of the drying performance for achieving optimal quality	HVG Spalt	Hop growers from the Spalt growing area	Spalt, January 9, 2020
Münsterer, J.	Optimization of hop kilning	LfL	Hop growers from the Hallertau growing region	Hüll, January 14, 2020
Münsterer, J.	Optimization of Hop kilning	LfL	Hop growers from the Hallertau growing region	Hüll, January 16, 2020
Münsterer, J.	Optimal conditioning of hops	LfL	Hop growers from the Hallertau growing region	Hüll, January 24, 2020
Münsterer, J.	New findings in hop kilning	LfL	Members of the Hop Working Group	Haunsbach, February 4, 2020
Obermaier M., Weihrauch F.	Establishment of predatory mites in the hop growing practice via cover crops	LfL	Farmers, scientists, and representatives of organic farming associations	Freising / online, October 27, 2020

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Obermaier, M., Weihrauch, F.	Establishment of predatory mites in the hop growing practice via cover crops	Bioland e.V.	Organic hop farmers, association advisor	Plankstetten Abbey, February 4, 2020
Obermaier, M., Weihrauch, F.	Cover crops to establish predatory mites in hop gardens	LfL	Organic hop growers from Germany, Austria and France; and representatives of the hops trade	Sallingberg, July 21, 2020
Obster R.; Euringer, S.	AMP test design (Good Engineering Practices; GEP Quality Audits)	LfL	BASF, Video-conference	September 30, 2020
Obster, R.; Euringer, S.	GEP Quality Audits 2020	LfL	LfL employees	December 14, 2020
Obster, R.; Euringer, S.; Kaindl, K.	Trial design using the example of our „powdery mildew trial 2020“	LfL	CEG members	Online Meeting, November 4, 2020
Portner, J.	Current information on the fertilizer ordinance	BayWa Bruckbach	Employees of BayWa and hop advisors	Bruckbach, January 29, 2020
Portner, J.	Evaluation of drying performance and energy consumption	LfL	Working group members	Haunsbach, February 4, 2020
Portner, J.	Report on experiences with the Fertilizer Ordinance	LfL and AELF Roth	Hop growers	Hedersdorf, February 5, 2020
Portner, J.	Report on experiences with the Fertilizer Ordinance	LfL and AELF Roth	Hop growers	Spalt, February 5, 2020
Portner, J.	Expert review: hops	Stadt Moosburg	Prize winners and guests of the Moosburger hop assay	Moosburg, September 24, 2020
Portner, J.	Status of the research projects of IPZ 5a and current topics	Gesellschaft für Hopfen-forschung (GfH) *(Society for Hop Research, e.V.)*	Board of Gesellschaft für Hopfenforschung (GfH) *(Board of the Society for Hop Research, e.V.)*	Hüll, December 2, 2020
Schlagen-haufer, A.	The latest findings on storage, application, and effect of fertilization with shredded hop bines	BayWa Bruckbach	Advisers and employees of the warehouses	BayWa Bruckbach, January 2, 2020

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Schlagen-haufer, A.	The latest findings on storage, appli-cation, and effect of fertilization with shredded hop bines	LfL and AELF Abensberg	Hop growers	Biburg, February 3, 2020
Schlagen-haufer, A.	The latest findings on storage, appli-cation, and effect of fertilization with shredded hop bines	LfL and AELF Roth	Hop growers	Spalt, February 5, 2020
Schlagen-haufer, A.	The latest findings on storage, appli-cation, and effect of fertilization with shredded hop bines	LfL and AELF Roth	Hop growers	Hedersdorf, February 5, 2020
Schlagen-haufer, A.	The latest findings on storage, appli-cation, and effect of fertilization with shredded hop bines	LfL and AELF Pfaffenhofen	Hop growers	Unterpindhart, February 6, 2020
Schlagen-haufer, A.	The latest findings on storage, appli-cation, and effect of fertilization with shredded hop bines	LfL and AELF Abensberg	Hop growers	Marching, February 7, 2020
Schlagen-haufer, A.	The latest findings on storage, appli-cation, and effect of fertilization with shredded hop bines	LfL and AELF Erding	Hop growers	Osseltshausen, February 10, 2020
Schlagen-haufer, A.	The latest findings on storage, appli-cation, and effect of fertilization with shredded hop bines	LfL and AELF Landshut	Hop growers	Oberhatzkofen, February 11, 2020
Schlagen-haufer, A.	The latest findings on storage, appli-cation, and effect of fertilization with shredded hop bines	LfL and AELF Abensberg	Hop growers	Mainburg, February 12, 2020
Schlagen-haufer, A.	The latest findings on storage, appli-cation, and effect of fertilization with shredded hop bines	LfL and AELF Pfaffenhofen	Hop growers	Lindach, February 12, 2020
Schlagen-haufer, A.	Research project on the storage, application, and effect of fertilization with shredded hop bines	Gesellschaft für Hopfenfor-schung (GfH) *(Society for Hop Research, e.V.)*	Members of the technical scientific committee of the Society for Hop Research	Wolnzach, Hop Museum, October 21, 2020

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Schlagen-haufer, A.	Overview from the research projects: N-dynamics in hop soils and composting of shredded hop bines	LfL	IPZ 5	Wolnzach, Haus des Hopfens, December 14, 2020
Schlagen-haufer, A. Stampfl, J.	Experimental results on N-fertilization in hops	LfL	Hop growers	Hüll, March 3, 2020
Schlagen haufer, A., Stampfl, J.	Experimental results on N-fertilization in hops	LfL	Hop growers	Hüll, March 12, 2020
Seigner, E.	Research and field work on *Verticillium* wilt in hops	Hop Sales Cooperative (HVG)	HVG supervisory board	Wolnzach, November 11, 2020
Seigner, E.	Research on *Verticillium* wilt in hops	LfL	Hop team	Wolnzach, December 14, 2020
Seigner, E., Doleschel, P.; Portner, J.; Euringer, S.; Lutz, A.; Kammhuber, K.; Weihrauch, F.	LfL hop research	Gesellschaft für Hopfen-forschung (GfH) *(Society for Hop Research, e.V.)*	Hop bloggers	Hüll, September 11, 2020
Seigner, E., Doleschel, P.; Portner, J.; Stampfl, J.; Euringer, S.; Lutz, K.; Lutz, A.; Kammhuber, K.; Weihrauch, F.; Obermeier, M.	Experimental and research activities of the LfL hop team in 2020	Deutscher Brauer-Bund *(German Brewers Association)*	Agrarausschuss des Deutschen Brauer-Bundes *(agricultural committee of the association)*	Wolnzach, September 1, 2020
Seigner, E., Lutz, A.	Cross breeding with the Tettnang land race	Ministry for Rural Areas and Consumer Protection, Baden-Württemberg	Ministry of Rural Areas, Baden-Württemberg, Hop Growers Association, Tettnang	Stuttgart, February 17, 2020
Seigner, E., Lutz, A.; Kammhuber, K.; Albrecht, T.; Mohler, V.	Genome-based precision breeding for quality hops	Gesellschaft für Hopfen-forschung (GfH) *(Society for Hop Research, e.V.)*	GfH-Vorstandschaft *(GfH Management)*	Hüll, December 2, 2020

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Seigner, E., Lutz, A.	Current state of cross-breeding with the Tettnang landrace	Ministry for Rural Areas and Consumer Protection, Baden-Württemberg	Participants in the hops service meeting of the Ministry for Rural Areas and Consumer Protection, Baden-Württemberg	Straß, Tettnang, August 19, 2020
Weihrauch, F.	Plant protection in organic hops	Beiselen GmbH	Staff of the trade	Hebronts-hausen, Januray 31, 2020
Weihrauch, F.	New ways of conventional plant protection in hop cultivation - entirely organic?	BarthHaas	Hop growers and the hop trade	Mainburg, February 14, 2020
Weihrauch, F.	Request for continued funding of a research project on the topic of 'Hops and Biodiversity' until 2023	HVG	Supervisory board of the producer group HVG e.G.	Wolnzach, August 25, 2020
Weihrauch, F.	Funding of pesticides initiative: Application for funding of a research project	German Federal Environment Foundation	Expert committee of the DBU	Osnabrück / online, August 27, 2020
Weihrauch, F.	Presentation of copper monitoring in hops by associations	BÖLW & JKI	Scientists, plant protection services, consultants and plant protection companies with an interest in organic farming	Berlin / online, November 25, 2020
Weihrauch, F.	Continuation of a research project on the topic, 'Hops and biodiversity' until 2023: Concept of the Eichelberg biodiversity backdrop	Gesellschaft für Hopfen-forschung (GfH) *(Society for Hop Research, e.V.)*	Board of GfH	Hüll, December 2, 2020
Weihrauch, F., Obermaier, M.	Copper minimization in hops: Trial results from 2019	Bioland e.V.	Organic hop farmers, association advisors	Plankstetten Abbey, February 4, 2020

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Weihrauch, F., Obermaier, M.	Funding application for project „Minimization of the use of copper-containing fungicides in ecological and integrated hop cultivation“	HVG	Supervisory board of the producer group HVG e.G.	Wolnzach, August 25, 2020

9.3.8 Internships

Theme	Supervisor	Intern(s)	Start	Finish
Hop research	Kammhuber, K.	Student	September 21, 2020	February 12, 2021
Hop research	Lutz, A.	Student	March 16, 2020	July 10, 2020
Hop research	Lutz, A.	Student	February 18, 2020	July 10, 2020
Hop research	Lutz, A.	Student	June 15, 2020	June 19, 2020

9.3.9 Guided tours (No. = number of participants)

Date	Name	Subject/Title	Guest(s)	No.
September 18, 2020	Doleschel, P. Lutz, A.	LfL hop research, hop breeding, hop cultivation, and harvesting	Team assistants	2
August 20, 2020	Lutz, A.	Harvest 2020 - optimal harvest time for the varieties	ISO hop farms	50
Sptember 28, 2020	Lutz, A.	LfL hop research, hop breeding, and varieties	BarthHaas group and brewers	5
August 4, 2020	Lutz, A.	LfL hop research, hop breeding, beer tasting	Research group at TUM, Dr. Remco Stam	7
August 24, 2020	Lutz, A.	LfL hop research, hop breeding, and hop cultivation	CBCVd monitoring group	25
August 27, 2020	Lutz, A.	LfL hop research, hop breeding, and hop varieties	TUM, Experimental brewery	10
July 23, 2020	Lutz, A.	LfL hop research, hop breeding, crop cultivation	Organic hop growers	30
January 17, 2020	Lutz, A.	LfL hop research, hop breeding, new varieties	BayWa - Evergrain barley breeder	3
January 22, 2020	Lutz, A.	LfL hop research, breeding of varieties, variety of hop aromas	Naturfreunde Pfaffenhofen, (Friends of Nature, Pfaffenhofen)	40

Date	Name	Subject/Title	Guest(s)	No.
January 13, 2020	Lutz, A.	LfL hop research, hop breeding, and cultivation	Students - Agricultural School	10
September 15, 2020	Lutz, A. Seigner, E.	LfL hop research, hop breeding, hop cultivation, hop harvest, beer tasting	LfL, Human Resources	5
June 16, 2020	Lutz, A. Seigner, E.	LfL hop breeding	BayWa	4
May 15, 2020	Münsterer, J. Lutz, A.	LfL hop research, hop breeding, varieties, hop cultivation	Agricultural school, Pfaffenhofen	9
September 9, 2020	Seigner, E.	LfL hop research, hop breeding, hop varieties, hop analytics, hop cultivation, plant protection, ecological issues	Kalsec and Hopfenhäcker Brewery	9
August 26, 2020	Seigner, E.	LfL hop research, hop breeding, hop cultivars	Suntory, Hop processing cooperative	3
February 5, 2020	Seigner, E. Kammhuber, K. Weihrauch, F.	LfL hop research, breeding of new varieties, hop cultivation, hop analyics; ecological issues	Technical college, Ostwestfalen-Lippe	16
September 11, 2020	Seigner, E. Lutz, A.	LfL hop research, hop breeding, hop aroma assays	Hop bloggers	20
June 16, 2020	Seigner, E. Lutz, A. Kammhuber, K.	LfL hop research, hop breeding, hop cultivation, hop analytics	Lutz scholarship from the city of Pfaffenhofen	1
July 9, 2020	Weihrauch, F.	Ecological crop protection in hops, ecological hop cultivation	Koppert Biological Systems	3
September 9, 2020	Weihrauch, F.	Ecological crop protection in hops, organic hop cultivation, trial harvest	Brewing scientist, University of Edinburgh	1

9.4 Participation in working groups, memberships

Member	Organization (Native language)	Organization (English)
Doleschel, P.	Bayerische Pflanzenzuchtgesellschaft	Bavarian Plant Breeding Society
	DLG e.V., Deutsche Landwirtschafts-Gesellschaft	DLG e.V, German Agricultural Society
	DLG-Ausschuss für Pflanzenzüchtung und Saatgutwesen	DLG Committee for Plant Breeding and Seed Science
	GIL, Gesellschaft für Informatik in der Land-, Forst- und Ernährungswirtschaft e.V.	GIL Society of Computer Science in Agriculture, Forestry and Food Science e.V.
	Gesellschaft für Hopfenforschung	Society for Hop Research
	Gesellschaft für Pflanzenbauwissenschaften e.V.	Society for Plant Cultivation Sciences, e.V.
	Gesellschaft für Pflanzenzüchtung	Society of Plant Breeding
	ISIP e.V. (Informationssystem Integrierte Pflanzenproduktion)	ISIP e.V. Information System Integrated Plant Production)
	Kartoffelgesundheitsdienst Bayern e.V.	Potato Health Service Bavaria
	LKP	LKP
	Testgremium für Pflanzkartoffeln in Bayern	Test Team for Seed Potatoes in Bavaria
Euringer, S.	EU Commodity Expert Group Minor Uses Hops	EU Commodity Expert Group Minor Uses Hops
	Ring junger Hopfenpflanzer e.V.	Young Hop Growers e.V.
Fuß, S.	Prüfungsausschuss für den Ausbildungsberuf Landwirt am Fortbildungsamt Landshut	Board of Examiners for Qualified Agriculturalist at Landshut authority for continuing education
Kammhuber, K.	Arbeitsgruppe für Hopfenanalytik (AHA)	Hop Analytics Working Group (AHA)
	European Brewery Convention (Hopfen-Subkomitee) Analysen-Kommitee	European Brewery Convention (Hops Subcommittee), Analysis committee
	Gesellschaft Deutscher Chemiker (GDCH)	Society of German Chemists (GDCH)
Münsterer, J.	Prüfungsausschuss für den Ausbildungsberuf Landwirt am Fortbildungsamt Landshut	Board of Examiners for Qualified Agriculturalist at Landshut authority for continuing education
Portner, J.	AG Nachhaltigkeit im Hopfenbau	WG Sustainability in Hop Production
	JKI - Fachbeirat Geräte-Anerkennungsverfahren zur Beurteilung von Pflanzenschutzgeräten	equipment approval procedure for assessing plant production equipment
	Meisterprüfungsausschüsse Niederbayern, Oberbayern-Ost und	Boards of Examiners Lower Bavaria, Upper Bavaria East,

Member	Organization (Native language)	Organization (English)
	Oberbayern-West für den Ausbildungsberuf Landwirt	Upper Bavaria West, for Qualified Agriculturalist
Seigner, E.	Gesellschaft für Hopfenforschung	Society of Hop Research
	Gesellschaft für Pflanzenzüchtung	Society of Plant Breeding
Weihrauch, F.	Chairman der EU Commodity Expert Group (CEG) Minor Uses in Hops	Chairman of the EU Commodity Expert Group (CEG) Minor Uses in Hops
	Chairman der Wissenschaftlich-Technischen Kommission (WTK) des Internationalen Hopfenbaubüros (IHB)	Chairman of the Scientific and Technical Commission (WTK) of the International Hop Growers' Convention (IHB)
	Arbeitsgemeinschaft Bayerischer Entomologen e.V	Working Group of Bavarian Entomologists
	British Dragonfly Society	British Dragonfly Society
	Deutsche Gesellschaft für allgemeine und angewandte Entomologie (DGaaE)	German Society for General and Applied Entomology (DGaaE)
	DGaaE, AK Neuropteren	DGaaE, Study Group Neuroptera
	DGaaE, AK Nutzarthropoden und Entomopathogene Nematoden	DGaaE, Study Group Beneficial Arthropods and Entomopathogenic Nematodes
	Deutsche Phytomedizinische Gesellschaft (DPG)	DPG, German Phytomedicinal Society
	Deutsche Gesellschaft für Orthopterologie (DGfO)	DGfO, German Society of Orthopterology
	Gesellschaft deutschsprachiger Odonatologen e.V.	Society of German-speaking Odonatologists e.V.
	Gesellschaft für Hopfenforschung e.V.	Society of Hop Research
	Münchner Entomologische Gesellschaft e.V.	Munich Entomological Society e.V.
	Rote Liste Arbeitsgruppe der Neuropteren Deutschlands	Red List Working Group Germany's Neuroptera
	Rote-Liste-Arbeitsgruppen der Libellen und Neuropteren Bayerns	Red List Working Groups Bavaria's Dragonflies and Neuroptera
	Worldwide Dragonfly Society	Worldwide Dragonfly Society

10 Our Team

The following groups and persons were active in 2019 on behalf of the Landesanstalt für Landwirtschaft - Institut für Pflanzenbau und Pflanzenzüchtung - Hüll/Wolnzach/Freising

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(AG = Working Group)

IPZ 5

Overall Management: Director at LfL Dr. Peter Doleschel

Alexandra Hertwig
Birgit Krenauer

IPZ 5a
AG Hopfenbau, Produktionstechnik
( )
Managing Director (LD): Johann Portner

Elke Fischer
LAR Stefan Fuß
LAR Jakob Münsterer
B.Sc. Andreas Schlagenhaufer
M.Sc. Johannes Stampfl

IPZ 5b
AG Pflanzenschutz im Hopfenbau
( )
Head: Simon Euringer

Anna Baumgartner
Maria Felsl
Korbinian Kaindl
Kathrin Lutz
Marlene Mühlbauer
Regine Obster (since April 1, 2020)
Johann Weiher
Laura Wörner (to March 10, 2020)

IPZ 5c

AG Züchtungsforschung Hopfen
( )
Head: Bureau Director (RD) Dr. Elisabeth Seigner

Brigitte Brummer
LTA Renate Enders
CTA Brigitte Forster
Stephan Gast (since March 1, 2020)
CTA Petra Hager
LTA Brigitte Haugg
Maximilian Heindl
Elfriede Hock (to September 30, 2020)
Agr.-Techn. Daniel Ismann
LTA Jutta Kneidl
LAR Anton Lutz
Katja Merkl
Sonja Ostermeier
Ursula Pflügl
Andreas Roßmeier

IPZ 5d
AG Hopfenqualität und -analytik
( )
Head: Bureau Director (RD) Dr. Klaus Kammhuber

MTLA Magdalena Hainzlmaier
CL Evi Neuhof-Buckl
Dipl.-Ing. agr. (Univ.) Cornelia Petzina
CTA Silvia Weihrauch
CTA Birgit Wyschkon

IPZ 5e
AG Ökologische Fragen des Hopfenbaus
( )
Head: Dipl.-Biol. Dr. Florian Weihrauch

M.Sc. Maria Obermaier