LfL

Bayerische Landesanstalt für Landwirtschaft

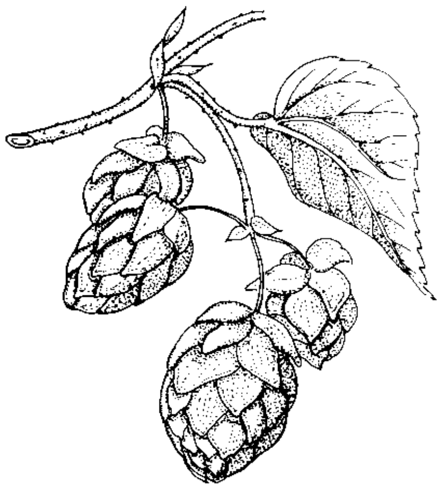
GfH

Wir forschen Hopfen

Gesellschaft für Hopfenforschung e.V.

Annual Report 2021

Special Crop: Hops



Bavarian State Research Center for Agriculture

- Institute for Crop Science and Plant Breeding -

and

Society for Hop Research e.V.

May 2022

LfL-Information

Imprint

Publisher:	Bayerische Landesanstalt für Landwirtschaft (LfL) *(Bavarian State Research Center for Agriculture)* Vöttinger Straße 38, 85354 Freising-Weihenstephan Internet: http://www.LfL.bayern.de
Edited:	Institut für Pflanzenbau und Pflanzenzüchtung, Arbeitsbereich Hopfen *(Institute for Crop Science and Plant Breeding, Hops Department)* Hüll 5 1/3, D-85283 Wolnzach E-Mail: Hopfenforschungszentrum@lfl.bayern.de Tel.: (+49) 81 61/86 40 23 00
Translation:	Cerevisia Communications LLC (Massachusetts USA)
Print:	Logo! Design und mehr…, 84307 Eggenfelden
Nominal fee:	15.00 €

Annual Report 2021

Special Crop: Hops

Foreword

The Corona pandemic has been a major topic also in crop year 2021. The Delta variant was followed by the Omicron variant, which turned out to be much more contagious but resulted in less severe cases. Eventually, Corona might transition into a regular infectious disease, similar to the flu, which would finally allow for the resumption of normal life with folk festivals and other public events. Two other challenges of existential significance for humanity and of great importance for hop cultivation are the changing climate and the preservation of biodiversity. Both challenges can be met only through a more sustainable and resource-saving life style in all areas; and hop cultivation must make its contribution to these objectives. Humans not only have the privilege to use nature but also the duty to preserve it.

"The Lord God took the man and put him in the Garden of Eden to work it and take care of it!" (Gen. 2,15)

Our hop research is well positioned for its mission. Our hop breeding efforts are focused on the development of stress-tolerant varieties that can cope with such extreme weather conditions as heat, drought, and excess moisture, while also ensuring a combination of stable yields and stable alpha acid values next to exceptional brewing qualities. The new varieties from Hüll can already be considered a huge success.

The Working Group IPZ 5a is developing fertigation methods for the use of fertilizers in a more targeted, needs-based, and more efficient manner to allow the plants to make better use of available nutrients. The seepage of nitrogen from agriculture into the soil is another hotly debated topic. The investigation of nitrogen dynamics in hop soils, as well as experiments in composting and recycling shredded hop bines should generate important insights. The optimization of hop kilning processes saves heating oil, while also securing hop quality. At the same time, it reduces CO_2 greenhouse gas emissions and generates savings for the grower.

The "Green Deal" of the EU envisions a reduction in the application of herbicides and pesticides of 50 percent by 2050. This represents a huge and far-reaching future challenge for plant protection measures in hop cultivation. During the crop year 2021, the CBCVd was monitored again; and three hop farms had to be added to list of infected operations, which brings the total numbers to 10 farms.

The Working Group IPZ 5 focused on several important projects that contribute to the preservation of biodiversity and the environment in hop cultivation. In addition, a large new research project will soon focus on naturally induced resistances against spider mites.

The Annual Report presented here gives a comprehensive picture of the many activities currently carried out at the Hop Research Center in Hüll. Successful hop research is the work product of many diligent, dedicated, and creative staff members. They deserve our special thanks.

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

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

Table of Contents

Page

1 Statistical Hop Production Data

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

1.1 Acreage data

1.1.1 Structure of hop production

Table 1.1: 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	2005	1,611	10.66
1980	5,716	3.14	2010	1,435	12.81
1985	5,044	3.89	2015	1,172	15.23
1990	4,183	5.35	2020	1,087	19.05
1995	3,122	7.01	2021	1,062	19.42
2000	2,197	8.47			

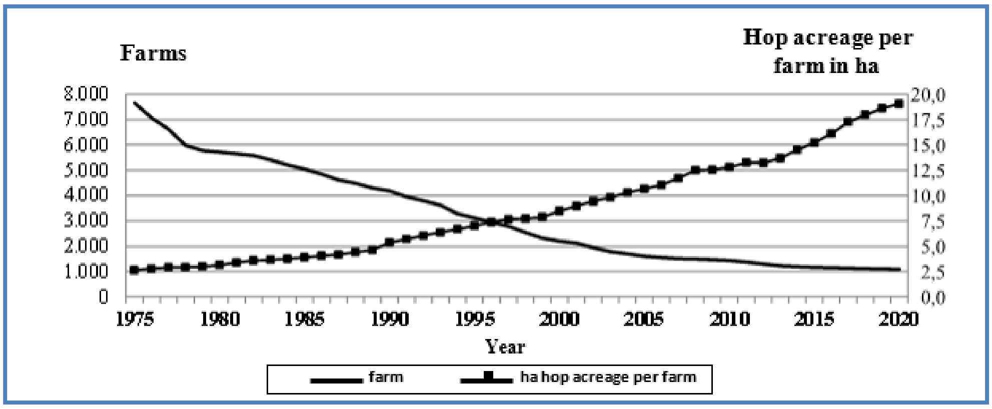


Figure 1.1: Number of hop farms and their acreages in Germany

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 2020	in ha 2021	Increase + / Decrease - 2020 to 2021 ha	Increase + / Decrease - 2020 to 2021 %	2020	2021	Increase + / Decrease - 2021 to 2020 Farms	Increase + / Decrease - 2021 to 2020 %	2020	2021
Hallertau	17,233	17,122	- 111	- 0.6	880	860	- 20	- 2.3	19.58	19.91
Spalt	408	400	- 8	- 1.9	51	46	- 5	- 9.8	7.99	8.69
Tettnang	1,479	1,494	42	15.0	125	125	± 0	± 0	11.84	11.96
Baden, Bitburg, Rhein-Palatinate	22	22	0	± 0	2	2	± 0	± 0	11.00	11.00
Elbe-Saale	1,564	1,582	18	1.1	29	29	± 0	± 0	53.93	54.55
Germany	**20,706**	**20,620**	**- 86**	**- 0.4**	**1,087**	**1,062**	**- 25**	**- 2.3**	**19.05**	**19.42**

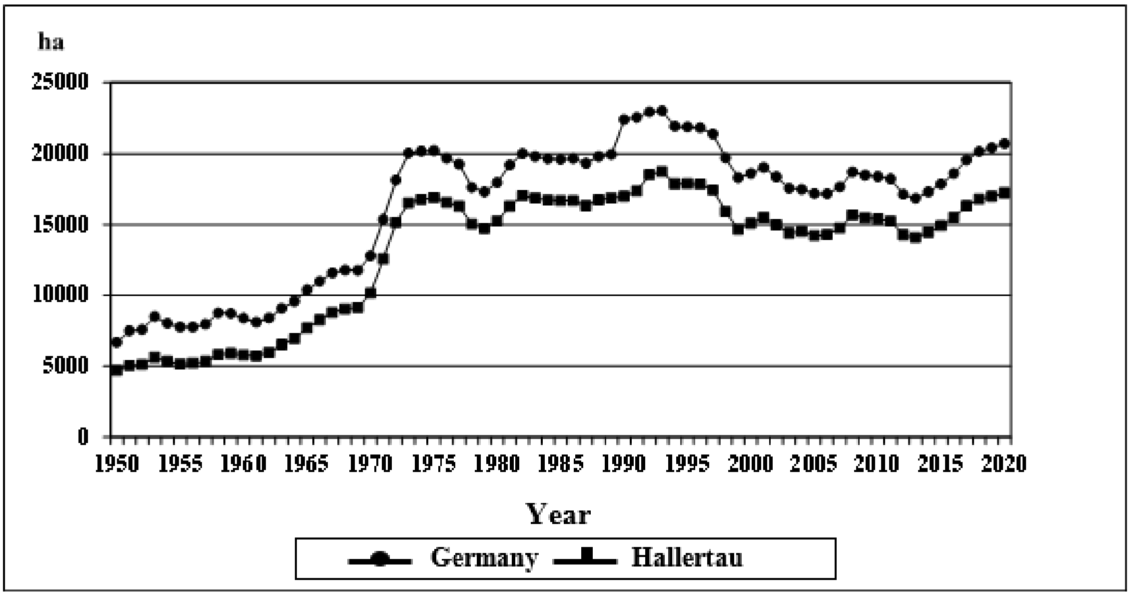


Figure. 1.2: Hop acreage in Germany and in the Hallertau

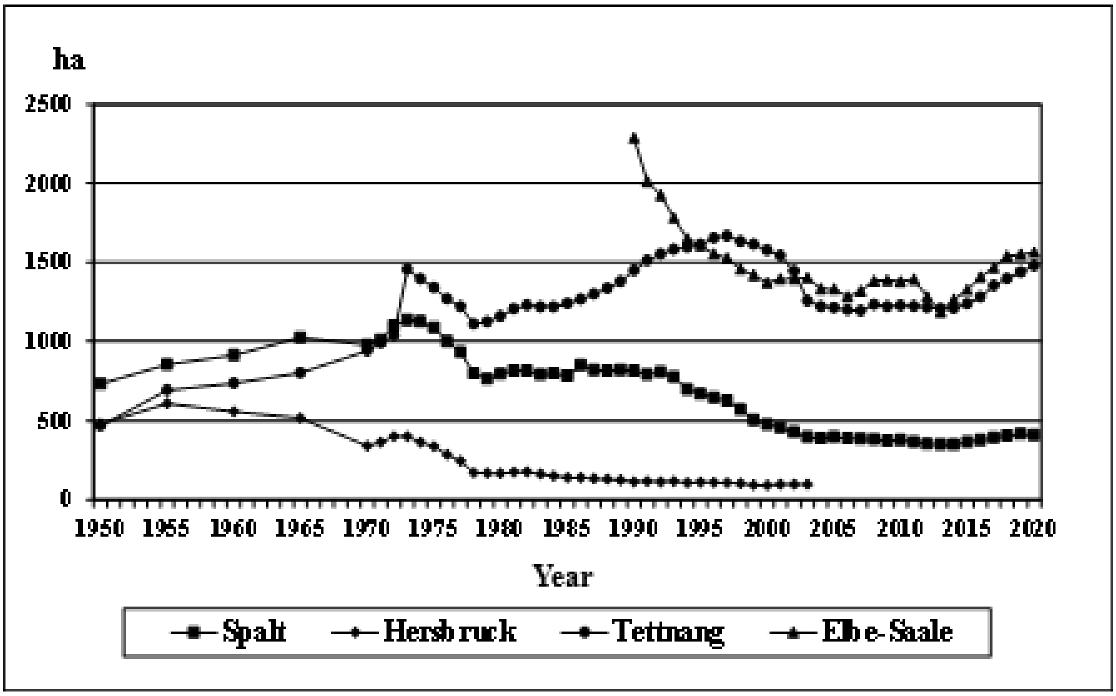


Figure 1.3: Hop acreage in Spalt, Hersbruck, Tettnang and Elbe-Saale

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

1.1.2 **Hop varieties**

After seven years of acreage increases, the **German hop acreage** decreased for the first time in 2021, by 86 hectares (ha). The total acreage is acreage now **20,620 ha**.

The portion planted with **aroma varieties** decreased slightly and is now at 53.3%. Germany now cultivates 29 aroma varieties on 11,000 ha. Most aroma varieties lost acreage. The largest decrease in the aroma category was for Herbrucker Spät, which lost 83 ha. In addition, significant acreage eliminations occurred for Saphir, Spalter Select, Tettnanger, and Hallertauer Mittelfrüh, as well as for varieties once called "Flavor" hops. Perle, on the other hand, experienced an increase in acreage, as did a few new aroma varieties, such as Akoya.

Bitter hop cultivation increased once again in Germany, this time by 252 ha. It now accounts for 46.7% of all German hop cultivation. Again, older bitter varieties, such as Hallertauer Magnum, Taurus, Nugget, and Merkur declined in acreage, whereas Herkules (+ 257 ha) and Polaris (+ 96 ha) once again gained acreage. This has propelled Herkules to the position of the most plentiful hop variety by far in Germany (6,974 ha). This is almost one-third of the total hop acreage.

Table 1.3: Hop varieties in German growing regions in hectares in 2021

Aroma Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Akoya	90		3	9	1	**104**	**0.5**	**78**
Amarillo	127		8	10		**144**	**0.7**	**-34**
Ariana	73	5	2			**79**	**0.4**	**-3**
Aurum			1			**1**	**0.0**	**0**
Brewers Gold	17					**17**	**0.1**	**-2**
Callista	44	1	8	9		**62**	**0.3**	**1**
Cascade	48	4	2	8	1	**64**	**0.3**	**-14**
Comet	4		0			**4**	**0.0**	**-4**
Diamant	9	5	0			**14**	**0.1**	**3**
Hallertau Blanc	127	3	13	6		**149**	**0.7**	**-18**
Hallertauer Gold	4	2				**6**	**0.0**	**0**
Hallertauer Mfr.	478	26	138	7	1	**650**	**3.2**	**-21**
Hallertauer Tradition	2,661	42	81	55	4	**2,844**	**13.8**	**-26**
Hersbrucker Pure	1	2				**3**	**0.0**	**0**
Hersbrucker Spät	815	6	0			**821**	**4.0**	**-83**
Hüll Melon	54	5	10	2		**71**	**0.3**	**-36**
Mandarina Bavaria	205	3	11	10		**230**	**1.1**	**-48**
Monroe	15		3			**18**	**0.1**	**-5**
Northern Brewer	127			128		**255**	**1.2**	**-11**
Opal	135	1	1			**138**	**0.7**	**-7**
Perle	2,886	37	123	272	8	**3,331**	**16.2**	**34**
Relax	5					**5**	**0.0**	**0**
Saazer	7			155		**162**	**0.8**	**6**
Saphir	317	18	40	20		**395**	**1.9**	**-55**
Smaragd	58	1	14			**73**	**0.4**	**-9**
Solero	11					**11**	**0.1**	**8**
Spalter	1	107				**108**	**0.5**	**-5**
Spalter Select	444	86	23	4		**557**	**2.7**	**-51**
Tettnanger			682			**682**	**3.3**	**-37**
Total (ha)	**8,764**	**353**	**1,169**	**696**	**15**	**10,997**	**53.3**	**-338**
Percentage (%)	**42.5**	**1.7**	**5.7**	**3.4**	**0.1**	**53.3**		**-1.6**

Bitter Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Hallertauer Magnum	1,234	2		621	3	**1,861**	**9.0**	**-58**
Hallertauer Merkur	2	3		1		**6**	**0.0**	**-2**
Hallertauer Taurus	165	1	0	3		**169**	**0.8**	**-42**
Herkules	6,499	38	294	137	5	**6,974**	**33.8**	**257**
Nugget	107			4		**111**	**0.5**	**-12**
Polaris	291		27	119		**437**	**2.1**	**96**
Record	1					**1**	**0.0**	**0**
Xantia	2					**2**	**0.0**	**2**
Others	56	2	3	1		**62**	**0.3**	**10**
Total (ha)	**8,358**	**47**	**325**	**886**	**8**	**9, 623**	**46.7**	**252**
Percentage (%)	**40.5**	**0.2**	**1.6**	**4.3**	**0.0**	**46.7**		**1.2**

All Varieties

	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Total (ha)	**17,122**	**400**	**1,494**	**1,582**	**22**	**20,620**	**100.0**	**-86**
Percentage (%)	**83.0**	**1.9**	**7.2**	**7.7**	**0.1**	**100.0**		**-0.4**

1.2 Harvest volumes, yields, and alpha acid contents

The **2021 hop harvest** in Germany brought in 47,862,190 kg (= 957,244 German hundred-weight), which was just above the previous year's good harvest result of 46,878,500 kg (= 937,570 German hundredweight). Except for 2019, this was the second largest hop harvest ever in Germany. Considering that the total hop area had declined by 86 ha, this result was better than average.

With an average yield of 2,321 kg/ha for the total area, the **hectare yield** this year is 57 kg/ha above that of the previous year, but it did not reach the record set in 2019.

In 2021, the most important hop varieties achieved top values for **alpha acid content**. These were often above the long-term average. At this writing, the overall amount of alpha acids produced in Germany in 2021 is estimated to be 6,240 metric tons (MT), which is about 780 MT more than the previous year; and even almost 1,000 MT more than for the record harvest of 2019. This development is a clear sign of the growing impact of high-alpha varieties as well as the growing portion of alpha-focused cultivation.

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

	2016	2017	2018	2019	2020	2021
Yield kg/ha	2,299	2,126	2,075	2,374	2,264	2,321
Acreage in ha	18,598	19,543	20,144	20,417	20,706	20,620
Total harvest in kg	42,766,090	41,556,250	41,794,270	48,472,220	46,878,500	47,862,190

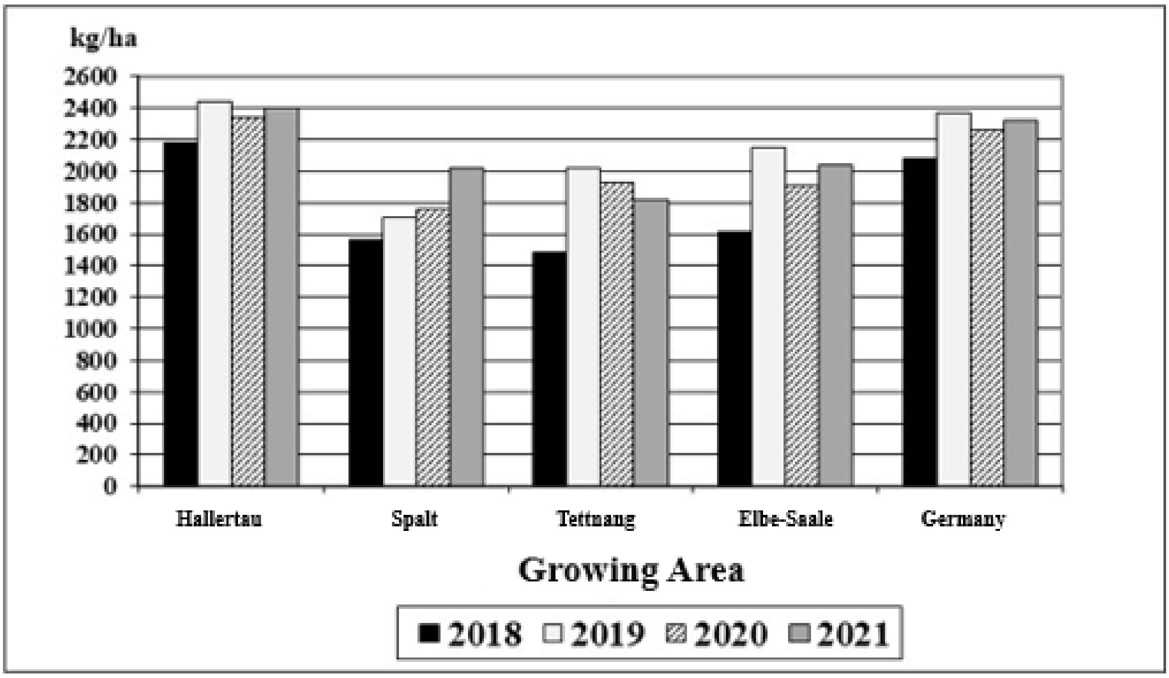


Figure 1.4: Average yields of the different growing regions in kg/ha

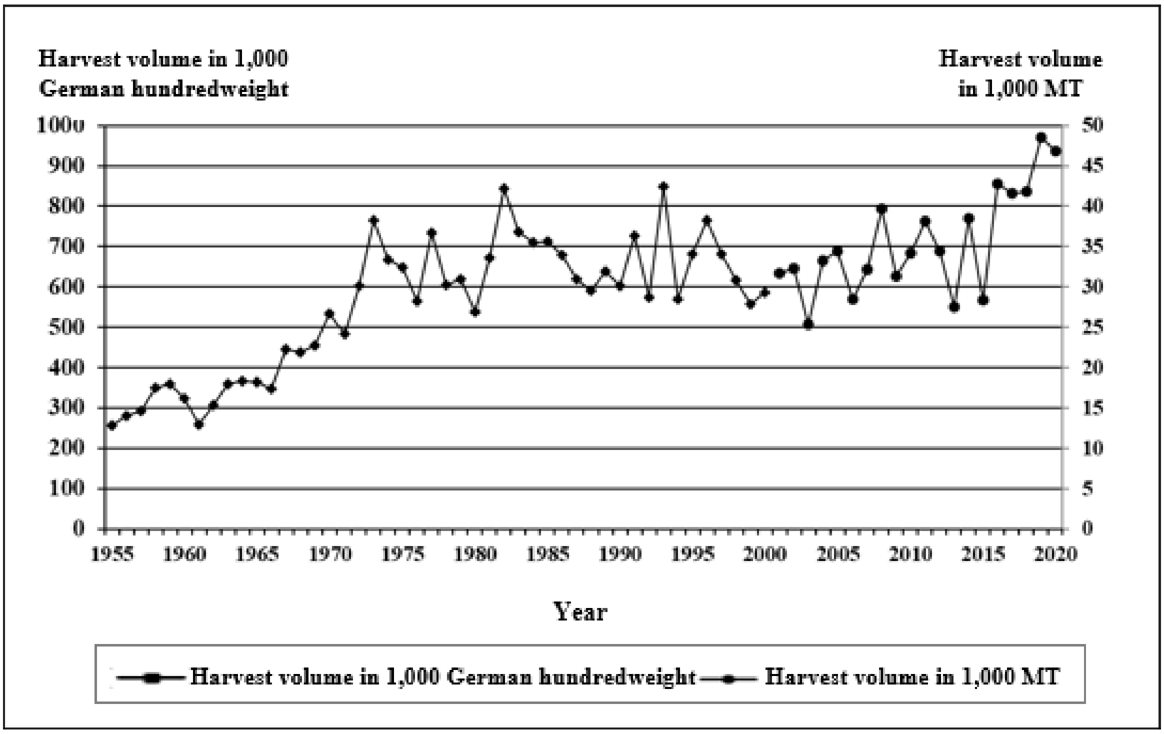


Figure 1.5: Total harvest volume in Germany

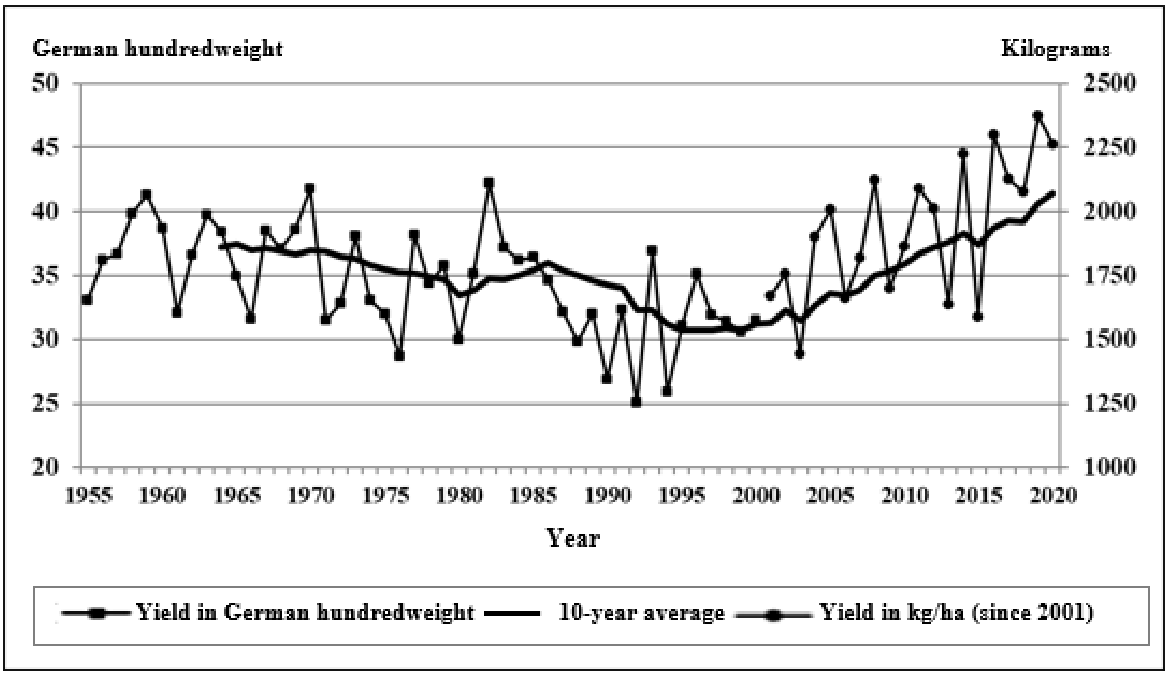


Figure 1.6: Total harvest volume in Germany

Figure 1.7: Average yield per hectare in Germany

Table 1.5: Yields per hectare in German cultivation areas

Growing area	Yield in kg/ha total area								
	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hallertau	1,638	2,293	1,601	2,383	2,179	2,178	2,441	2,338	2,400
Spalt	1,428	1,980	1,038	1,942	1,949	1,564	1,704	1,759	2,020
Tettnang	1,184	1,673	1,370	1,712	1,677	1,486	2,024	1,927	1,818
Rhineland-Palatinate/Bitburg	1,953	2,421	1,815	1,957	1,990	1,985	2,030	2,003	973
Elbe-Saale	2,116	2,030	1,777	2,020	2,005	1,615	2,150	1,906	2,038
∅ Yield/ha Germany (kg)	**1,635**	**2,224**	**1,587**	**2,299**	**2,126**	**2,075**	**2,374**	**2,264**	**2,321**
Total harvest Germany (MT)	27,554	38,500	28,337	42,766	41,556	41,794	48,472	46,879	47,862
Acreage Germany (ha)	16,849	17,308	17,855	18,598	19,543	20,144	20,417	20,706	20,620

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

Growing area/variety	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Ø 5 Years	Ø 10 Years
Hallertau Hallertauer	4.6	3.3	4.0	2.7	4.3	3.5	3.6	4.1	4.5	**5.2**	**4.2**	**4.0**
Hallertau Hersbrucker	3.0	1.9	2.1	2.3	2.8	2.3	2.0	2.5	3.3	**2.9**	**2.9**	**2.7**
Hallertau Hall. Saphir	4.4	2.6	3.9	2.5	4.0	3.0	3.3	3.3	4.2	**3.6**	**3.6**	**3.6**
Hallertau Opal	9.0	5.7	7.3	5.9	7.8	7.2	6.4	7.3	8.5	**8.7**	**7.6**	**7.4**
Hallertau Smaragd	6.0	4.3	4.7	5.5	6.2	4.5	3.0	5.0	5.8	**7.6**	**5.2**	**5.3**
Hallertau Perle	8.1	5.4	8.0	4.5	8.2	6.9	5.5	6.7	7.4	**9.0**	**7.1**	**7.0**
Hallertau Spalter Select	5.1	3.3	4.7	3.2	5.2	4.6	3.5	4.4	5.2	**6.4**	**4.8**	**4.6**
Hallertau Hall. Tradition	6.7	5.0	5.8	4.7	6.4	5.7	5.0	5.4	6.3	**6.1**	**5.7**	**5.7**
Hallertau Mand. Bavaria	8.8	7.4	7.3	7.0	8.7	7.3	7.5	7.9	9.0	**9.9**	**8.3**	**8.1**
Hallertau Hall. Blanc	9.6	7.8	9.0	7.8	9.7	9.0	8.8	9.0	10.9	**9.9**	**9.5**	**9.2**
Hallertau Hüll Melon	7.3	5.3	5.4	5.8	6.8	6.2	5.8	6.6	7.2	**8.4**	**6.8**	**6.5**
Hallertau North. Brewer	9.9	6.6	9.7	5.4	10.5	7.8	7.4	8.1	9.1	**10.5**	**8.6**	**8.5**
Hallertau Polaris	20.0	18.6	19.5	17.7	21.3	19.6	18.4	19.4	20.6	**21.5**	**19.9**	**19.7**
Hallertau Hall. Magnum	14.3	12.6	13.0	12.6	14.3	12.6	11.6	12.3	14.2	**16.0**	**13.3**	**13.4**
Hallertau Nugget	12.2	9.3	9.9	9.2	12.9	10.8	10.1	10.6	12.0	**11.1**	**10.9**	**10.8**
Hallertau Hall. Taurus	17.0	15.9	17.4	12.9	17.6	15.9	13.6	16.1	15.5	**17.8**	**15.8**	**16.0**
Hallertau Herkules	17.1	16.5	17.5	15.1	17.3	15.5	14.6	16.2	16.6	**18.5**	**16.3**	**16.5**
Tettnang Tettnanger	4.3	2.6	4.1	2.1	3.8	3.6	3.0	3.8	4.3	**4.7**	**3.9**	**3.6**
Tettnang Hallertauer	4.7	3.3	4.6	2.9	4.4	4.3	3.8	4.3	4.7	**5.0**	**4.4**	**4.2**
Spalt Spalter	4.1	2.8	3.4	2.2	4.3	3.2	3.5	3.9	4.7	**5.2**	**4.1**	**3.7**
Spalt Spalter Select	4.6	3.3	4.5	2.5	5.5	5.2	2.9	4.1	4.7	**6.4**	**4.7**	**4.4**
Elbe-S. Hall. Magnum	14.1	12.6	11.6	10.4	13.7	12.6	9.3	11.9	11.9	**13.8**	**11.9**	**12.2**

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

2 Weather and Growth Development 2021

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

2.1 Weather and Growth Development

The 2021 hop year started with dry conditions and cold temperatures. Although all initial field work during March and April was completed on time and on dry soil, subsequently, the emergence and growth of hops progressed only slowly. Therefore, the pruning of excess growth and the training of hop shoots had to wait until the beginning of May; and for some varieties and locations, this work dragged on until the end of that month. In addition, above-average precipitation and cool temperatures in May delayed such necessary measures as tilling and further pruning. June turned out to be warmer than average, but this could not make up for the growth deficit of up to 14 days. As a result, flowering began about a week later than normal. July and August were once again cool and also wet, which is why the hops took their time with cone formation. The maturation phase before the harvest started very late this year, only in early September. It took some warm and dry harvest weather in September to finally accelerate maturation.

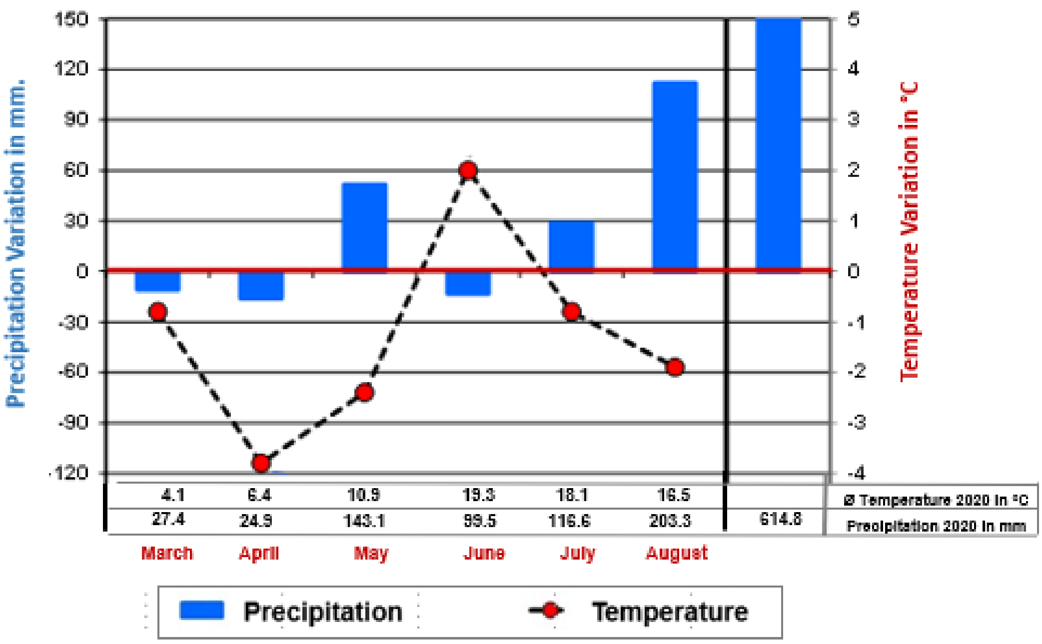


Figure 2.1: Weather during the 2021 growing season in Hüll by month, as a deviation from the 10-year average

On the positive side, the Hallertau and the hops grown there were mostly spared the severe downpours that caused serious large erosion damage in many parts of Germany, including in Bavaria. Overall, during the hop growing season from March to August, the Hüll site experienced 150 mm more precipitation than the average for the previous 10 years. But there was a local differential in the Hallertau, with the northern regions getting about 100 mm less rain during July and August than the southern region. This year, however, the soil moisture was sufficient everywhere so that the hops did not suffer from drought stress. The heavier soils in the southern Hallertau even showed signs of a lack of oxygen, because the water could not drain away and the soils remained too wet.

2.2 Problems resulting from disease and pest infestations

There were only local and sporadic infestations of lovage weevils, but these could be combated with Exirel, a pesticide that was approved on short notice on an emergency basis. Fleas and, on the other hand, caused considerable damage through their feeding, in several areas.

Peronospora (downy mildew) primary infections occurred only sporadically during the cold spring. Only after the onset of precipitation in May and the rise in temperatures in June (around June 3) did strong outbreaks of downy mildew primary infections occur in some locations. *Peronospora*-induced melanized sporangia could be observed on bottom, side, and main shoots until well into July. Thus, downy mildew pressure because of secondary infections was correspondingly high for all varieties. Throughout the growing season up to harvest time, therefore, seven mitigation campaigns were necessary. Unfortunately, plant protection measures could not always be carried out when needed because of the wet soil conditions or softened ground; and many farms had to contend with *Peronospora* infestation from flowering to harvest time.

Fighting powdery mildew was also difficult. Although there were fewer symptoms of infestation this year compared to 2020, the powdery mildew fungus recurred throughout the season, particularly in dense stands of the bitter variety Herkules. The strong antidote Luna Sensation was also approved on an emergency basis, because most growers considered milder, conventional, mid-strength preparations no longer sufficient.

Among the hop diseases, the feared *Verticillium* wilt was also rather severe this year, mostly because of the cool and damp conditions in May, which favored infections of the roots. The first wilt symptoms and early signs of plant deaths could already be observed in mid-June, and these intensified in August all the way to harvest time.

Thanks to the emergency approval of Movento SC 100, which allowed for a timely fight against animal pathogens, infestations of hop aphids could be kept in check with relatively little effort. Common spider mite infestations also caused hardly any problems in 2021 because of the weather. The side effects of Movento often proved sufficient, so that no further acaricide measures were necessary.

The spread of the citrus viroid or "Citrus Bark Cracking Viroid" (CBCVd), which was detected in the Hallertau for the first time in 2019, continued to be monitored in an extensive risk-based study in Bavaria in 2021. In total, three more farms had to be added to the list of farms known to be infested. This brings the total of currently pathogen-infected operations to nine, at two locations in the Hallertau. CBCVd infestations and the spread of the pathogen, therefore, are still very limited.

2.3 Out-of-the-ordinary events in 2021

Plant protection issues - especially those associated with downy mildew - and the use of plant protection products were both very intensive in the 2021 crop year. In particular, the massive occurrence of hop wilt and the further potential spread of the Citrus Bark Cracking Viroid pose major challenges for hop growers and the entire hop industry.

Another factor that made the past season noteworthy were, of course, the delays in the plants' growth and development and the late harvesting, which could only be completed because of the sunny harvest weather that finally accelerated plant maturation.

*Tab. 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	2021	-1.0	-5.5	2.5	99.0	60	21	37.9
∅	10-y	0.2	-3.3	3.7	93.3	68.4	17.4	39.5
	30-y	-2.3	-5.9	1.1	86.7	50.8	14.8	47.1
February	2021	2.0	-2.5	7.6	94.6	45.3	14	99.3
∅	10-y	0.6	-4.0	5.6	87.8	45.7	12.1	79.6
	30-y	-1.0	-4.9	3.1	81.4	46.8	13.3	72.1
March	2021	4.1	-0.8	10.3	87.6	27.4	14	162.1
∅	10-y	4.8	-0.9	10.8	81.5	35.7	12.6	156.1
	30-y	2.8	-1.7	7.8	78.9	47.7	13.8	132.2
April	2021	6.4	0.2	13.1	79.9	24.9	11	211.3
∅	10-y	10.2	3.3	16.0	73.1	40.8	9.4	207.6
	30-y	7.1	1.9	12.8	73.8	60.8	14.1	164.3
May	2021	10.9	5.5	16.3	87.3	143.1	20	175.2
∅	10-y	13.0	7.3	18.7	77.8	99.4	15.5	199.3
	30-y	11.9	6.1	17.7	73.9	82.3	15.4	203.6
June	2021	19.3	12.1	26.3	80.3	99.5	11	287.5
∅	10-y	17.6	11.3	23.7	77.5	112.2	12.9	239.7
	30-y	15.1	9.0	20.8	74.6	103.5	15.3	212.3
July	2021	18.1	12.5	24.3	90.1	116.6	19	196.1
∅	10-y	19.0	12.4	25.7	77.4	76.7	12.3	248.3
	30-y	16.7	10.5	23.1	74.3	90.5	14.1	236.8
August	2021	16.5	11.9	22.5	92.8	203.3	20	162.8
∅	10-y	18.2	11.8	25.1	81.9	102.7	12.1	235.9
	30-y	16.0	10.2	22.6	78.2	91.7	13.8	212.4
September	2021	14.8	8.9	22.1	90.3	19.8	5	213.9
∅	10-y	13.9	8.1	20.2	86.5	54.4	10.7	171.4
	30-y	12.7	7.4	19.1	80.7	67.9	11.6	175.0
October	2021	8.1	3.4	14.0	95.4	27.7	5	130.1
∅	10-y	9.2	4.5	14.3	91.9	53.0	11.4	109.3
	30-y	7.6	3.2	13.1	84.2	51.1	11.0	117.2
November	2021	3.0	0.3	5.9	99.7	37.1	14	33.5
∅	10-y	4.4	1.0	8.2	94.9	50.9	11.8	49.7
	30-y	2.6	-0.6	6.1	85.5	57.5	14.4	52.9
December	2021	2.0	-0.6	4.7	99.7	93.1	22	32.1
∅	10-y	1.8	-1.4	5.7	95.1	51.4	15.1	39.9
	30-y	-0.9	-4.3	1.8	86.5	52.2	15.0	38.7
Ø-Year	**2021**	**8,7**	**3.8**	**14.2**	**91.4**	**897.8**	**176**	**1.741.8**
10-Year Mean		**9.4**	**4.7**	**14.8**	**84.9**	**791.3**	**153.3**	**1.776.3**
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 2012-2021

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

3 Research and Permanent Technical Tasks

3.1 IPZ 5a – Hop growing production technology

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

Working Groups Project Management, Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5a J. Portner, A. Schlagenhaufer	Nitrogen dynamics in hop soils in commercial hop farms with different types of soil and fertilizer systems (6054)	2018-2022	Erzeugergemeinschaft HVG *(HVG Hop Producer Group)*	21 hop farms; IPZ 5b, 5c
IPZ 5a J. Portner, A. Schlagenhaufer	Composting trial using shredded bines to optimize the nutrient efficiency of organically bound nitrogen (6141)	2018-2022	Erzeugergemeinschaft HVG *(HVG Hop Producer Group)*	Prof. E. Meinken, HSWT Dr. D. Lohr, HSWT Prof. T. Ebertseder, HSWT M. Stadler, AELF PAF; IPZ 5b, 5c

Permanent tasks: Product-technical trials

AG	Project	Duration	Collaborators
5a	Training and continued education of hop growers	Permanent task	
5a	Specialized production engineering and business management consulting in hop production	Permanent task	
5a	Development and updating of documents for consulting services	Permanent task	
5a	Dissemination of advisory strategies and exchange of information with group advisory services	Permanent task	Hopfenring e.V. *(Hop Circle)*
5a	Generation of *Peronospora* infestation forecasts and warning messages	Permanent task	
5a	Generation of business data for 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
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 and SR, ECOZEPT
5a	HopNO$_3$ - practical optimization of the nitrogen cycle in hop cultivation	2016-2022	Ecozept, LfU Leader-AG
5a	Optimization of settings of multi-tier kilns to adjust for different drying behaviors of different hop varieties	2018-2022	Hop growers
5a	Optimization of drying processes in belt dryers	2018-2022	Hop growers
5a	Investigation of the nitrogen increases of hops as a function of fertilization with fertigation (master thesis)	2020-2021	TUM Florian Weiß

AG	Project	Duration	Collaborators
5a	Simulation of agro-PV systems in hops with regard to the occurrence of pathogens, yield and quality of the hops	2021	Tubesolar, Augsburg, hop grower
5a	Suitability of different plant protection dosing models related to leaf volume and leaf wall area in hop cultivation	2021-2022	Bachelor thesis Tobias Berger
5a	Investigation of labor-intensive and labor-extensive methods of hop training and their impact on subsequent work and yield	2021-2022	Bachelor thesis Christina Sternecker

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 (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 2015-2021) Engelbrechtsmünster (from 2016-2022) Gebrontshausen (from 2020)	2015-2024	Erzeugergemeinschaft Hopfen HVG *(HVG Hop Producer Group)*	IPZ 5c
IPZ 5b S. Euringer K. Lutz	Remote sensing: hyperspectral sensors in hops	2021	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research)*	Geo-konzept GmbH
IPZ 5 S. Euringer, F. Weiß, N.N.	CBCVd-Monitoring	2020-2022	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (StMELF) *(The Bavarian State Ministry for Food, Agriculture and Forestry);* Erzeugergenossenschaft HVG e.G. *(HVG Hop Producer Group)*	IPZ 5a, IPS 4b, IPS 2c

Permanent tasks: Crop protection trials

Working Group	Project	Duration	Collaborators
5b	Official means test	Permanent task	
5b	Execution and supervision of residue analyses in hop cultivation (GEP portionl)	Permanent task	
5b	Spray tower experiments to monitor the potential development of resistance in hop aphids	Permanent task	
5b	Aphis fly monitoring	Permanent task	
5b	ELISA-Testing for ApMV and HpMV in hops for breeding purposes	Permanent task	
5b	Monitoring of the plant protection product approval situation in hop growing	Permanent task	
5b	Preparation of emergency use applications according to Art. 53	Permanent task	Verband dt. Hopfenpflanzer *(German Hop Growers Association);* Hopfenring e.V. *(Hop Circle)*
5b	Technical commentary on emergency permits for individual farms, according to Art. 22	Permanent task	Verband dt. Hopfenpflanzer *(German Hop Growers Association);* Hopfenring e.V. *(Hop Circle)*
5b	Training and continuing education of hop growers	Permanent task	
5b	Development and updating of advisory documents	Permanent task	
5b	Viroid monitoring (CBCVd and HSVd)	Permanent task	IPZ 5c, IPS2c
5b	Organization and supervision of plant protection trials after consultation with the official hop advisory service	Permanent task	IPZ a, Hopfenring e.V. *(Hop Circle)*
5b	Technical support for the implementation of plant passports in hops	Permanent task	
5b	Implementation of the Eppo-Guideline PP 1/239 (Leaf Wall Area) in hop cultivation	2018 to present	
5b	Maintenance of the reporting address, hop.pfla@lfl.bayern.de, for special fertilizers, plant strengtheners, bio-stimulants, and pesticides in hop cultivation	2019 to present	
5b	Powdery mildew GWH trials to test current and new crop protection products	2019 to resent	
5b	Development of a concept for a blower sprayer prototype for the AMP	2020 to present	
5b	Establishment of the test software ARM in the AMP	2021- to present	

3.3 IPZ 5c – Hop breeding research

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

Working Groups Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
<u>IPZ 5c</u> A. Lutz Dr. E. Seigner	Development of high-performance, 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 f. Umwelt, Landwirtschaft und Energie des Landes Sachsen-Anhalt *(Ministry for Science, Energy, Climate Protection and the Environment of the State of Saxony-Anhalt);* Sächsisches Staatsministerium für Energie, Klimaschutz, Umwelt und Landwirtschaft *(Saxon State Ministry for Energy, Climate Protection, Environment and Agriculture);* Erzeugergem. Hopfen HVG *(HVG Hop Processing Cooperaive) e.G.*	IPZ 5d: Dr. K. Kammhuber & Team; Hopfenpflanzerverband Elbe-Saale e.V. (*Hop Growers Association Elbe-Saale e.V.*) Betrieb Berthold, Thüringen *(Hop Farm Berthold, Thuringia);* Hopfengut Lautitz, Sachsen (*Hop Farm Lautitz, Saxony*); Agrargenoss. Querfurt, Sachsen-Anhalt *(Agricultural Cooperative Querfurt, Saxony-Anhalt)*
<u>IPZ 5c</u> 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 Hopfenforschung *(Society for Hop Research)*: W. König; Hopfenverwertungsgen. *(Hop Sales Cooperative)*; HVG: Dr. E. Lehmair
<u>IPZ 5c</u> Dr. E. Seigner	Research and work on *Verticillium* wilt in hops — molecular proof of presence	2015-2023	Erzeugergemeinschaft Hopfen HVG *(HVG Hop Producer Group)*	IPZ 5c: A. Lutz; IPZ 5b: S. Euringer, K. Lutz; Dr. Radišek, Slovenian. Institute of Hop Research and Brewing, Slovenia
<u>IPZ 5c</u> Dr. E. Seigner A. Lutz	Powdery mildew isolates and their use in breeding for powdery mildew resistance in hops	2017-2021	Gesellschaft für Hopfenforschung *(Society for Hop Research)*	EpiLogic, Freising

Permanent tasks: Hop breeding research

Workng Grouip	Project	Duration	Collaborators
5c	Breeding hop varieties with excellent brewing quality	Permanent Task	IPZ 5d: Dr. K. Kammhuber & Team; Beratungsgremium der GfH *(Society of Hop Research Advisory Committee)*; TUM, Lehrstuhl Getränke- und Brautechnologien, (*Department of Beverage and Brewing Technology)*; Bitburger Versuchsbrauerei *(Bitburger Pilot Brewery)*; Versuchsbrauerei St. Johann *(Pilot Brewery St. Johann)*; Breweries worldwide; Hop growers
5c	Breeding of quality varieties with increased levels of health-promoting, anti-oxidative, and microbial substances, also for alternative areas of application of hops outside the brewing industry	Permanent task	IPZ 5d; EpiLogic, Freising
5c	Testing for aphids	Permanent task	IPZ 5b: M. Felsl
5c	Leaf system for testing hops for *Perono-spora* tolerance for the purpose of breed-ing disease-tolerant hops	Permanent task since 2012	
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	2019-2021	Wissenschaftliche Sta-tion für Brauerei Mün-chen e.V. *(Scientific station for Brewery Munich e.V.)*	TU Berlin Dr. Witstock

Permanent tasks: Hop quality and hop analytics

Working Group	Project	Duration	Collabrators
5d	All analytical investigations in support of the Working Groups of the hop division, in particular regarding hop breeding	Permanent task	IPZ 5a, IPZ 5b, IPZ 5c, IPZ 5e
5d	Development and optimization of a reliable method for the analysis of aromas using gas chromatography-mass spectroscopy	Permanent task	
5d	Establishment and optimization of NIRS-methods for analyses of hop bitter substances and water content	Permanent task	
5d	Development of methods for analyzing hop polyphenols	Permanent task	Arbeitsgruppe für Hopfenanalytik (AHA) *(Hop Analytics Working Group)*
5d	Organization and evaluation of chain analyses for hop contracts	Permanent task	Labore der Hopfenwirtschaft (*Laboratories in the hop industry*)
5d	Analysis, evaluation, and dissemination of follow-up and control examinations for hop contracts	Permanent task	Labore der Hopfenwirtschaft (*Laboratories in the hop industry*)
5d	Administrative assistance in the analyses of hop varieties for food safety authorities	Permanent task	Lebensmittelüberwachung der Landratsämter *(Food safety monitoring by district offices)*
5d	Supervision of IT and the 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 Management Project Operations	Project	Duration	Cost Allocation	Collaborators
IPZ 5e Dr. F. Weihrauch M. Obermaier	Reduction in the use of copper-containing crop protection agents in organic, as well as integrated hop cultivation	2014-2022	Erzeugergemeinschaft Hopfen HVG *(HVG Hop Producer Group) e.G.*	Betrieb Robert Drexler, (*Farm Robert Drexler*) Riedhof; Forschungsinstitut für Biologischen Landbau (FiBL), Frick, Schweiz *(Research Institute for Organic Agriculture, Frick, Switzerland)*; IFA-Tulln Institut für Umweltbiotechnologie, Österreich *(IFA-Tulln Institute for Environmental Biotechnology, Austria)*

Working Groups Project Management Project Operations	Project	Duration	Cost Allocation	Collaborators
IPZ 5e Dr. F. Weihrauch M. Obermaier	Further development of culture-specific strategies for organic crop protection with the help of divisional networks - Hop Division.	2017-2022	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 measures to promote biodiversity in hop cultivation	2018-2023	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Producer Group)*	IGN Nierderlauterbach AELF PAF, FZ Agraökologie (Dr. S. Gresset); *(IGN Niederlauterbach AELF PAF, FZ Agroecology)* TU München, Department of terrestrial ecology (Prof. Dr. Weiser); LBV, KG PAF (Ch. Huber)
IPZ 5e Dr. F. Weihrauch M. Obermaier	Introduction of predatory mites in hop cultivation via cover crops	2018-2021	Bundesanstalt für Landwirtschaft und Ernährung (BLE), BÖLN-Projekt 2815NA131; GfH e.V. (*Federal Agency for Agriculture and Food)*	Companies practicing ecological and integrated hop cultivation
IPZ 5e Dr. F. Weihrauch M. Obermaier	Induced resistance in hops to spider mites	2021-2026	Deutsche Bundesstiftung Umwelt (*German Federal Foundation for the Environment) DBU (FKZ 35937*/01-34/0)	20 commercial farms practicing integrated hop cultivation; AG IPZ 5d

4 Hop Cultivation, Production Techniques

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

4.1 N_{min}-Investigation 2021

Analyses of soils for available nitrogen and N_{min} are required by the new German Fertilizer Ordinance (DüV) for hop farms located in so-called "red areas." These analyses have become crucial benchmarks for determining fertilizer needs in different locations.

In 2021, more than half the hop-growing farms in the Bavarian growing regions of the Hallertau and Spalt took part in N_{min} studies. A total of 3,344 hop gardens were examined (2020: 3,782 samples), with the average N_{min} content of all soils used for hop cultivation in Bavaria at 59 kg N/ha, a value that is unchanged from the previous year. As is the case every year, the 2021 N_{min} studies showed large fluctuations from one farm to the next, as well as among individual hop plots and different varieties cultivated by the same farm.

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

Hop farms **outside the "red areas"** are not obliged to account for their N_{min} requirements individually. Instead, they can use regionalized, provisional averages listed in Table 4.1 to calculate N requirements for their plots.

Table. 4.1: Number of sample, preliminary, and final N_{min} values 2021 *in the various hop growing districts and regions*

County/Region	Number of tests	Preliminary N_{min} value (As of March 22, 2021)	Final N_{min} value
Eichstätt (including Kinding)	240	69	**69**
Freising	330	63	**60**
Hersbruck	76	53	**68**
Kelheim	1,317	61	**61**
Landshut	174	70	**69**
Pfaffenhofen (and Neuburg-Schrobenhausen)	1,102	48	**50**
Spalt	105	89	**88**
Bavaria	**3,344**	**58**	**59**

Hop growing operations that calculate their nitrogen requirements using the provisional N_{min} averages for their district or growing region need to correct these values if the final, empirically determined N_{min} value is more than 10 kg N/ha higher than the provisional N_{min} value in the table. In 2021 this was the case in the Hersbruck growing region, where the average final N_{min} value was 15 kg N/ha above the provisional N_{min} value. Hop growing operations in the Hersbruck region that had calculated their requirements using the provisional N_{min} value of 53 kg

N/ha, therefore, had to correct their fertilizer requirement calculations using the higher final N_{min} value of 68 kg N/ha.

Farms **<u>in</u> the "red areas"** had to test at least 3 plots for N_{min}, in 2021. If they operated additional hop plots in the red area, the average N_{min} values had to be transferred to these as well!

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

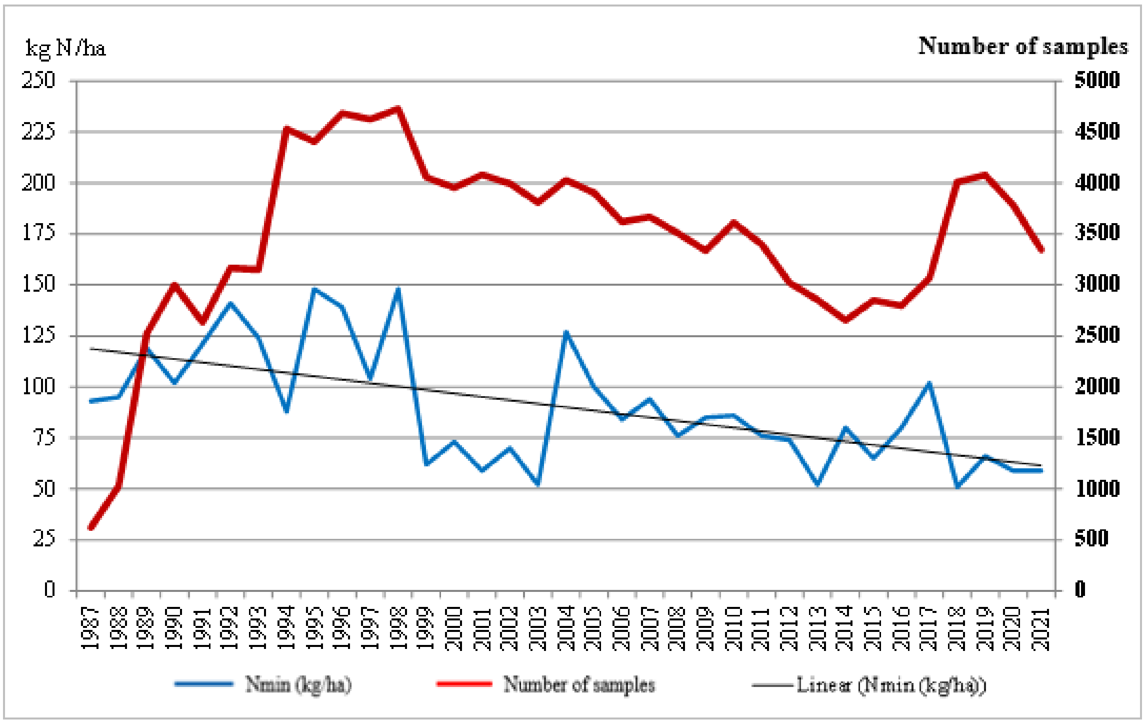


Figure 4.1: N_{min} investigations, N_{min} amounts and the trend line for N_{min} values in hop gardens in Bavaria over the years

4.2 Summary of research work about "Drip irrigation and fertigation in hops"

The working group Hop Cultivation and Production Technology IPZ 5a started to conduct irrigation trials in hop gardens in the early 1990s. Research into hop irrigation received more emphasis starting in 2011 as a result of two major research projects (doctoral dissertations).

Research in recent years has no longer focused on the need for additional watering of hops because this issue is no longer under dispute among experts. Instead, the focus has been on the questions of when and in which quantities additional water is required.

An irrigation app developed in cooperation with the Association of Land Technology and Agricultural Construction in Bavaria (ALB Bayern) was adapted specifically to hop irrigation needs. It offers hop growers a suitable tool for regulating irrigation amounts. They key objective of this work is the sustainable use of irrigation water and the conservation of resources. Therefore, the LfL recommends only the use of water-saving drip irrigation systems for hops.

Figure 4.2: Drip irrigation systems for hops

Research into new fertilizer systems with nutrients delivered via irrigation water (fertigation) was another goal of the irrigation experiments. In conventional practice, the amount of nitrogen is delivered in three separate doses. Using a combined irrigation/fertilization system instead, allows for the administration of nitrogen exactly at the time when it is needed. While nitrogen fertilizer spread into the fields often fails to dissolve if there is no rain, thus making it unavailable for the plants, plants can take up nitrogen supplied via targeted fertigation immediately and as required. This means that less residual nitrogen remains in the soil, where it could shift among different soil layers; or it might get washed entirely out of the soil after the harvest.

Once the results of the study had been collected, it was time to share the knowledge thus acquired with hop growers in a practical and understandable manner. This resulted in a 74-page LfL information brochure, "Drip irrigation and fertigation in hops." A printed version is available from the Bavarian State Institute for Agriculture. It can also be downloaded from the LfL website using the following link:

https://www.lfl.bayern.de/publikationen/informationen/268104

In addition, a summary of the brochure is available in an ALB working paper approved by environmental authorities. This so-called ALB worksheet is entitled "Drip irrigation and fertigation for hops."

https://www.alb-bayern.de/De/Bewaesserung/Bewaesserungs-forumBayern/Ergebnisse/hopfenanbau-klimawandel-bewaesserungsmanagement_bef11.html

Detailed research results can also be found in the doctoral dissertation "Needs-based nitrogen uptake of hops (*Humulus Lupulus L.*) by way of fertigation fertilizer systems" by Dr. Johannes Stampfl.

http://opus.uni-hohenheim.de/volltexte/2021/1889/

4.3 Nitrogen dynamics in hop soils of different types and with 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 a very densely cultivated specialty crop. Because such intensive cultivation especially of old landraces comes with a huge nutrient demand, nitrogen fertilizer requirements are also correspondingly high. This often results in increased nitrate levels in the soil, especially on farms with generous applications of organic fertilizers. After the harvest, hops obviously no longer absorb any residual nitrogen in the soil. Thus, such excess nitrogen loads can only be partially reduced by intermediate cover crops; and any nitrogen that still remains can shift in the soil. It can also cause nitrate leaching.

Goal

As part of the project, the nitrogen dynamics in hop soils were investigated at 21 hop farms. For this purpose, intensive N_{min} investigations were conducted in the spring, fall, and winter. This involved determining the nitrogen requirements for these plots and recording their actual amounts of N fertilization. The data was summarized into an operational nutrient comparison. This allowed for an estimate of nitrogen shifts in the soil and of depletion potentials during the growing season, for different farm types, with different fertilization systems, on different soils. It also allowed for the development of possible approaches to optimizing nitrogen management in hop cultivation. The aim was to optimize operational processes for optimal yields and qualities, while still observing and complying with the specifications of the Fertilizer Ordinance, as well as protecting clean water resources.

Method

For each of the 21 farms, three plots were selected. The 63 sub-areas reflect the actual range of varieties grown in the Hallertau. They also represent a wide variation of operating and fertilizer systems. N_{min} sampling was carried out at the start of the vegetation period in March and after the harvest in October to record the remaining nitrogen levels in the soil, as well as during dormancy in winter to identify possible N shifts in the soil. The available nitrogen in the form of ammonium and nitrate was examined up to a soil depth of 90 cm. Each sample was divided into three 30 cm deep soil sections to better determine the displacement in the different soil layers. Each farm received individual advice on fertilization strategies. All nitrogen fertilizer applications were recorded in terms of timing and quantity.

During the first harvest in 2018, cones and residual plants were sampled to calculate the exact nitrogen removal from the soil. The purpose was to determine area-specific nutrient balances and their connections to the N_{min} levels in the soil. Because the exact amount of cones and bine shreds at harvest time could only be approximated in these working farms, such sampling was abandoned in the succeeding two years. Instead, various hop gardens with the most important Hallertau varieties in Hüll were harvested with great precision. well as for the entire plant, for different varieties, at different yield levels:

Figure 4.3: N_{min} soil sampler

- Fresh mass (FM) and dry mass (DM) per ha
- Total solids (TS) levels
- N contents
- N-removal by cones and by bine shreds
- Ratio of accumulation of cones and bine shreds (ratio of main harvest crop to waste ratio = HNV)

With the help of this data, the nitrogen removal as well as the accumulation of bine shreds could be re-assessed for a greatly expanded range of varieties, as a function of the cone yield.

Results

The trial years 2018-2021 provided extensive insights into the nitrogen dynamics in hops. Based on 10 samples, the distribution of N_{min} contents in the respective soil layers can be shown as a function of the sample dates (Figure 4.4). The higher N_{min} levels in the upper 30 centimeters in the fall are striking, in both relative and absolute terms. The decline of these levels until the spring can be explained by the N-uptake of intermediate cover crops. However, nitrogen shifts into deeper soil layers — especially when there was plenty of precipitation in the fall and winter — cannot be ruled out as a cause either.

In addition, strong annual fluctuations in N_{min} levels were evident.

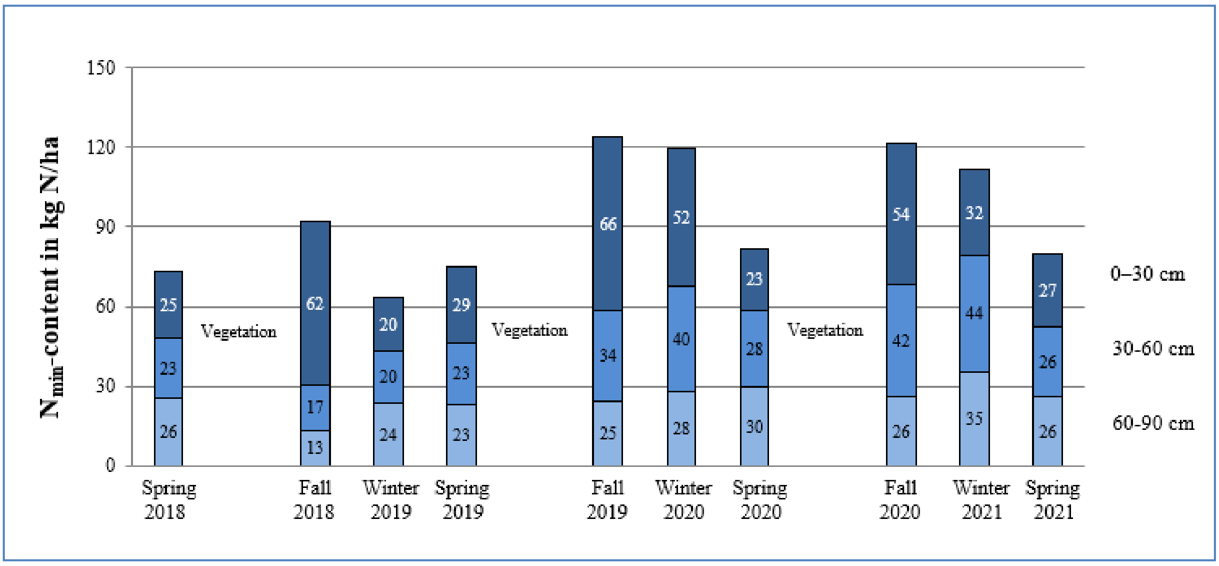


Figure 4.4: N_{min} levels across all sampling dates, broken down by soil layers (0-30 cm, 30-60, 60-90), 2018-2021

Further analysis reveals that the N_{min} content depends on the variety cultivated in the respective sample plots. It also shows that aroma varieties have higher Nmin levels than do bitter varieties. Because the new Hüll aroma varieties and old landraces were sampled on only a small number of plots, the data does not allow for an evaluation of their variety-specific N_{min} content (Figure 4.5). Differences in N_{min} content between aroma and bitter varieties were particularly pronounced in the fall samples. The differences can be explained by a more extended root system and a resulting higher N-removal by bitter varieties near harvest time. In addition, as part of the fertilization documentation, we discovered that, in the past, growers did not always make a distinction between varieties and different yield levels in N fertilization routines. However, a new approach of differentiating between varieties and site-specific yields in N fertilization is now considered essential for optimizing N fertilization in hops.

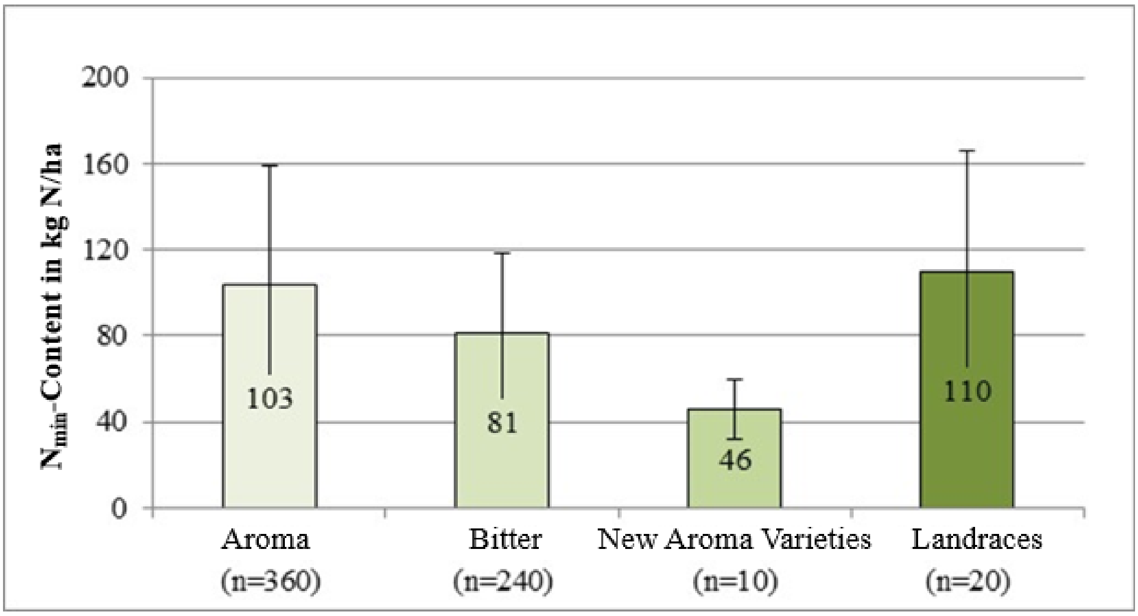


Figure 4.5: Mean N_{min} levels across all sampling dates broken down by variety groups (2018-2021)

As part of the project and where applicable, N_{min} levels of organic fertilizations were also precisely recorded and categorized. Three out of 21 farms fertilized their hop gardens without any organic fertilizer, while four farms fertilized them in conjunction with an organic fertilizer (without bine shreds). Yet others applied organic fertilizer exclusively in the form of bine shreds; and seven farms used additional organic fertilizers next to the bine shreds in the fall. When looking at the spring N_{min} levels as a function of organic fertilization, a clear trend emerged (Figure 4.6). The more organic fertilizer was used on the farm, the higher was the average N_{min} content. The long-term fertilizing effect of organically bound nitrogen is therefore reflected in the N_{min} content; and the supply of nitrogen from organic fertilizers must be taken into account when supplementing organic in conjunction with mineral fertilizers.

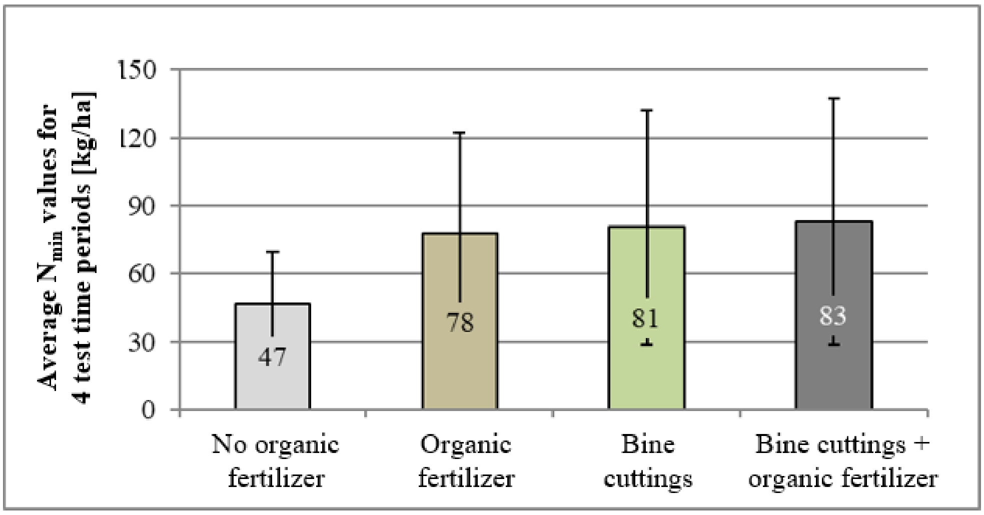


Figure 4.6: Average spring N_{min} contents for 4 tests as a function of the types of organic fertilizers used in commercial hop garden (2018 – 2021)

During the four sampling years, however, differences in soil types proved to have no significant influence on the mean N_{min} content (Figure 4.7). The N_{min} contents tended to be lowest in areas with very light soils (02). Medium sites with sandy loam (04) showed the highest average N_{min} content.

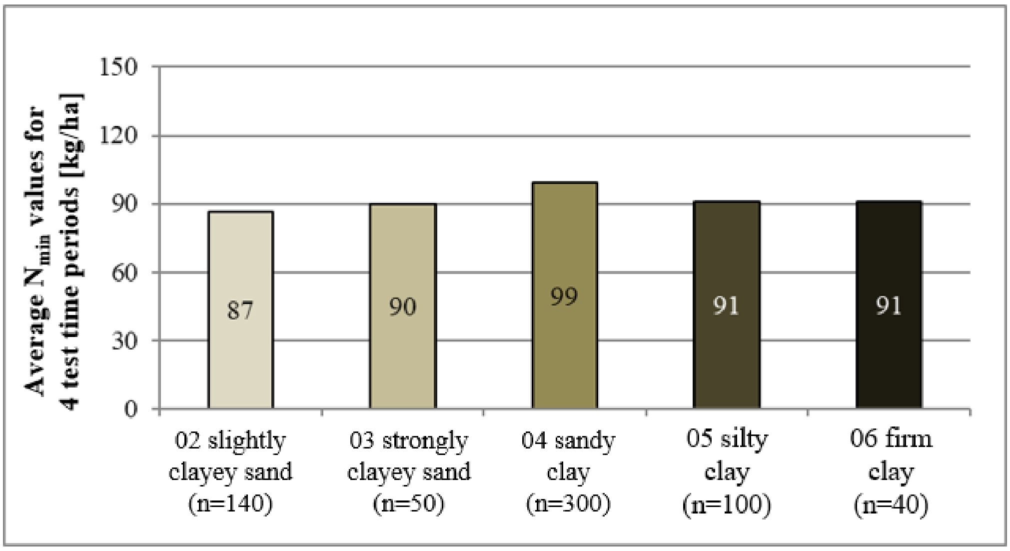


Fig 4.7: Average N_{min} contents of all test periods as a function of the soil type (2018 – 2021)

4.4 Experiments with composting and recycling of shredded hop bines to optimize the nutrient efficiency of organically bound nitrogen (ID 6239)

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 (LfL), Dr. Dieter Lohr Hochschule Weihenstephan-Triesdorf (HSWT)
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, 860 farms cultivate 17,000 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 soil 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, while avoiding N-dispersion into other ecosystems. To meet these requirements, extensive composting and field trials with shredded hop bines were 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 m^3). 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 no-turning, microbial carbonization (MC) compost technique developed by Walter Witte (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 regarding the practicality and the conservation potential for the nitrogen present in the shredded hop bines. Furthermore, these trials should produce the material for plot tests to determine the N-efficiency of the four materials (stored shredded hop bines; aerobic and MC compost; and 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), is also based on 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. This work continued as part of this project.

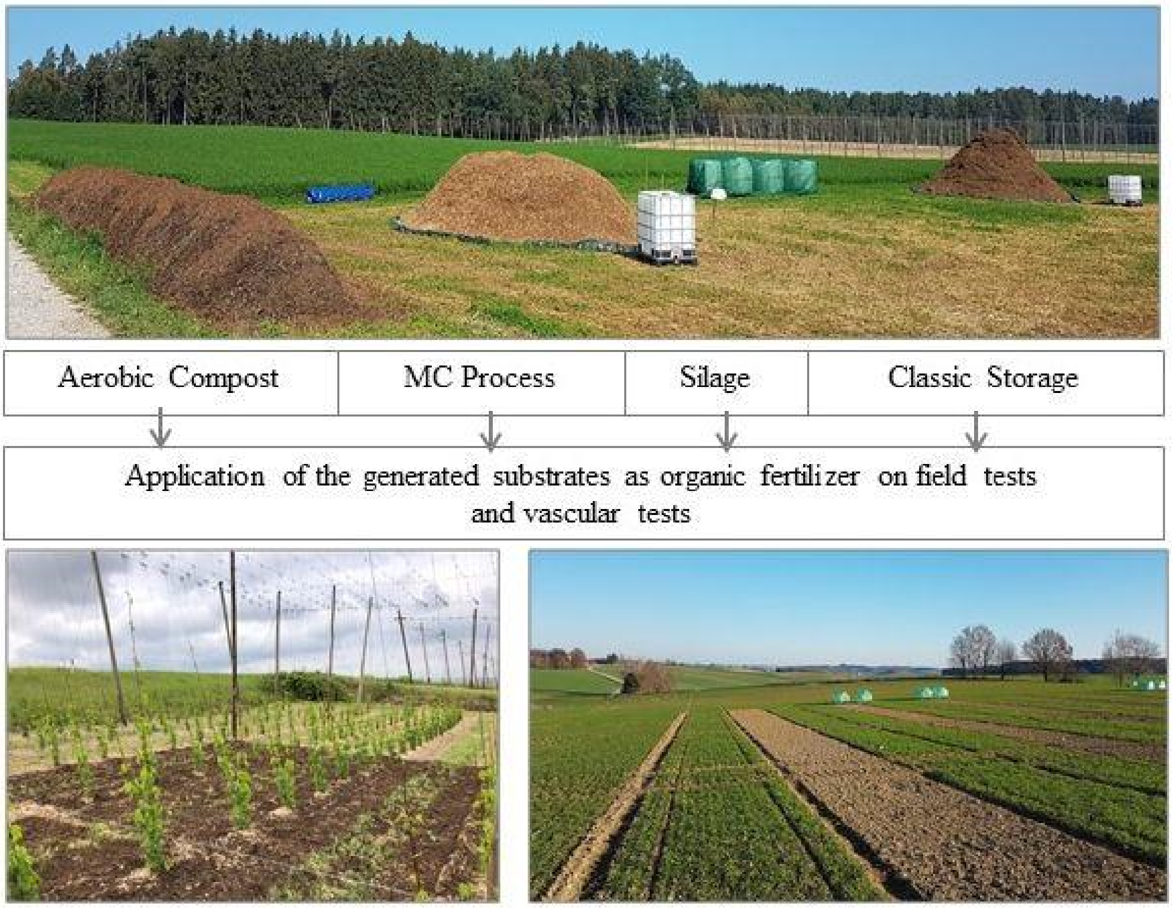


Figure 4.8 Representation of the experimental scheme:
Above: AP 2, practical composting experiment
Bottom left: AP 4, field trial with hops, shredded bines applied in May
Below right: AP 3, plot tests with shredded bines

Results

Small-scale composting trials (AP 1):
As part of the small-scale composting trials, the basic suitability for composting of hop bine shreds was examined in the first trial year. Six compost boxes were equally filled with homogeneously chopped bine material; and during the hot rotting phase, they were turned over at different intervals. During composting, measurements of the essential process parameters were taken at regular intervals (temperature, as well as O_2, CO_2, CH_4, H_2S, and NH_3 concentrations). In addition, the losses in dry matter and nitrogen in the six variants were also determined. Escaping seepage water was collected and analyzed for nitrate.

Figure 4.9 shows the temperature profile in the six compost boxes. No influence of the turning frequency could be determined, (box 1 was turned most frequently, box 6 was turned not at all). Shortly after setting up the boxes, the temperatures rose sharply to over 60 °C. Temperatures stayed at that level for the first seven days and then dropped steadily.

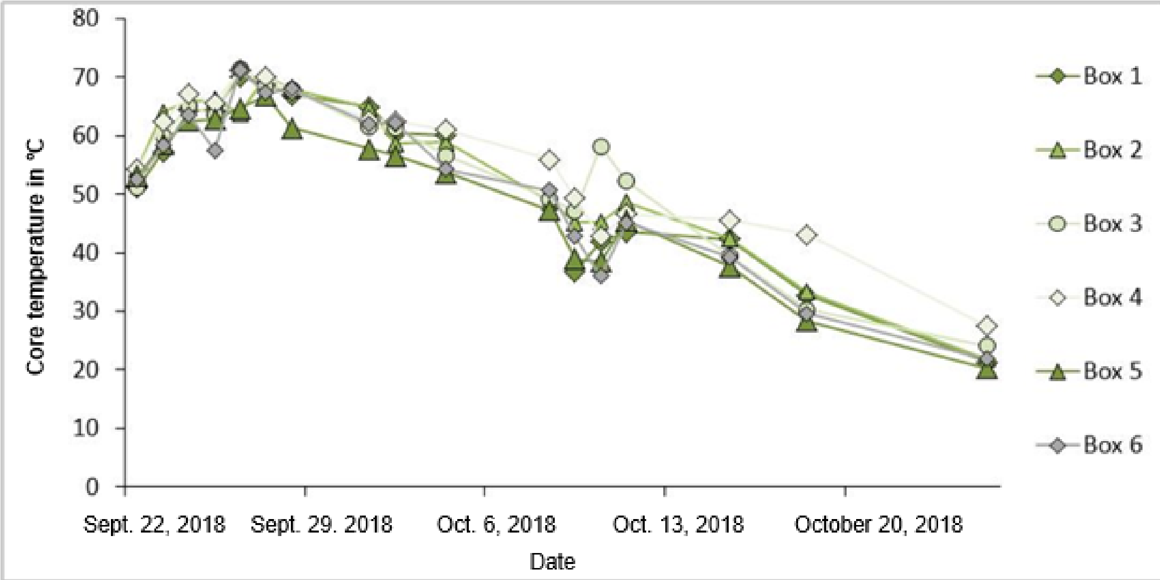


Figure 4.9: Progression of the core temperature in the compost boxes (mean value at a depth of 50 and 75 cm; 2 samples each, taken from the top and from the side)

The turning frequency between the boxes also had no effect on dry mass (33%) and nitrogen losses (14%). There was also no leaching of liquids because of the relatively efficient aeration of the compost boxes, which is why the nitrogen losses were entirely gaseous. In the second test year, therefore, the investigation turned to whether the gaseous N losses could be reduced by adding chabazite or biochar. However, the addition of these substances failed to influence the composting process in any significant way. During the third trial year, the small-scale composting trials were also used to study the effects of thermal treatments on bine shreds infested with *Verticillium* wilt. This work was conducted in cooperation with the *Verticillium* research on hops carried out by the LfL working group IPZ 5b. The results of these experiments are presented in the annual reports of the research project on *Verticillium* wilt.

Practical composting experiment (AP 2):
In the practical composting experiment, the rotting material was tested for the following variables: Fresh Mass (FM), Total Solids (TS), Dry Mass (DM), as well as N content in the DM at the beginning and the end of the experiments.

- Classic storage method → 4 Weeks (September-October)
- Aerobic composting
- MC process } 7 Months (September- May)
- Silage
- Layered storage → 1 Year (September-September)

In composting bine shreds according to conventional practices, dry mass losses after only 4 weeks amounted to around 20% and nitrogen losses, to around 8% (mostly as gaseous losses). (Figure 4.9). Using the two new composting methods, these losses continued at roughly the same rates with longer storage times. Eventually, the dry mass losses were in the range of 50% and the nitrogen losses were 14% in aerobic composting and 21% for the MC composting process. As expected, neither significant mass nor nitrogen losses occurred during the silage process. With the layered "superimposition" process, dry mass losses were around 60% and the N losses 28%.

In all variants, cumulative N emissions via leached liquids were very low.

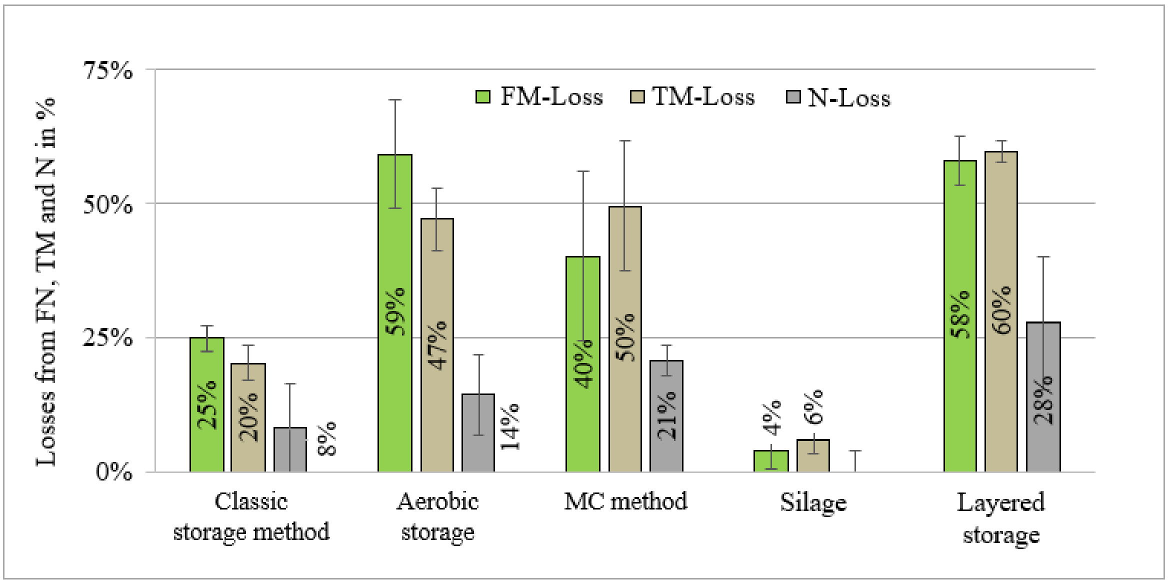


Figure 4.10: N losses (in percentages) of fresh and dry masses as a function of storage types

Plot trial in cereals (AP 3):

The substrates of “classic storage,” “aerobic compost,” the “MC process,” “silage,” a control, and a mineral fertilizer variant were tested in repeat trials for their nitrogen efficiency as organic fertilizer. For this, equal amounts of organic fertilizer, measured by their N values, were dispersed in all plots. The plots were divided into those that remained fallow but received bine shreds and those that were planted with cereal crops. This allowed for an assessment of N fertilization effects on the substrates.

In the first year of the trial, organic fertilizers were applied to green rye, as this places high demands on the nitrogen supply. The shredded bines applied in the fall increased the biomass production of green rye by almost 7% compared to the zero-control; and the nitrogen uptake was 46 kg N/ha higher, taking into account, from sowing to harvest, the change in N_{min} reserves up to a depth of 90 cm. However, these differences could not be statistically verified.

The summer oats that followed did not develop well, regardless of the variant. The reason for this is probably the very late sowing date as a result of the trial and the weather, combined with the drought that followed.

Differences in the N fertilization effect between the organic fertilizers could not be determined up to that point. The subsequent crop rotation consisted of winter wheat, an intermediate cover crop, and siloed corn. At the time of this writing, there is no harvest evaluation of the last two crops, wheat and corn.

Field trials in hops (AP 4):

In field trials with hops, the main focus was an investigation of the short- and long-term N-fertilization effect of bine shreds applied in the fall, which is in line with current practice. For this purpose, a field trial was set up in the fall of 2018, on an easy site, with Herkules cultivation. The fertilizer variants for this field test are listed in the table below.

Table 4.2: Fertilizer variants in the hop field trial

Month	October 19		April				May					June				July				Total
KW	Rebh.	N_{ges}	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	[kg N/ha]
Control					50				40											90
Fall bines	15 t	90			50				40											180
Mineral-rich					50				40				45				45			180

The N-fertilization effect of hop bine shreds could be determined on the basis of N-removal during the test harvest. Figure 4.10 shows the nitrogen removal during harvest, broken down into cone removal and residual plant removal of the three variants presented as averages from the three test years. The N fertilization effect of the shredded bines can be calculated from the difference between the "control" and the "rebh. fall" (bine shreds in the fall). Given a nitrogen removal that was only 15 kg N/ha higher, the short-term N fertilization effect from bine shreds can be regarded as minimal.

To assess the long-term N fertilization effect of bine shreds, this part of the test will be continued for several years to come.

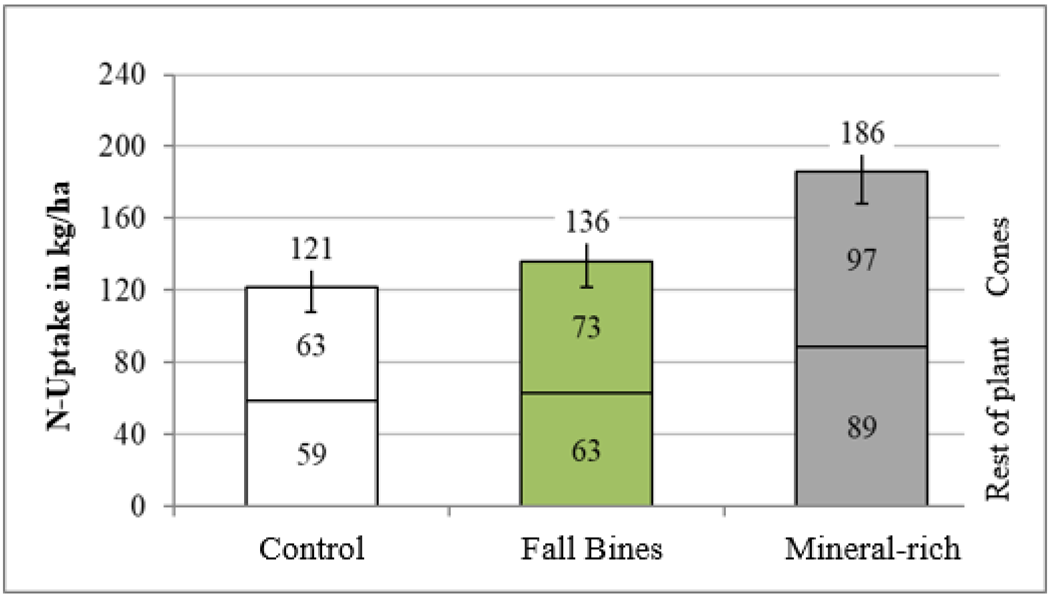


Figure 4.11: 3-year mean N withdrawals broken down into withdrawals by cone and residual plant matter as a function of the N fertilization (control = 90 N mineral; Fall bines = 90 N mineral + 90 N via bines; mineral = 180 N mineral) 2018-2021, variety Herkules, easy location

4.5 An investigation into the suitability of calculating dosages of plant protection preparations in hop cultivation based on aggregate leaf volumes and leaf wall areas (Bachelor thesis by Tobias Berger)

Team:	T. Berger (Bachelor Thesis) A. Schlagenhaufer (LfL)
Collaboration:	Prof. Dr. T. Ebertseder, Fakultät Nachhaltige Agrar- und Energiesysteme, *(Faculty of Sustainable Agriculture and Energy Systems)* Hochschule Weihenstephan-Triesdorf (HSWT)
Duration:	May 2021 to September 2021

Background and Objectives

The European and Mediterranean Plant Protection Organization is calling for the introduction of a new plant protection model in hops as a function of the total leaf surface (the leaf wall). The question is whether or not the Leaf Wall Area model (LWA) or the Tree Row Volume model (TRV) are suitable as a replacement of the current model, which is based on the plant's development stages. According to the new models and contrary to current practice, pesticides should no longer be applied in three stages but should be adapted to the foliage area of the crop. This would require the development of a uniform reference system that could be used for all plant cultures. This would also allow for regulatory approvals of plant protection products to become transferable among different crops and cultivation methods. To determine the suitability of the various models specifically for hop cultivation, part of the research of the bachelor thesis involved leaf area measurements, as well as plant height and width measurements.

Method

The experiments were set up with Perle and Herkules at two locations. At the start of vegetation, ten plants of each variety were planted, each with two shoots whose height and average width were measured weekly. For the height determinations, the length of each shoot was measured separately. In addition, the leaf areas of three bines of the two varieties were measured on three separate dates. This involved plucking all leaves on these bines by hand and sorting them according to size, with the aid of 10 templates. The templates allowed for the sorting of leaves into 10 categories. Figure 12 shows the template for category 8 as an example.

Figure *4.12: Template for categorizing leaf surfaces according to size*

Next, the leaves in each category were counted and their number multiplied by the area of their respective templates. Figure 4.13 shows the experimental set-up for plucking, sorting, and counting the leaves.

Figure 4.13: Experimental set-up for plucking, sorting, and counting the leaves of selected hop bines

This procedure produced values for each date and variety, approximating reality as closely as possible. On the last date of the leaf area measurements (the middle of August), cones were already present. These were also picked, counted, and photographed. The images were evaluated by an image processing program called ImageJ. Figure 4.14 shows the photo setup. The software counted the cones and calculated the surface area in cm^2. When the results were added to the leaf area measurements, the sum represented the total leaf area for each bine.

Figure 4.14: Setup for hop cone photographs

The growth height and width measurements were fed into the formulae of the LWA and TRV models. These are:

$$\text{LWA}= \frac{10.000\ m^2}{row\ spacing\ [m]} * treated\ canopy\ height * number\ of\ sides$$

$$\text{TRV} = \frac{10.000\ m^2}{row\ spacing\ [m]} * treated\ canopy\ height * mean\ width\ [m]$$

The calculation results of both models were compared with the leaf and cone area measurements to check which dosing model best matches reality. For the LWA model, values were calculated for LWA 2 sides and LWA 4 sides. In the TRV model, values were calculated for a TRV row, a TRV cylinder, and a TRA cylinder. The two formulae differed merely in their calculation bases.

Results

The following table gives an overview of the size of the measured foliage areas and the number of leaves and cones per bine. The small foliage areas of Herkules at T3 could be attributed to the cones not being fully developed at the time of the measurement.

	HKS			PER		
	23. Jun	22. Jul	19. Aug	23. Jun	22. Jul	19. Aug
	T1	T2	T3	T1	T2	T3
Cone surface/bine [m²]	--	--	6,5	--	--	9,3
Leaf surface/bine [m²]	3,05	14,02	15,46	3,03	11,71	12,50
Total surface/bine [m²]	**3,05**	**14,02**	**21,99**	**3,03**	**11,71**	**21,77**
Cones/bine	--	--	6.109	--	--	9.144
Leaves/bine	259	2.128	3.249	204	2.475	3.073

Table *4.3: Size of the foliage area and number of leaves and cones per bine for Herkules (HKS) and Perle (PER) on three different dates*

When determining pesticide dosages, the surface areas of the leaves and, at a late stage, also that of the cones play an important role. Another factor is the amount of water in the application to deliver enough active ingredients exactly to the parts of the plant that need to be protected. In the past, concentration specifications were guided by the amounts of active ingredients needed based on the plant’s development stage and leaf mass. Especially for contact agents, a uniform distribution of active ingredients is essential to achieve the intended pest control effect.

Any evaluation of the suitability of the various dosing models, therefore, should be based on the "measured leaf and cone area" (Figure 4.15) as a reference value.

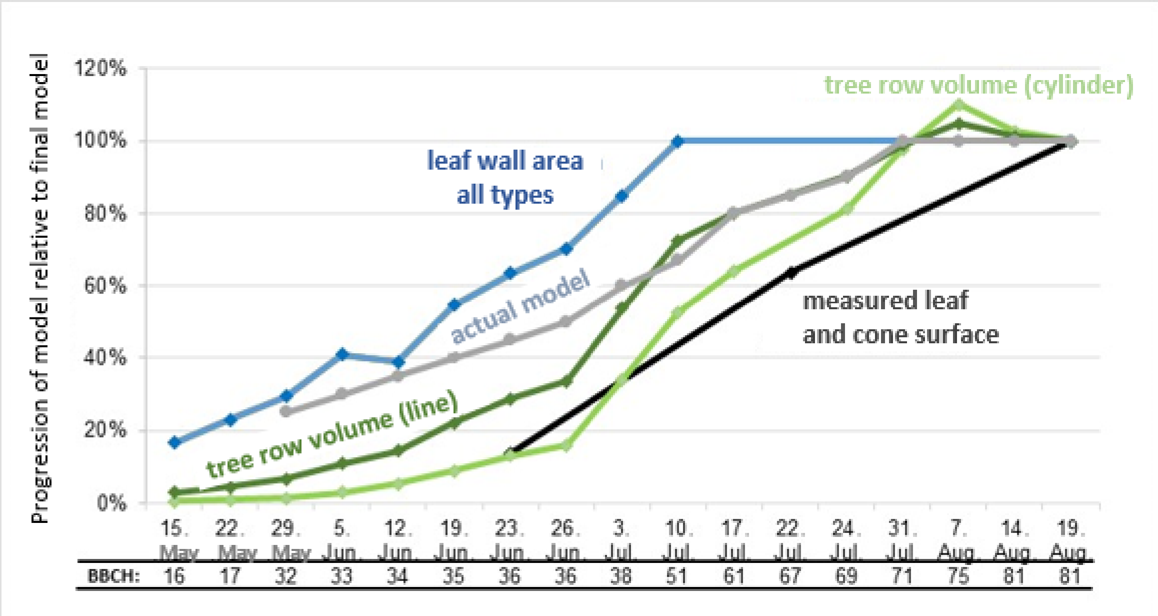


***Figure** 4.15: Percentage change in the dosage models depending on the final value on August 19 for Perle*

All calculated models (LWA, TRV series and TRV cylinder), as well as the current model based on plant development stages prescribe dosages that are slightly premature when related to the actual leaf and cone area. The LWA models differ most in this regard. The main problem is related to the growth spurt of the hop plant during the early stages of development. The LWA formula considers only the growth height of the shoots. At the beginning of the vegetation period, the plants reached a great shoot length rather quickly, while the actual foliage area was still rather small because there are fewer and smaller leaves. This is the reason for the large discrepancy between the two LWA models, on the one hand, and reality, on the other. Another problem with this model is the maximum trellis height of approx. 7 m. Once the plants reach that height at the end of June, growth stops and the LWA value no longer changes because the growth height remains constant. However, from this date onwards, there is still a substantial increase in leaf area and eventually in cone surface, too, neither of which the LWA model takes into account.

The TRV models, on the other hand, are a better fit. At the beginning of the vegetation period, these come closest to the measured foliage areas because they take both the plant width and height into account. Starting in the middle of June, there is a stronger increase in the rapid growth of side shoots, which greatly increases the plant diameter and thus also its apparent volume. In reality, however, though the volume of the plants continues to increase, it does not do so as much as calculated by the TRV models.

The graphic representation of the model that is based on development stages reveals one fact: It shows good parallels with the TRV models. This is not surprising because the plant mass and thus the volume is the primarily determinant of dosages, instead of a fictitious leaf wall area, which no longer changes after the plant has reached the trellis height.

Therefore, the current model is still best suited for hop cultivation. Should this model ever be dropped for administrative reasons, for instance, it might become necessary to adjust any new dosing model, as well as its correction factors or concentration instructions, based on the actual leaf area.

4.6 LfL projects as part of the production and quality initiative

For the period 2019 to 2023, the Bavarian State Research Center for Agriculture is conducting a survey of yields and qualities of selected crops within the framework of a production and quality initiative. On behalf of the IPZ Hops Working Group, the Hopfenring group serves as a partner in this initiative. The following is a summary of the objectives of these hop projects and of the results for 2021.

4.6.1 TS and alpha acid monitoring

During the period between August 17 and September 28, one hop bine each of Hallertauer Mittelfrüh, Hallertauer Tradition, Perle, Hersbrucker Spät, Hallertauer Magnum and Herkules (5 aroma and 7 bitter varieties) were harvested in 10 commercial hop gardens, in different locations in the Hallertau, and dried at weekly intervals. The following day, an accredited laboratory analyzed the green hops at a 10-percent moisture content for their dry matter and alpha acid content. These data were transmitted to the LfL hop advisory service for evaluation. The results were tabulated, averaged, converted to graphic representations, and posted with comments on the Internet. These postings provided hop growers with information about optimal harvest maturities of the most important hop varieties.

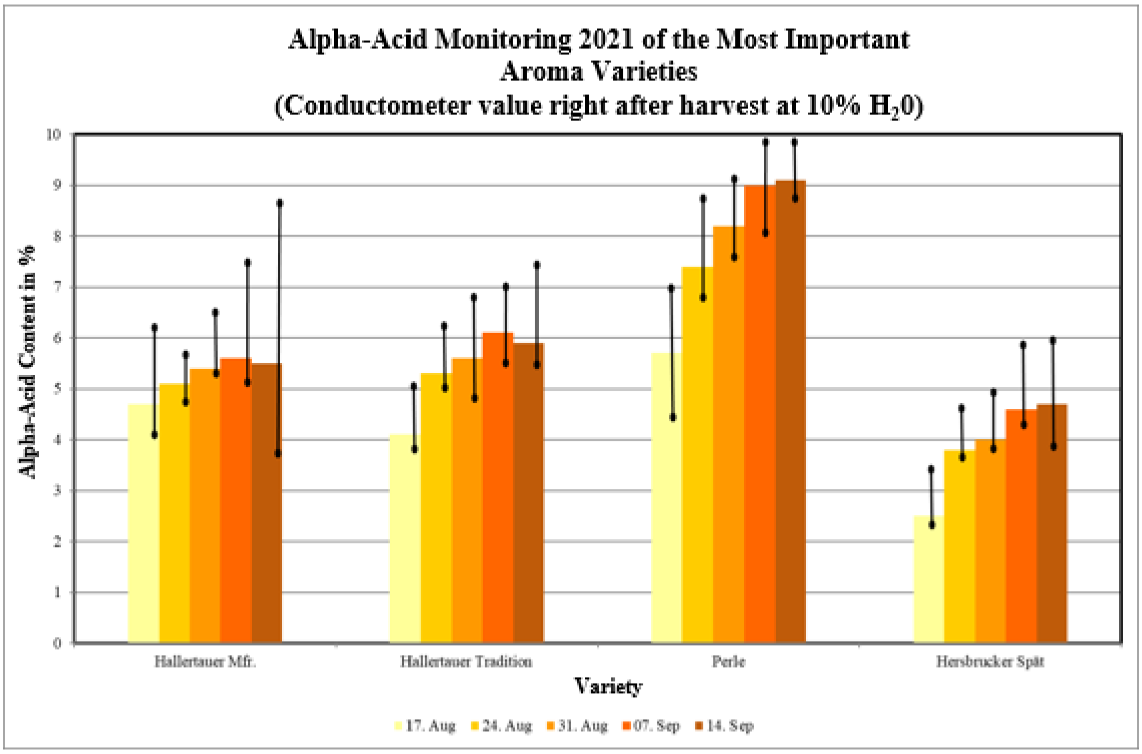


Figure 4.16: Monitoring of the development of alpha acid levels in 2021 for the most important aroma varieties

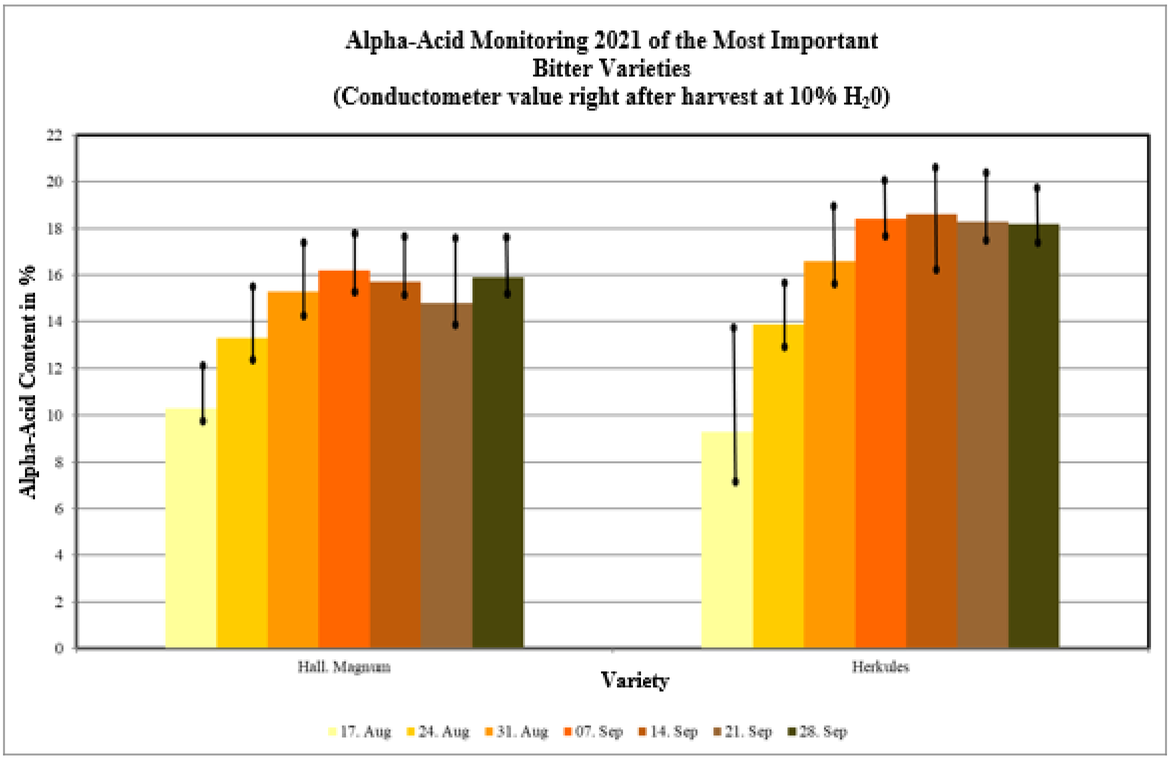


Figure 4.17: Monitoring of the development of alpha acid levels in 2021 for high alpha varieties

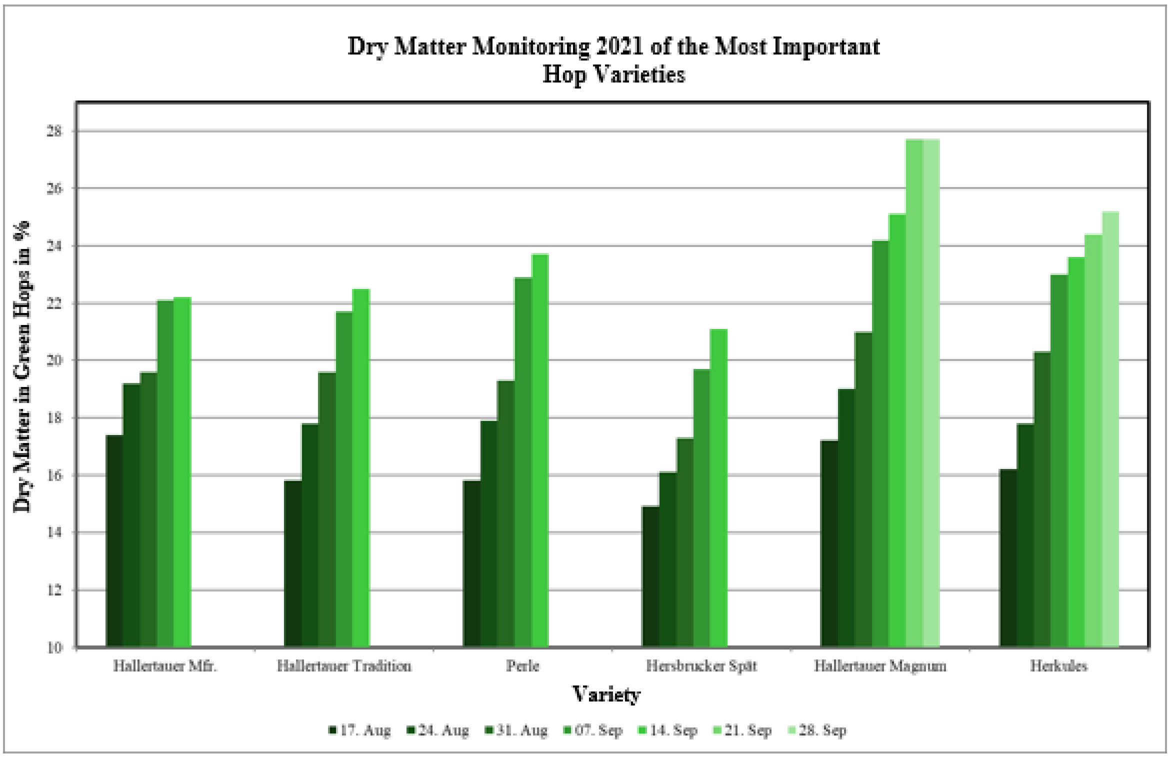


Figure 4.18: Monitoring of the development of the dry matter content in 2021 for the most important hop varieties

Another graphic overview compared the data from 2020 and 2021, as well as the averages of the last 6 years, as a function of staggered harvest times. These comparisons to previous years were helpful in assessing alpha acid levels of different varieties. Using Perle and Herkules as examples, the figure below shows how, in 2021, alpha acid levels increased at a relatively late point in time. This confirmed the LfL recommendation last year for a later start of the harvest because of a delay in plant maturity.

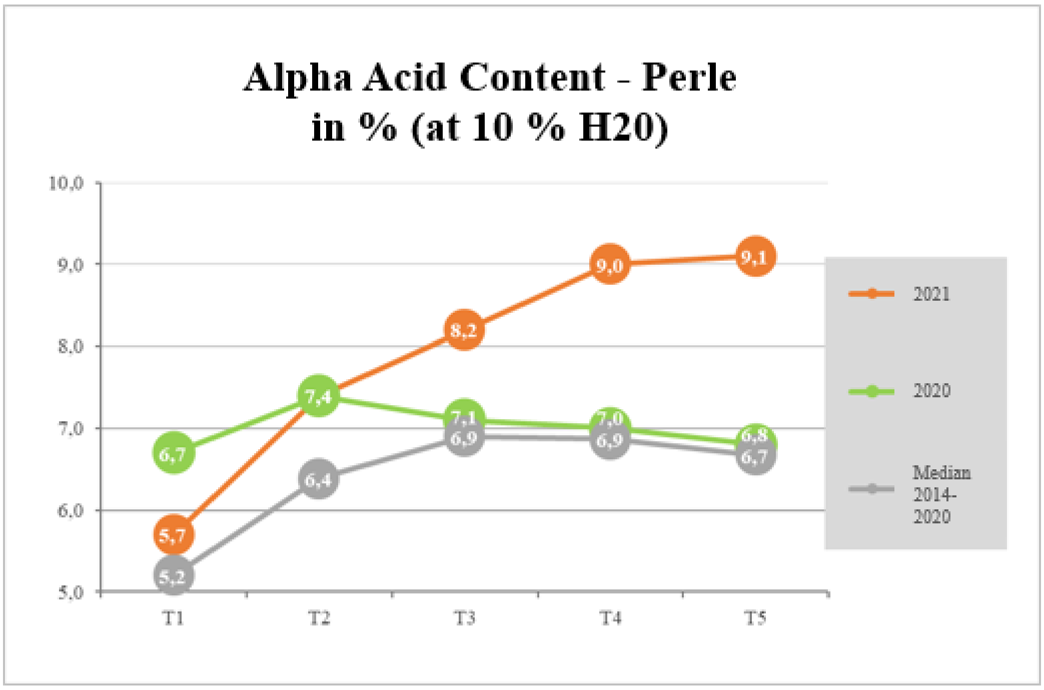


Figure 4.19: Development of alpha acid content in Perle in 2021 compared to previous years.

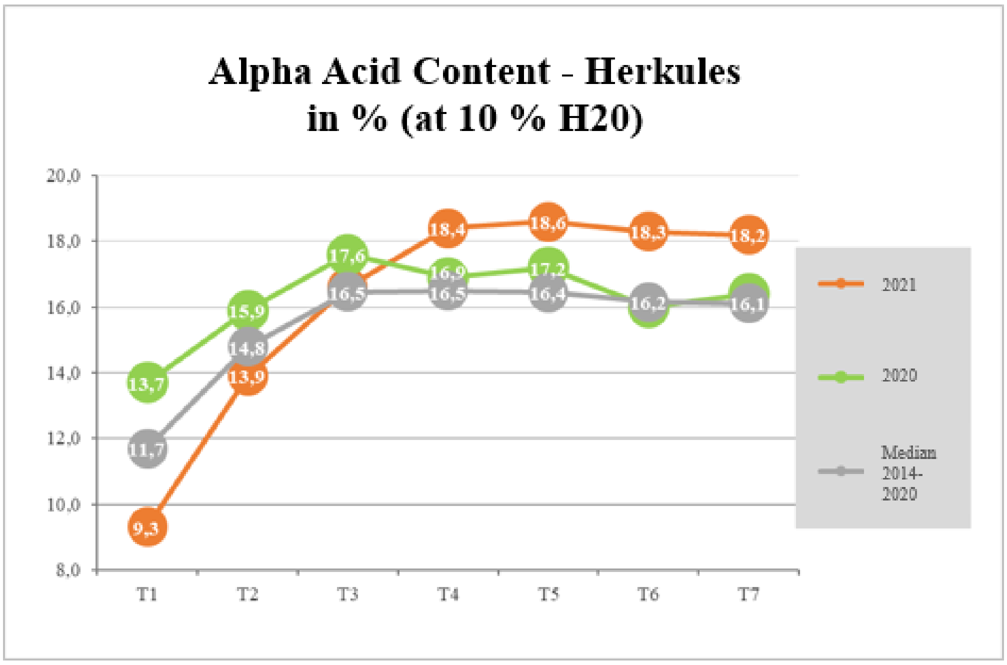


Figure 4.20: Development of alpha acid content in Herkules in 2021 compared to previous years

4.6.2 Annual survey and investigation of pest infestations in representative hop gardens in Bavaria

To assess the extent of aphid and spider mite infestations for the purpose of disseminating cultivation advice and control strategies, surveys and exact examinations of such infestations in commercial hop gardens are a necessity.

For this purpose, investigations were conducted on location, on 12 dates in weekly intervals, in 33 representative hop gardens (including 3 organic hop gardens), between May 25 and August 9, 2021. The hop gardens were in the Hallertau (23), in Spalt (7), and in Hersbruck (3). Assessments covered infestations with hop aphids (a count) and common spider mites (according to an infestation index). These served as the basis for formulating advice and control strategies.

As an example, Figure 4.21 shows an overview of the evolution of the spider mite infestation index. Because of the cool spring in 2021, spider mites were first detected relatively late and the infestation progressed much more slowly than it did in the two previous years. However, by calendar week 26, a sudden increase in spider mite infestations in numerous areas triggered the control threshold, just as it did in previous years. Following the control measures, the infestation index decreased.

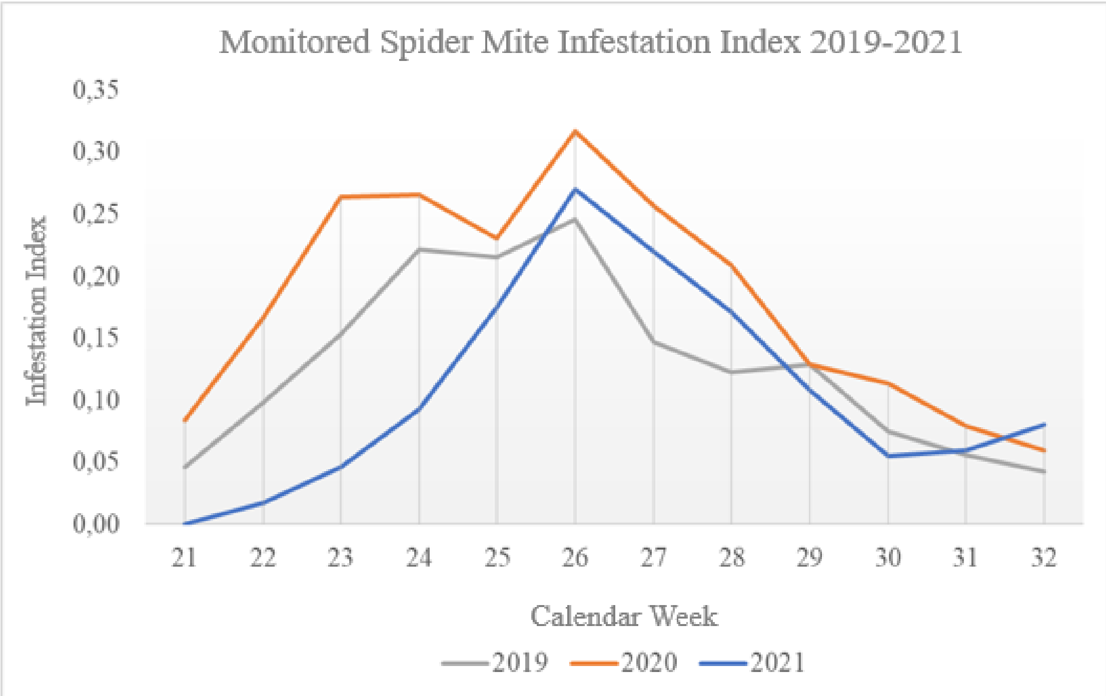


Figure 4.21: The spider mite infestation index as an average across all 33 monitoring locations

4.6.3 Chlorophyll measurements on hop leaves to estimate the nitrogen supply and the need for fertilizer

Objective

The specifications and restrictions contained in the new Fertilizer Ordinance pose major challenges for hop-growing operations. On the one hand, it is important to maintain high yield and quality levels. On the other hand, water protection goals must be pursued consistently. Regarding nitrogen fertilization, this means that the nitrogen must be administered in a needs-based, targeted, and nutrient-efficient manner, even more so than in the past. Since hops take up most of their nitrogen in June and July, nitrogen fertilizer might not dissolve if the weather is too dry; or organically bound nitrogen might mineralize if the soil is too moist. This can make it difficult to estimate the nitrogen supply in the soil and the amount of fertilizer that is still required. Therefore, regular leaf examinations at different locations and of different varieties are intended to provide information about the nutritional status of the hop plants, which, in turn, yields recommendations for needs-based fertilizer applications.

Method

Using a SPAD meter (soil plant analysis development SPAD-502 plus) chlorophyll measurements are carried out on hop leaves of two varieties at two different locations in the Hallertau, in 10 weekly intervals, from the end of May to the middle of August. To obtain representative results, on each date, four samples of 20 individual measurements are taken on leaves at a height of approx. 1.6 m. To determine the actual N supply status, the 20 leaves are plucked, dried, and examined by the Dumas method for their total N content. The SPAD values are tabulated individually for each variety and location and then averaged. Using linear regression models, the relationship between measured chlorophyll values and actual N levels can then be analyzed.

In a mineral fertilizer experiment conducted in 2019, a chlorophyll meter was able to clearly identify differences in N supplies in the test (see Annual Report 2019).

In 2021, such measurements were carried out for the second time in field trials, as part of the project "Trials for composting and recycling hop bine shreds." This investigation focused on whether the SPAD meter could detect N supply differences caused, among other factors, by fertilization with shredded hop bines. Figure 4.22 shows that there were indeed differences in nitrogen supplies between the variants. Initially, the differences were small, but they increased starting in mid-June.

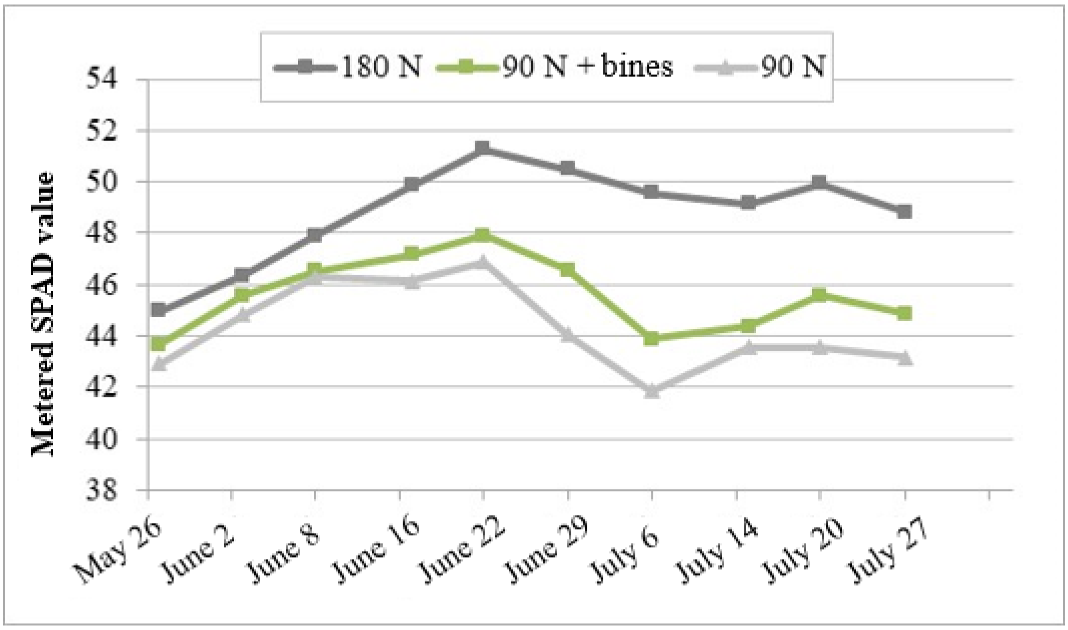


Figure 4.22: SPAD values in 2021 for Herkules on an easy location with three fertilizer levels: 180 N = 180 kg N/ha mineral, 90 N + Shredded Bines = 90 kg N/ha mineral + 100 kg N/ha organic (vine shreds), 90 N = 90 kg N/ha mineral (control)

Figure 4.23 shows the relationship between chlorophyll measurements with a SPAD meter and N levels in the leaves. In 2021, precise conclusions about the actual N content in the measured leaves and thus about the N supply of the plants were possible only after T6 (June 22). Before that date, chlorophyll measurements were inconclusive because, in this experiment, higher determination coefficients (R^2) of over 0.60 could not be achieved. Before that date, there is no data that would establish a connection between the measured chlorophyll values and the actual nitrogen supply. However, later on in the vegetation period, such a connection could be established.

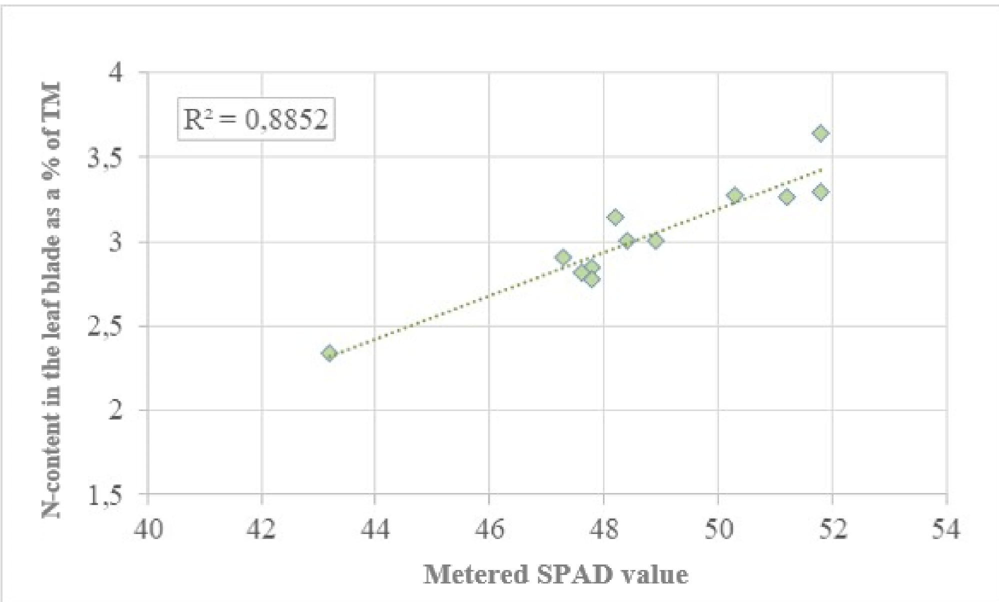


Figure 4.23: N content of the leaves in % of dry matter of the dry mass as a function of SPAD meter readings, HKS, easy location, T6 = June 22, 2021

4.6.4 Ring analysis for quality assurance in the determination of alpha acid values for hop supply contracts

For years, there has been a clause in hop supply contracts, in which the alpha acid content of the delivered hop batches is part of the basis for determining payments. Depending on the availability of testing capacity, the alpha acid content is determined by government laboratories, corporate laboratories, or private laboratories. However, the procedure (sample processing, storage) is precisely defined in specifications issued by the "Working Group for Hop Analysis," which also determines which laboratories carry out follow-up examinations. This group also determines the tolerances permitted for analysis results. To ensure the quality of the alpha acid analysis. It is in the interest of hop growers that chains of analyzes are organized, carried out, and evaluated by the Bavarian State Institute for Agriculture as a neutral body.

As part of the project, it is the task of the Hopfenring to carry out the sampling of a total of 60 randomly selected hop batches on 9 or 10 dates, in the Hallertau, and to make the results available to the LfL laboratory in Hüll.

4.7 Consulting and training activities

In addition to applied research in the field of production technology in hop growing, the working group Hop Cultivation, Production Technology (IPZ 5a) is tasked with the preparation of test results for network and cultivation advice. This helps hop growers obtain access, for instance, to special consultations, training lessons, training courses, seminars, lectures, print media, Internet information, and working groups. The organization and implementation of the downy mildew warning service and the updates used by that service are as much a part of these tasks as is the cooperation with hop organizations or the training and technical support of the Hopfenring as a partner.

The training and consulting activities during the past year are summarized below.

4.7.1 Information in written form

- The “Green Book” entitled “Hops 2021 – Cultivation, Varieties, Fertilization, Plant Protection, Harvesting” was updated and published in coordination with the consulting services of the federal states of Baden-Württemberg and Thuringia, as well as the plant protection working group. The press run was 2,100 copies. The LfL distributed these to the ÄELF and research institutions; and the Hopfenring Hallertau distributed them to the hop growers.
- The 74-page LfL information brochure “Drip Irrigation and Fertigation of Hops” is a comprehensive reference work with compilations of many years of test results and practical experience with irrigation and fertilizer application in hop cultivation. It is available to all hop growers via the HVG producer group.
- A distribution list of approximately 1000 subscribers via Fax is maintained by the Hopfenring. It serves to broadcast up-to-date hop growing instructions and warning calls by the LfL. Some 33 faxes were sent to hop growers in 2021. A total of 68 faxes went to addresses in the Hallertau, in Spalt, and in Hersbruck.
- Advice and specialist articles for hop growers and the brewing industry were published in circulars by the Hopfenring, as well as in 9 monthly issues of the Hopfen-Rundschau; and in 3 articles in the Hopfenrundschau International.

4.7.2 Internet and Intranet

Warning service and advisory information, specialist articles, lectures, and 3 videos were made available to hop growers via the Internet.

4.7.3 Telephone advice, announcement services

- The *Peronospora* warning service maintained by the Hop Growing Working Group, Production Technology in Wolnzach, in cooperation with the Plant Protection Working group in Hüll, was updated 79 times between May 11 and September 1, 2021. It supplied answers via answering machine (Tel. 08161 8640 2460) and on the Internet.
- The consultants of the Working Group Hop Cultivation, Production Engineering provided information over the telephone some 1,300 times, as well as advice in one-on-one meetings or on site on special questions relating to hop cultivation.

4.7.4 Lectures, conferences, guided tours, training courses and meetings

- Weekly exchange of experiences during the growing season with Ringfach advisors
- 15 specialist lectures
- Various conferences, specialist events, seminars, and workshops

4.7.5 Education and training

- Provided topics for 4 examinations and 4 work projects as part of the master craftsman's examination
- Gave 13 lessons on hop cultivation to students at the Pfaffenhofen agricultural school
- Held a 4-evening BiLa seminar on hop cultivation
- 1 day of schooling during the summer semester of the agricultural school in Pfaffenhofen
- 1 information event for vocational students at Pfaffenhofen
- 1 meeting of the working group “Hop Farm Management”

5 Plant Protection in Hops

Simon Euringer, M.Sc. Agricultural Management

5.1 Pests and diseases in hops

5.1.1 *Peronospora* warning service 2021

During the 2021 growing season, a total of seven spraying campaigns against downy mildew secondary infection were necessary for both susceptible and tolerant varieties.

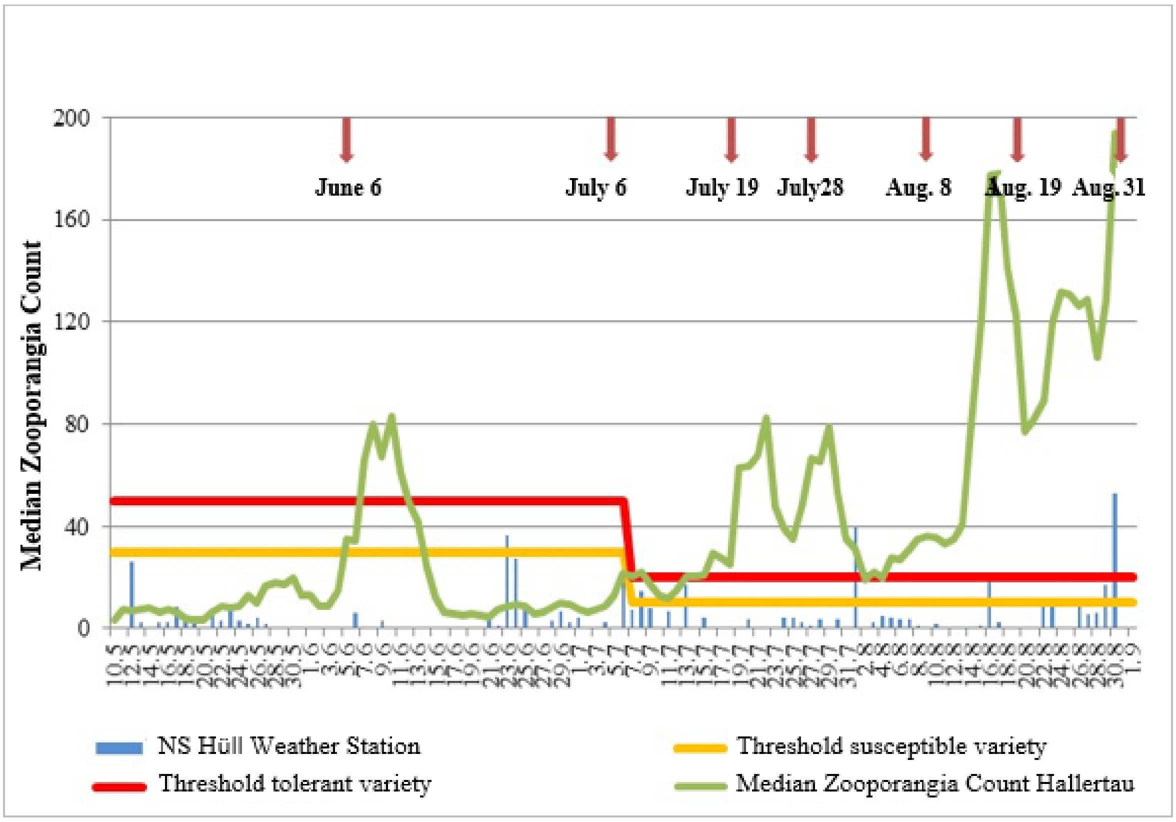


Figure 5.1: Representation of the Peronospora warning service 2021 (median zoosporangia count Hallertau (4-day total, 5 locations) and mitigation campaigns), source IPZ 5a

5.1.2 Arrival date of the aphis fly in 2021

During the 2021 aphis fly migration, no unusual events occurred in the Wolnzach area. The first aphis flies were discovered on winter hosts in May. The influx increased until mid-June and then subsided until the end of June.

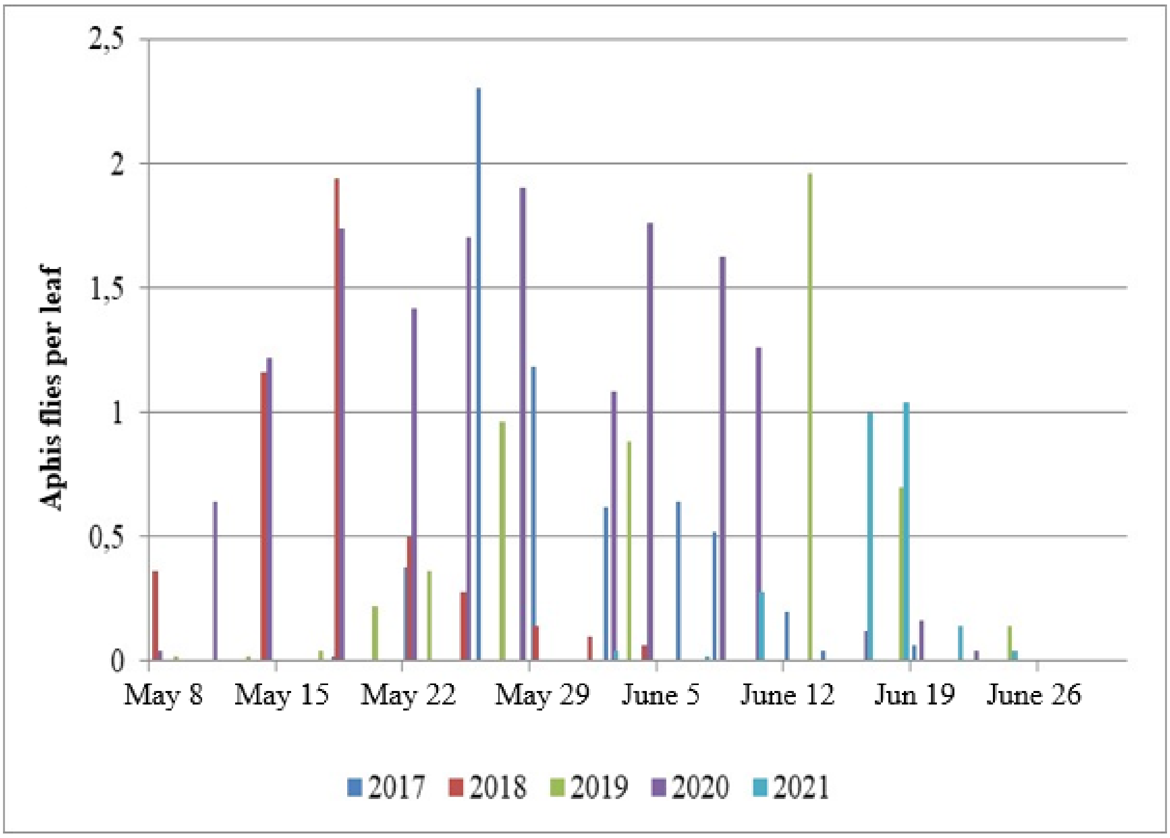


Figure 5.2: Arrival date of aphis flies in the Wolnzach area, 2017 - 2021

5.2 Official means test

Management: S. Euringer

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

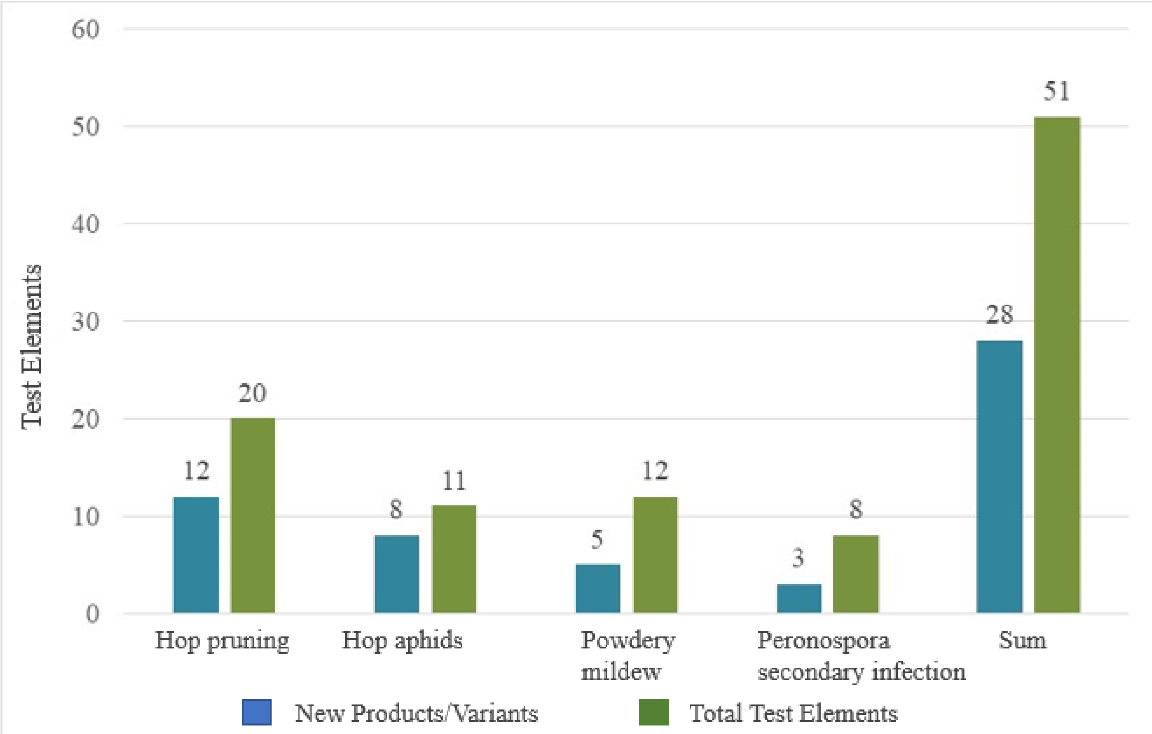


Figure 5.3: GEP tests as part of the official means test 2021

In the 2021 test year, six AMPs (official means tests) were carried out according to GEP (Guidelines for Good Engineering) standards (Figure 5.3). Five indications were covered in these GEP trials, which meant that 28 new products or combinations could be tested in 51 trial variants on about 5 hectares.

Furthermore, a greenhouse test for indications of powdery mildew, as well as two field tests in cooperation with hop growers and the Hopfenring were conducted to check for powdery mildew and common spider mites. In order to generate results and solutions concerning residue problems with fluopicolide (EU standard: reduction to 0.15 ppm) and to generate a pelargonic acid MRL (Maximum Residue Limits) test for Japan, the LfL also conducted residue tests in cooperation with producers of plant protection chemicals. The problem of potential captan residues from Folpan 80 WDG was also part of the test plan.

In the 2022 season, further residue tests regarding fluopicolide and Folpan 80 WDG are in the planning stage.

5.3 Introduction of the experimental ARM (Agriculture Research Management) software

In recent years, the main tool for planning and evaluating trials in connection with the AMP was Excel. This led to a great deal of additional work for all parties because the data had to be entered laboriously into the test software for additional calculations. In order to improve cooperation and teamwork, a user survey was conducted, which unearthed that an absolute majority of growers works within the ARM framework. After a great effort by the head of the institute, Dr. Doleschel, the IPZ 5b working group was the first German regulatory authority to acquire two ARM licenses.

5.4 Setting up a test garden for investigating the effectiveness of crop protection

For future tests of the effectiveness of various products within the AMP framework, a special test hop garden was set up in 2021. Its purpose is to provide early insights into and support for the development of crop protection products and to ensure that new products become quickly available for use in the field. In October 2021, this new hop area of roughly 1 ha was planted with certified Herkules seedlings. There is enough space for nine experimental plots. The first effectiveness tests for plant protection products are planned for the 2023 growing season. However, only one efficacy trial per year can be carried out there, which means that, even after 2023, commercial hop gardens will still have to be used for any additional trials.

The lease cost of the area is covered by the GfH (German Society for Hop Research).

5.5 Purchase of weather stations

When conducting plant protection product tests, it is extremely important to collect weather data from the test site. However, at some locations, this can be a problem because weather stations may be located more than 5 to 15 km distant, which makes it impossible to gather local precipitation data. Yet, knowing the exact time frame in which the first precipitation after the treatment occurred is absolutely crucial for the implementation and evaluation of the experiments. If active substances are washed off by rain, their effectiveness declines, which means that follow-up applications might become necessary earlier than otherwise.

Thanks to the splendid support by Mr. Walter Kerscher, Agrarmeteorologie Bayern (*Agricultural Meteorology Bavaria*), three weather stations will be available for the AMP in the 2022 season. One of these will be placed permanently inside the new test yard to compare the weather data obtained in the hop garden with the data from stations elsewhere.

5.6 Automatic aphid counts via APP

A joint project with Dynamic Ventures, Inc., d/b/a CountThings has worked on the development of a hop aphid count template for the 2021 season. This is currently available free of charge. There are plans to improve this census template for aphids further. Current issues relate to the difficulties in distinguishing between lupulin glands and aphids, as well as coping with the curved surfaces of some hop leaves and ensuring that aphids are counted on young hop leaves.

5.7 Resistance and efficacy tests against hop aphids in spray towers

Management: S. Euringer

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

Hop aphids attack all hop varieties; and do so every year. The banning of important insecticides makes it much more difficult to alternate active ingredients to avoid creating resistances. Repeated use of the same active ingredient or ingredients relying on the same mechanisms leads to a one-sided selection of harmful organisms.

As a result, resistances develop; and combating harmful organisms will no longer be successful. Therefore, current and new active ingredients with regard to resistance to hop aphids are tested in spray tower tests. Depending on the active ingredient, the test results can vary greatly from those in real-world applications. Therefore, the results are not published. In 2021, seven active ingredients were tested in seven concentrations each.

5.8 Enzyme-linked Immunosorbent Assay (ELISA) for identification of Hop Mosaic Virus (HpMV) and Apple Mosaic Virus (ApMV) infections in hops

Management: S. Euringer

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

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

Table *5.1: Result of the ELISA tests in 2021*

	Investigation of Plant Material in 2021						
	Total number of plants	ApMV		HpMV		Sum of plants	
		n.d.	positive	n.d.	positive	n.d.	positive
Female plants for hop propagation—Part 2	72	72	0	72	0	72	0
Breeding material IPZ 5c	659	659	0	643	16	643	16
	Investigation of Plant Material in 2022						
Female plants for hop propagation—Part 1	270	261	9	263	7	256	14
Breeding material IPZ 5c	Spring 2022						

* 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 1001 plants tested, 30 were discarded. The healthy plants were provided as breeding material and as mother plants to the GfH's contract propagator (Table 5.1).

Special thanks go to Daniel Eisenbraun (IPZ 3a), who actively supported the IPZ 5b working group in the spring of 2021 in an effort to analyze the samples. He was there when needed, with advice and help.

5.9 Monitoring increased virus infestations in the spring 2021

Background

In June and July 2021, an increased number of hop plants with growth anomalies were observed in the Hallertau. Growth retardation, as well as the shape and color of the leaves indicated the presence of viral diseases. For this reason, virus monitoring was carried out in conjunction with the Hopfenring and the LfL (IPS 2c and IPZ 5a/5c).

Figure 5.4: Hercules with virus symptoms

Method

On July 14, 2021, samples of plants that appeared to be symptomatic were collected from various regions and hop gardens in the Hallertau. These were collected and passed on to the laboratory of Dr. Luitgardis Seigner (IPS 2c). There, a test for apple mosaic virus and hop mosaic virus was conducted via ELISA tests (DAS-ELISA based on PM 7/125(1) for viruses 2015-09). Other tests involved real-time reverse transcriptase polymerase chain reaction (RT-PCR) for the presence of American hop latent virus and hop latent virus.

Results

Based on the test results, it cannot be ruled out that there were also infestations from viruses that were not part of the test. Furthermore, it is unclear how various cross-infections affect the hop plant. Even after a negative test result, a very small infestation cannot be ruled out. The following table shows that none of the hop plants with symptoms were virus-free. The most common infection was with apple mosaic virus (ApMV), followed by hop mosaic virus (HpMV) and hop latent virus (HpLV). Only 5% of the plants showed an infection with American hop latent virus (AHpLV).

Table 5.2: Percentage representation of the results of virus infection tests

	AHpLV (American hop latent virus)	**HpLV (Hop latent virus)**	**ApMV (Apple Mosaic virus)**	**HpMV (Hop Mosaic virus)**
positive	5 %	48 %	76 %	62 %
unclear	5 %*	52 %**	24 %	38 %
nd	90 %	0 %	0 %	0 %

nd = Virus not detectible in the investigated material

* This sample gives a weak detection signal for AHpLV, the result is assessed as unclear. ** For HpLV, the result was unclear for some samples (weak, background fluorescence in real-time RT-PCR, atypical for positive samples). It is more likely that these cases represent negative findings. [Seigner, L., 2021]

5.10 Strawberries as indicator plants for powdery mildew (*Sphaerotheca macularis*)

Background

A forecast model for powdery mildew, which is one of the most important pathogens affecting hops, is currently still in the development and testing phase. For this reason, an indicator plant, i.e., a plant that is much more susceptible to powdery mildew, is of great interest. Once early symptoms of powdery mildew appear on the indicator plant, it is an indicator to consider using targeted spraying to protect the somewhat less susceptible hop plant against powdery mildew. This has a savings potential for pesticides at the beginning of the season. The indicator plants selected for the experiment were strawberries, more specifically, the variety Daroyal, a cultivar susceptible to powdery mildew. Like hops, these strawberries are attacked by *Sphaerotheca macularis*, specifically by the variety *Sphaerotheca macularis f. sp. fragariae*.

Method

Strawberry and hop plants were placed next to each other in a greenhouse and spores of *Sphaerotheca macularis* were seeded there on March 9, 2021. For this, a severely infected carrier plant was taken into the area and the spores were distributed by a leaf blower.

Result

Even after several weeks, the strawberry plants remained symptom-free, while the hop plants showed severe powdery mildew infections. Thus, this greenhouse experiment established that strawberries are not suitable as indicator plants for Sphaerotheca macularis in hops.

Figure 5.5 Hop plant on April 6, 2021

Figure 5.6: Strawberry plant without powdery mildew symptoms

5.11 Off-flavors caused by the application of sulfur preparations to protect hops against powdery mildew

Figure 5.7: Hop cones infested with powdery mildew

Background

There is a persistent view among members of the hop industry that liquid sulfur, in particular the liquid anti-fungicide Thiopron, leaves little or no odor on hop cones if used after the cones have formed. This year's effectiveness test offered a unique opportunity to test this theory because one test plot was treated with solid sulfur and another with liquid sulfur.

Method

The selected samples for odor testing come from an efficacy test for powdery mildew in Herkules. The sulfur samples were treated throughout the season with either just Thiopron or the solid-sulfur Microthiol WG. Another sample from the same plot was treated on the same spraying dates against powdery mildew with conventional plant protection products (PPP). No sulfur products were used on this sample plot. The test was conducted at a location 3 km distant from Hüll. A total of six treatments against powdery mildew were administered. The last application was administered on September 3, 2021. The samples were harvested on September 14, 2021.

Weather

The protocol indicates that there was precipitation only on the 3rd spraying date, within six hours after the application. Specifically, 28 mm of rain fell three hours after the application. There was no further precipitation between the last treatment date and the harvest date.

However, during the entire test phase, there was more precipitation in May, July, and August 2021 (between +19.6 and +104.6 mm, compared to the long-term mean between 1961 and 1990), while in September, precipitation amounted to much less (-53.2 mm). In May 2021, temperatures were slightly lower than the long-term mean (-1.2 °C), while they were slightly higher from June to September 2021 (+0.3 °C to +4 °C).

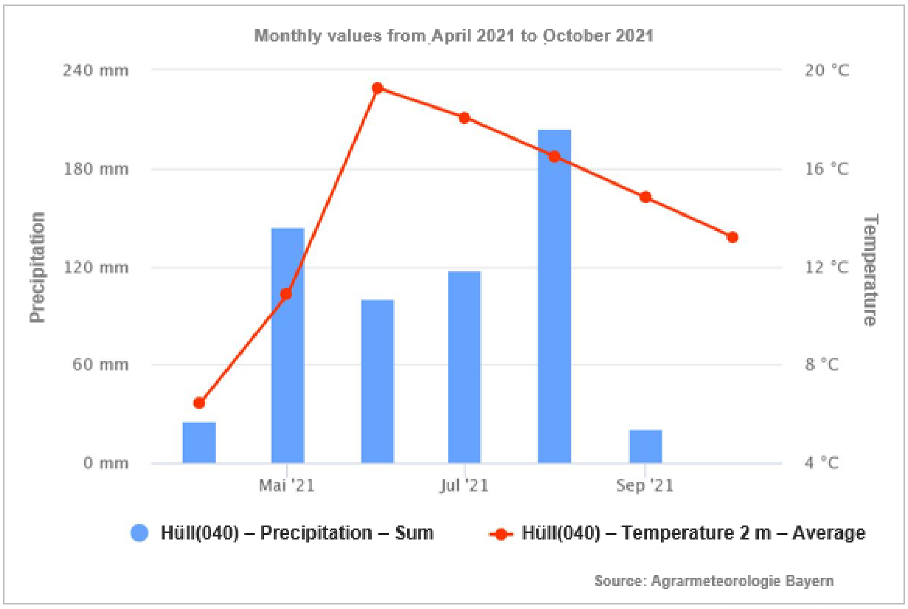


Figure 5.8: Weather data relating to precipitation and temperature for April to September 2021

Results

To generate a representative (result X), hop samples were blind-tasted by experts as well as by laypersons (X). Both groups were asked to evaluate individual samples for off-flavors caused by sulfur preparations and record these on a scale (sulfur odor imperceptible to very intense). These are the results:

Sample # 2 (conventional PSM without sulfur):

Sulfur Odor

Non-detectable → very intensive

0	1	2	3	4	5	6	7	8	9	10
	XX									

Sample # 3 (Thiopron/liquid sulfur):

Sulfur Odor

Non-detectable → very intensive

0	1	2	3	4	5	6	7	8	9	10
		X	X							

Sample # 6 (Microthiol WG [water dispersible granules] /solid sulfur):

Sulfur Odor

Non-detectable → very intensive

0	1	2	3	4	5	6	7	8	9	10
	X		X							

- The perception of sulfur odors was low in all samples. Some participants even detected slight sulfur smells in the reference cones, although none of them had come in contact with sulfur.
- The large amount of precipitation in 2021 and the continuous “washing” of the cones could explain why sulfur was hardly perceptible.
- In addition, Herkules may not have been the most suitable variety for the experiment, because its inherently intense odor could mask slight sulfur odors.
- Finally, even at full application rates, less product may have reached the Herkules cones compared to traditional aroma varieties, because this cultivar has an enormous cone area, which may have caused a certain dilution effect.

5.12 **Hop pruning: Vinegar as a way to reduce the amount of herbicides?**

Figure 5.9: Experiment 12c of 80%-vinegar (30%) + Adhäsit (0.1%) + Break Thru (0.04%)

Background

Hop pruning after training promotes growth. At the same time, pruning has a phytosanitary side effect. Normally, the lower leaves and side shoots of the hop bine, as well as new shoots sprouting from the ground are removed on twice in a season.

There are several pruning methods next to the non-chemical removal of leaves by hand or by flaming. Other methods rely on herbicides. In Germany, these include Beloukha (no JP MRL), Quickdown (US MRL 0.02 ppm; currently unknown whether sufficient); and Vorox F, which is currently approved only up to BBCH 55 and is not recommended for young hops or weak stocks. Hop pruning is limited to the ridges between the furrows, growers usually apply only one-third of the amount permitted per hectare. Because of regulations seeking to minimize the use of nitrogen, hop gardens in so-called red zones, for instance, may not even use two applications of nitrogenous nutrient solutions for hop pruning.

Overall efforts to reduce the use of pesticides are ongoing. Therefore, in this year's GEP trial, the vinegar was tested as a possible alternative for limiting nutrient solutions and serving as a herbicide substitute for both the first and the second hop pruning. Approval of vinegar as a raw material is easy to come by.

Experimental plan

The trial was conducted with Herkules at a location 5 km distant from Hüll. The design of the experiment relied on a randomly selected hop garden. Except for one untreated control plot, all other plots were treated individually on two dates. Only test segment four was different from the others in that the amount of Vorox F was changed between the first hop pruning on June 16, 2021 and the second one on July 22, 2021.

Overview of the individual test elements:

Test Element #	Product Name	Application Quantity	Unit	Appl. Code	Spray Dosage	Unit
1	Untreated Check					
2	AHL	30	% v/v	AB	1200	L/ha
4	Vorox F	0.06	kg/ha	A	1200	L/ha
	Vorox F	0.09	kg/ha	B	1200	L/ha
	AHL	30	% v/v	AB		
8	AHL	15	% v/v	AB	1200	L/ha
	Adhäsit	0.1	% v/v	AB	1200	L/ha
	Break Thru	0.04	% v/v	AB	1200	L/ha
10	60 % Vinegar	30	% v/v	AB	1200	L/ha
	Adhäsit	0.1	% v/v	AB	1200	L/ha
	Break Thru	0.04	% v/v	AB	1200	L/ha
11	60 % Vinegar	30	% v/v	AB	1200	L/ha
	AHL	15	% v/v	AB	1200	L/ha
	Adhäsit	0.1	% v/v	AB	1200	L/ha
	Break Thru	0.04	% v/v	AB	1200	L/ha
12	80 % Vinegar	30	% v/v	AB	1200	L/ha
	Adhäsit	0.1	% v/v	AB	1200	L/ha
	Break Thru	0.04	% v/v	AB	1200	L/ha

A Caffini Agricultural Mist-Blower Sprayer with two TD 80-04 nozzles on each side was used as the application device. For practical reasons, no more than two TD 80-04 nozzles can be used on each side. Obviously, three or four nozzles per side might generate better results. However, because this limitation was applied uniformly across all plots, it does not prevent a comparison of results.

Weather

The precipitation before and after the application dates (colored blue) is shown below:

Date	Precipitation NN050 in mm	Datum	Precipitation NN050 in mm
June 6, 2021	5.9	July 12, 2021	0.2
June 7, 2021	0.0	July 13, 2021	16.9
June 8, 2021	0.0	July 14, 2021	0.0
June 9, 2021	2.9	July 15, 2021	4.3
June 10, 2021	0.1	July 16, 2021	0.0
June 11, 2021	0.0	July 17, 2021	0.2
June 12, 2021	0.0	July 18, 2021	0.0
June 13, 2021	0.0	July 19, 2021	0.1
June 14, 2021	0.0	July 20, 2021	3.8
June 15, 2021	0.0	July 21, 2021	0.0
June 16.2021 1st Hop pruning	0.0	July 22, 2021 2nd Hop pruning	0.0
June 17, 2021	0.0	July 23, 2021	0.0
June 18, 2021	0.0	July 24, 2021	4.2
June 19, 2021	0.0	July 25, 2021	4.3
June 20, 2021	0.0	July 26, 2021	2.4
June 21,2021	3.3	July 27, 2021	1.2
June 22, 2021	1.3	July 21, 2021	3.6

[Source: Agrarmeteorologie Bayern Weather Station Hüll]

Results of leaf and side shoot evaluation

In the first assessment four days after the first hop pruning, test segment 4 (Vorox F + AHL 30%) showed the best results. The pure AHL 30% variant (VG 2) took second place, followed by the test with 80%-vinegar at 30% + Adhäsit + Break Thru (VG 12), while VG 10 (60%-vinegar at 30% + Adhäsit + Break Thru) showed the worst result.

A further assessment five days after the second hop pruning showed that neither vinegar nor AHL alone came close to the effects of the mixture with Vorox F (VG 4), while test segment 11 (60%-vinegar at 30% + AHL 15% + Adhäsit + Break Thru) showed a significantly better result than the same test (VG 8) without the vinegar. This indicates that vinegar had an effect, which is confirmed by VG 12 (80%-vinegar + Adhäsit + Break Thru).

On August 10, 2021, 19 days after the 2nd hop pruning, another evaluation was conducted. Once again, test 4 (VG 4) with Vorox F showed the best results, followed by the pure AHL 30% test (VG 2). In addition, VG 8 confirmed that it is worthwhile to upgrade AHL 15% (VG 8) with 30%-vinegar (VG 11). The test with 80%-vinegar at 30% (VG 12) performed better than the test with 60%-vinegar at 30% (VG 10), and also better than the test with AHL 15% (VG 8).

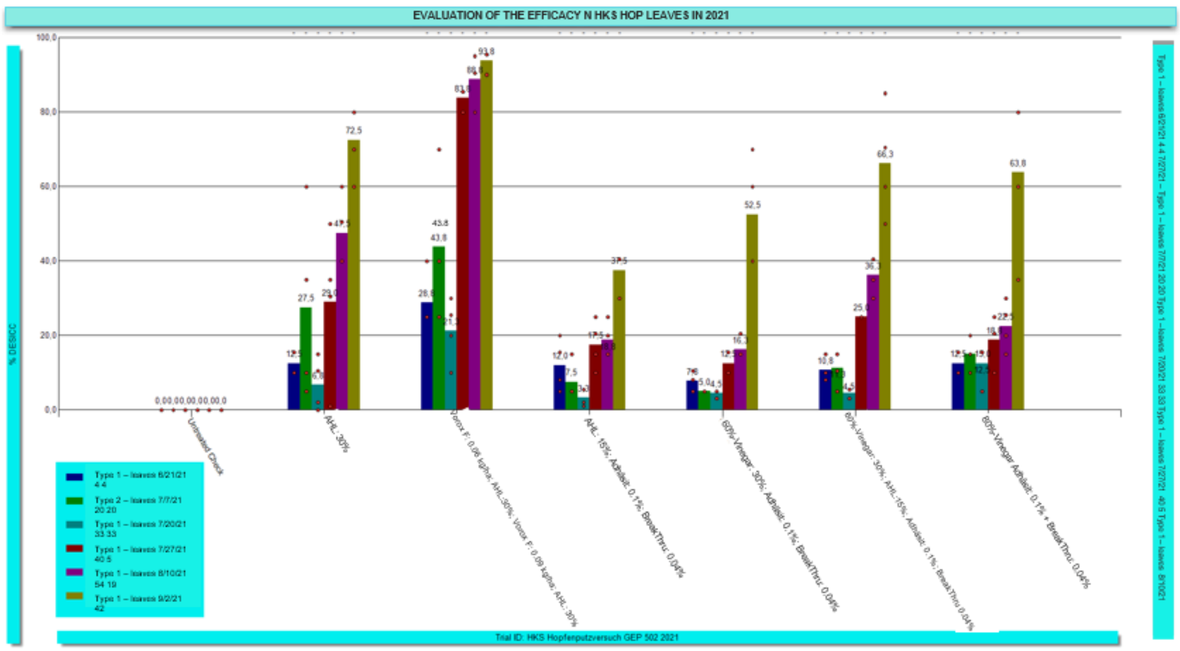


Figure 5.10: Effectiveness of the individual test variants on the hop leaves. Legend: Rating type; rating date; days after the 1st hop pruning; days after the 2nd hop pruning

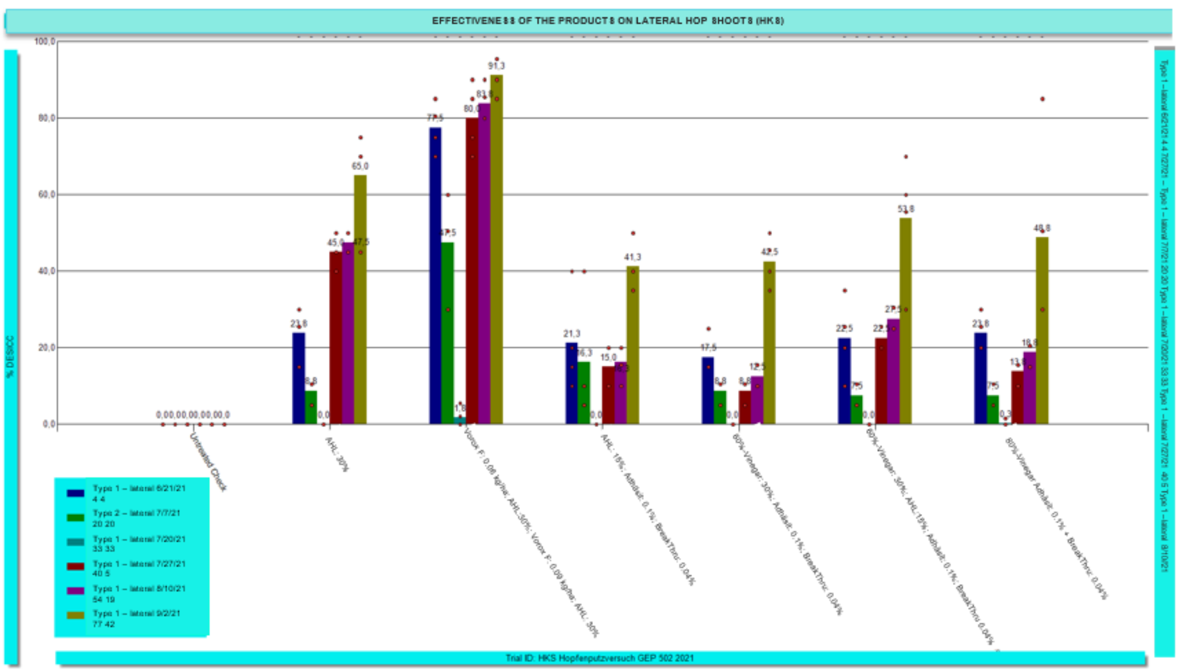


Figure 5.11 Effectiveness of the individual test variants on side shoots. Legend: Rating type; rating date; days after the 1st hop pruning; days after the 2nd hop pruning

Vinegar test results in a nutshell

- ✓ The use of vinegar was effective in the experiment
- ✓ 80%-vinegar had a better effect than 60%-vinegar
- ✓ Vinegar showed a better effect against hop leaves than side shoots
- ✓ The vinegar effect is currently still unsatisfactory

Conclusion: The effect of vinegar in different forms proved to be still insufficient in practice. Therefore, future work should concentrate on possible increases in effect, perhaps through improved application techniques or through the use of other mixing partners. Approval for vinegar as a raw material should be easy to come by.

5.13 GfH-Project in *Verticillium* 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) und der Erzeugergemeinschaft HVG (*Supported by the Society for Hop Research and the Hop Producers Group*)
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

Objective

Since the first emergence of lethal strains of *Verticillium nonalfalfae*, a cause of aggressive forms of hop wilt, in the Hallertau growing region, its spread has been continuous. The pathogen is a soil-dwelling fungus with a wide range of other hosts. It can survive in the soil for up to 5 years as a permanent mycelium without any host plant. It cannot be combated directly. This necessitates an integrated approach to disease infestations that encompasses sanitary measures, breeding efforts, adapted cultivation techniques, and reclamation efforts. A quick and regular transfer of all cutting-edge knowledge about the pathogen should help affected hop farms in implementing management measures and in achieving successful recoveries as quickly as possible.

Cooperation with commercial farms

In addition to making visual assessments in the field, the Breeding Research Group (see 6.5) analyzed 606 hop plants (the equivalent of 2,822 real-time qPCR (quantitative polymerase chain reaction, a technology used for measuring DNA sequences) for *Verticillium nonalfalfae*. Likewise, this group analyzed 147 plants from commercial plots. These real-time qPCR analyses are indispensable for validating visual assays. The results of the qPCR analyses also confirmed that the spread of lethal *Verticillium* races is on the rise. The lethal form of the fungus was detected in all hop gardens sampled in 2021.

Selection Gardens

The wilt tolerance of varieties under cultivation, as well as of breeding lines, is tested in so-called selection gardens that are infested with the lethal form of wilt (the only selection criterion) and are made available by the growers. In the 2021 season, the breeding material was tested at two locations in the Hallertau.

Starting in mid-May, assessments are conducted in regular two-week intervals. Each vine is checked and evaluated for typical wilt symptoms. Thus, at the end of the season, a wilt index can be compiled for each variety that can serve as an indicator of the resistance of the different varieties and breeding lines to hop wilt. Tolerances can vary slightly depending on the location and the year the plants were put into the ground. This, in turn, forms the basis for further research and breeding work.

After the 2021 season, one of the hop gardens, in Engelbrechtsmünster, was cleared because the five-year wilt test at this location had been completed. Table 5.3 shows a section of the evaluation. To better compare the different years and locations, Herkules, which is considered to be tolerant, served as a reference. After each season, Herkules receives a rating of 1.0. The other varieties and breeding lines are then evaluated relative to this reference. If a variety achieves a wilt index of less than 1.0, it is considered to have good *Verticillium* tolerance.

Table 5.3: Results for 2019, 2020, and 2021 in the Engelbrechtsmünster selection garden. The table shows wilt tolerances of different varieties relative to the reference variety Herkules, which was assigned the value 1.0. Varieties with values smaller than or equal to 0 have a good Verticillium tolerance and are marked in green.

Variety	Reference 2019	Reference 2020	Reference 2021
Northern Brewer	3.3	8.1	6.2
Hallertauer Mittelfrüh	3.7	8.8	6.9
Hallertauer Tradition	1.2	5.0	3.5
Opal	1.9	4.3	1.8
Perle	**0.7**	1.3	1.5
Smaragd	1.8	4.0	2.1
Hüll Melon	**0.9**	**0.8**	**0.4**
Htr. Magnum	**1.0**	1.6	1.3
Herkules	**1.0**	**1.0**	**1.0**
Polaris	**1.0**	**0.8**	**0.5**
Callista	1.2	1.5	**0.9**
Tango	1.0	**0.2**	**0.2**
Hallertau Blanc	1.5	1.3	1.1
Wye Target	1.6	3.1	3.0
Ariana	**0.9**	**0.6**	**0.5**
Mandarina Bavaria	0.8	1.7	0.7
Spalter Select	1.4	3.1	2.9
Cascade	**0.9**	1.3	1.2
2011/070/019	1.3	2.0	1.4
Saphir	2.3	7.7	6.9

Outlook

The testing of varieties and breeding lines for *Verticillium* tolerance should be continued. The evaluation of the other selection garden, in Gebrontshausen, continued into the 2021 season.

Host plants: *Verticillium* in intermediate cover crops and weeds

It is advisable to plant *Verticillium*-neutral cover crops between the furrows. Because of the low host specificity of *Verticillium*, all dicotyledonous plants can be considered as potential hosts for hop wilt. This is why grasses/cereals are preferable cultivars in infested areas. In addition, controlling and removing weeds that can serve as host plants also reduces the pathogen population.

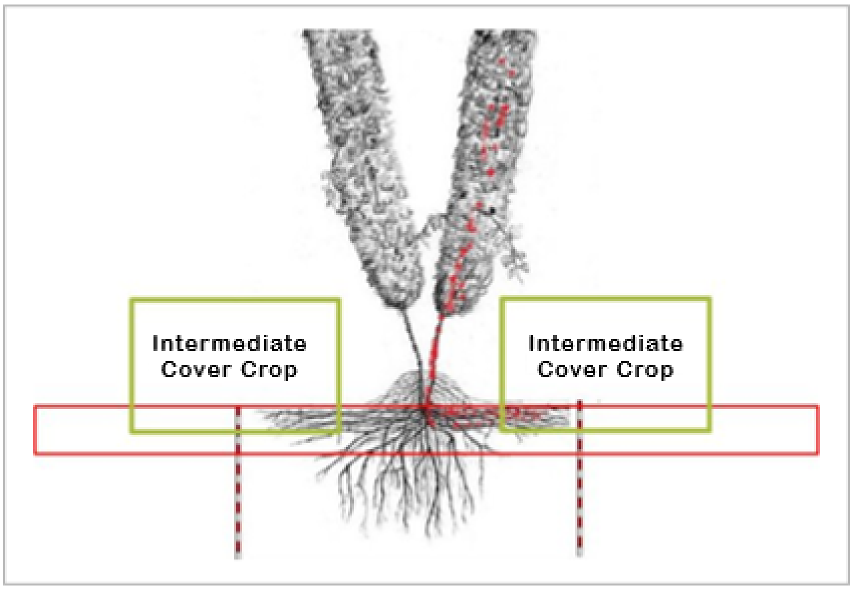


Figure 5.12: Verticillium nonalfalfae in the hop plant (marked in red); Graf, 2016 modified by Euringer, 2018

An experiment with potted plants showed that many of the common intermediate cover crops in hops can be infected with the fungus. Table 5.4 shows an overview of the plant species that have been tested thus far.

Table 5.4: Artificially infected plant species in which Verticillium nonalfalfae could be detected by means of qPCR analysis

Rapseed (Brassicaceae)	Common Vetch (Legume)
Mustard (Brassicaceae)	Clover (Legume)
Fodder Radish (Brassicaceae)	Niger Seed (Asterodeae)
Turnip Rape (Brassicaceae)	Thistle (Asterodeae)
Flax (Linaceae)	Dandelion (Asterodeae)

Outlook

Infection tests with other cover crops and weeds will be carried out in the coming season.

5.14 **Remote assessments of hops via UAV sensing**

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)
(*Support from the Society for Hop Research)*

Project Management: S. Euringer
Team: K. Lutz, F. Weiß, Team IPZ 5b
Collaboration: geo-konzept GmbH
Duration: May 2021 to August 2021

Objective

As a result of the progressive digitization in agriculture, data is increasingly being generated using remote sensing by UAVs (unmanned aircraft vehicles; colloquially known as drones). This technique is already in use for the early detection of pests or diseases and for the assessment of new varieties of several arable crops. Recently, there have also been advances in remote sensing as a form of non-destructive measurement of the N supply status of plants, as well as for estimates of biomass growth for optimal plant nutrition. Insights into the remote sensing of other arable crops should be transferred to hops. Specifically, such data might provide indications of *Verticillium* infestations before the appearance of visible symptoms.

Method

Remote sensing data was recorded with UAV flights. In addition to using different sensors for recording wavelengths in the visible spectrum, drones are also able to use different sensors for wavelengths that are not visible to the human eye. Such multi- and hyperspectral images are of particular interest to science because they can produce indicators of plant stress, for instance. The validation and classification of such digitally generated data, however, requires a large number of subsequent analogue assessments of the same growth areas. Only a combination of both drone and empirical observations can generate reliable data.

Hyperspectral varietal differences as features in breeding new hop varieties

With the help of hyperspectral recordings, the reflection of quanta outside the spectrum of visible light can be measured and gathered as objective, numerical values. These are complementary to the visual data generated by visual assessments of plant health and nutrition.

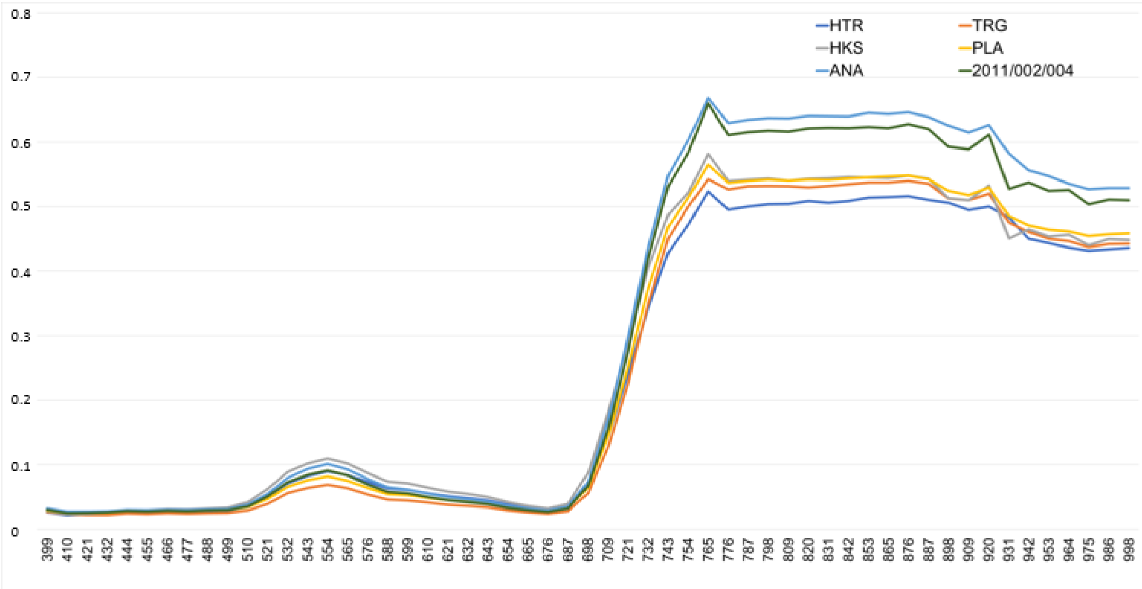
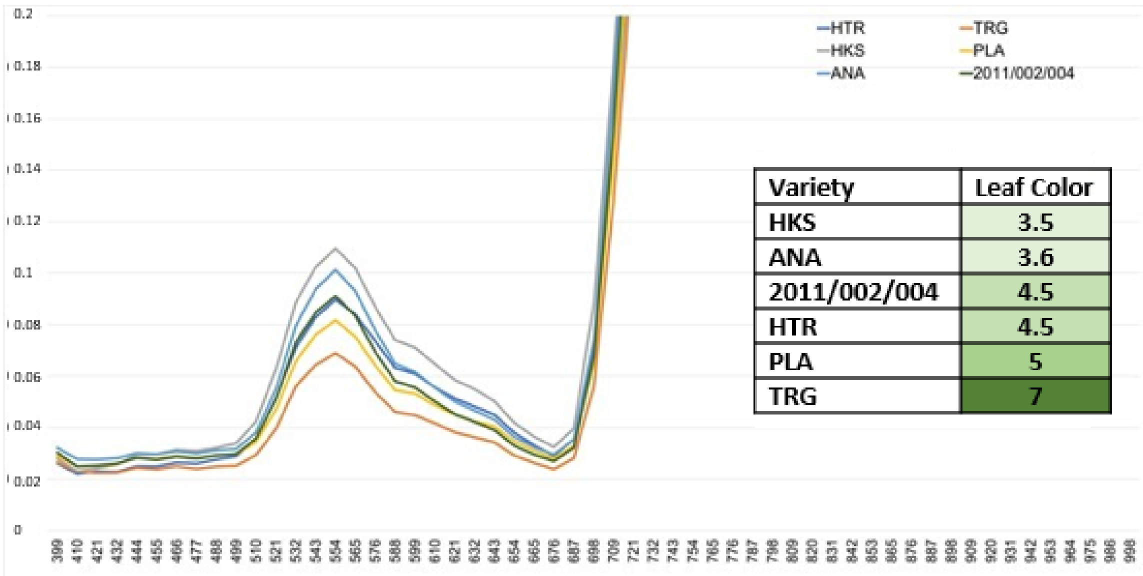


Figure 5.13: Reflectance curves of selected varieties

Figure 5.13 shows the reflection curves of different hop varieties over a wide spectrum. The measured values of each wavelength are averaged from three representative individual plants for each variety.



Variety	Leaf Color
HKS	3.5
ANA	3.6
2011/002/004	4.5
HTR	4.5
PLA	5
TRG	7

Figure 5.14: Reflection in the visible spectrum and evaluation of the leaf color of different hop varieties

Of particular interest was the visible part of the spectrum, because it allowed for the validation of measurements through visual assessments. Figure 5.14 shows that cultivars with lower readings appear darker and greener than cultivars with higher readings. The reflection curves, therefore, not only agree with the visual assessment of the leaf color; they may even be more accurate. While such varieties as Herkules and Ariana may be perceived by the human eye as identical, their reflection curves show their differences.

One challenge, however, is the non-transferability of data from one location to the next because the leaf color depends on the chlorophyll content of the plant, which is affected by the nitrogen supply and other factors at the specific location.

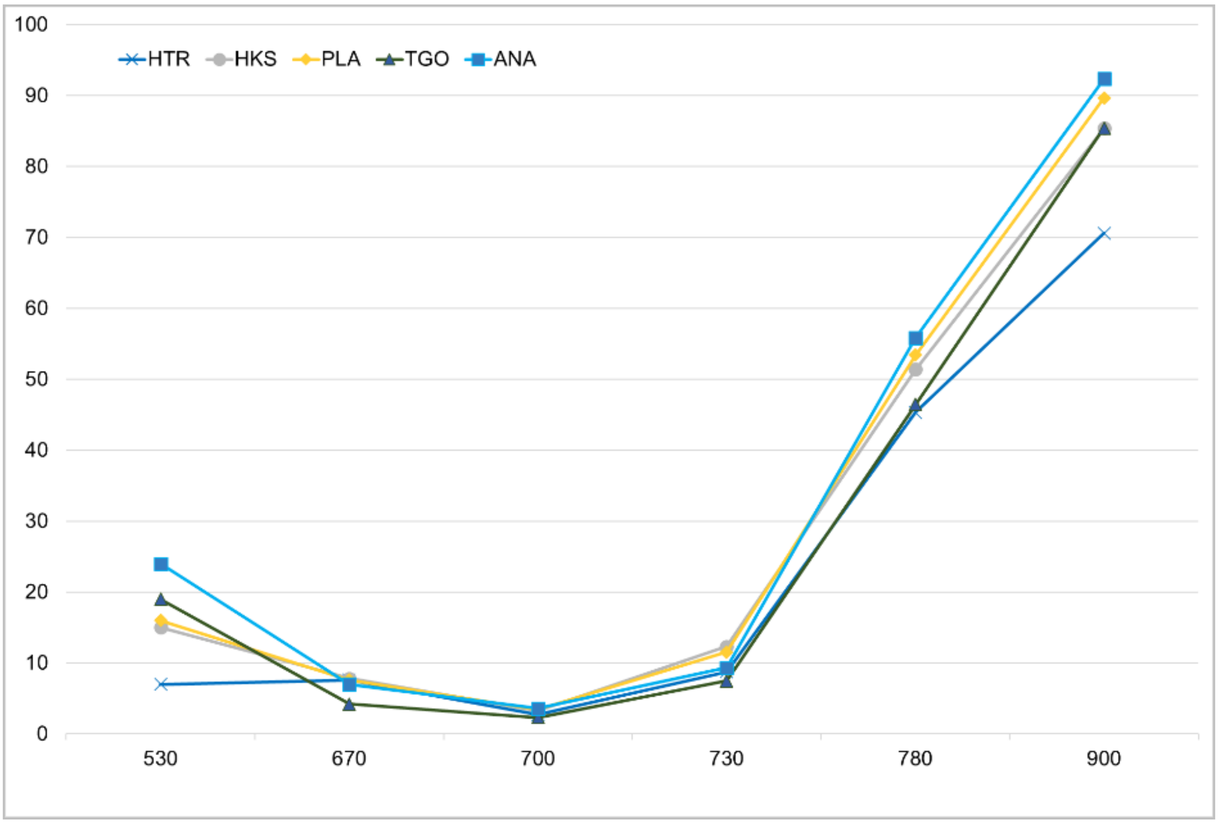


Figure 5.15: Multispectral measurement data from the Stadelhof site

The rank order established by multi- and hyperspectral measurements, therefore, changes depending on different amounts of fertilization applied at respective locations. At Stadelhof, for instance, fertilization is very moderate, which shows how different varieties react to lower nitrogen supplies. The lighter leaf coloring in the newer varieties is evidence of their increased N utilization efficiency. They form more biomass and greater yields with identical fertilization amounts.

Early detection of *Verticillium* in hops

After a hop is infected with *Verticillium nonalfalfae*, it can take several months before the first visual symptoms appear. As part of the project, tests were conducted to check if measured values from the visible and non-visible spectrum allow for earlier detections. If so, this would also simplify conventional assessments, which is currently conducted using individual plants for evaluation.

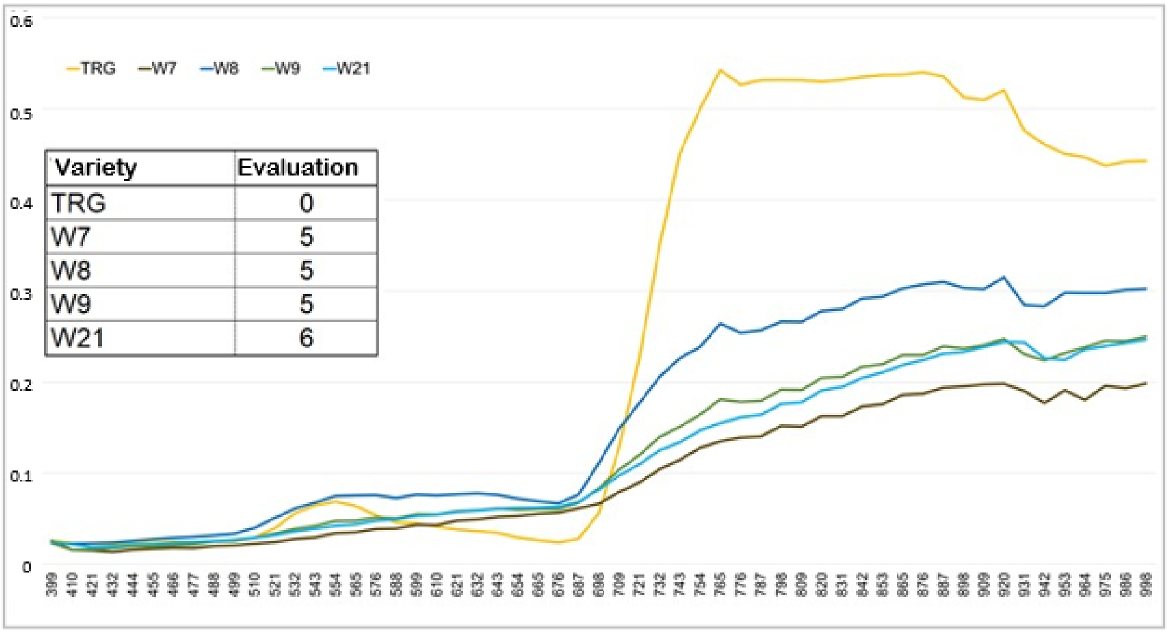


Figure 5.16: Reflection curves of plants with wilt; Score 0 = no visual symptoms, 9 = dead

Figure 5.16 clearly shows the differences in the reflection of healthy plants and of plants with wilt. Drought stress, which is a consequence of pathway-restricting *Verticillium* infections, is recorded very well in the hyperspectral image and is visible in the reflection curve.

Challenges and opportunities

A particular challenge in collecting high-quality data with this method was the growth height of the hops because the sensors used could often only record values from the upper 3 m of the plants. In addition, the plants' self-shading because of tight plant spacing also makes data collection more difficult. Changes in lighting conditions or radiation intensity caused by clouds during recording sessions can also negatively affect the readings by these highly sensitive sensors. For this reason, calibrating the sensors is essential for generating reliable data.

The automatic evaluation of individual plants posed another difficulty, especially towards the end of the vegetation period, because the side shoots from adjacent plants became intertwined.

To establish causal relationships, therefore, required extensive spectral measurements and intensive observations of the plant population. These are essential for subsequent statistical evaluations.

The advantages of remote sensing are based primarily on the non-destructive nature of observations of living plant populations using measurement techniques; and on the simplicity of implementing automated spectroscopic measurements. The data obtained describe the physiological development of the crop and provide information about the plants' nutrient supply, pest infestation, composition, and quality development. Remote sensing opens up new possibilities for monitoring populations. In addition, future projects involving the collection of spectral measurement data can build on these foundations.

Outlook

The remote monitoring of hops through drones will continue.

5.15 CBCVd-Monitoring 2021

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
Team: IPZ 5b, IPZ 5a, IPS 2c
Duration: April 1, 2021 to March 31, 2021
Sampling Period: June 2021 to September 2021

CBCVd monitoring was once again on the agenda in the Hallertau in the 2021 crop year. No monitoring was carried out in other German growing areas. The selection of plots for sampling was guided by their assumed risk of infection. Unlike in the previous year, 10 individual plants were always combined into a single mixed sample for a reduced number of sample units but an increased number of plants sampled.

Table 5.5: Classification of CBCVd monitoring in 2021

Classification of CBCVd monitoring in 2021	**Plot section**	**Samples**	**Sampled plants**	**Farms**
Cultivation area monitoring in infested regions	165	1650	16500	
HVG Biogas monitoring	137	137	1370	
Voluntary Monitoring (EG HVG)	~15	~15	150	
Areas of the newly infested farms (2021)	~30	~45	450	
Sum	~350	~1850	18470	187

Table 5.6: Results of CBCVd monitoring in 2021

Year	**2019**	**2020**	**2021**
Affected farms	3	7	10
Infested hop area [ha]	37	94	91

During monitoring in 2021, CBCVd was detected for the first time in 3 additional farms, which increased the total number of affected farms to 10. These farms are located on the periphery of areas that are already known to be infested. The overall area on which CBCVd was detected in 2021 decreased because plots on which CBCVd was detected in the previous year were cleared.

The following findings were the result of CBCVd monitoring in 2021. They confirmed data from the 2020 CBCVd monitoring:

- Infested areas are expanding
- The level of infestation in affected farms ranges from low to high. A future increase in the level of infestation ought to be expected
- There is a need to organize coordinated consultations for infested farms during their control efforts and containment measures
- Within a farm, the spread can progress very quickly without a mitigation concept
- There is great uncertainty on farms that tested negative but are located in areas containing infested farms
- There are indications that CBCVd infections have existed in the Hallertau growing region for several years
- Heterogeneous crops (in terms of soil, cultivation, and variety) make visual assessments more difficult – verification in the laboratory is a necessity
- The severity of symptoms is not the same every year and there may be time lags between infection and the appearance of symptoms

Outlook 2022

- Monitoring will continue in 2022
- EU regulations governing so-called “Plant Passports” (that is, safety clearance certificates) will be revised to include stipulations relating to sanitary standards for viroid pathogens

The Hüll Hop Research Center (LfL IPZ) is supported financially and in terms of staffing by StMELF, LfL IPS, GfH e.V. and the HVG e.G. Other research activities and any official appraisal activities are only marginally influenced by such support.

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.
- Bio-technological and genome-analytical techniques have been part of the classic breeding program in Hüll for years.

6.1 Crossings in 2021

A total of 92 crossings were completed in 2021.

6.2 Tango – into the future with climate tolerance and sustainability

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

Climate change and environmental protection make it necessary to realign modern hop production with new varieties that guarantee a supply of raw materials well into the future. Tango is such a new, Hüll-bred aroma variety. It reflects the success of the Hüll breeding strategy of “low input — high output.” It is now being cultivated and will be available in the marketplace after the 2022 harvest. It combines excellent brewing characteristics with tolerance against stresses caused by climate change, as well as optimal cultivation and resistance properties allowing for great sustainability. For brewers and hop growers alike, Tango is a future-oriented alternative to many current aroma varieties. According to Dr. Michael Möller, Chairman of the Board of Directors of the Society for Hop Research, "Tango follows in the footsteps of its grandmother Hallertauer Tradition and is simultaneously a pacesetter for the future."

Naming

Finding a name for the most recent Hüll-bred variety was not easy. The Society for Hop Research, together with Radio Bavaria, asked for suitable suggestions via social media channels and in radio broadcasts. It was clear that the list of precious stones such as pearl, sapphire, opal, and diamond for naming Hüll aroma varieties had been exhausted. Thus, a new naming convention had to be found. At the same time, any new series of names should do justice to the future-oriented characteristics of the new plant. We finally settled on a list of possible hop names from the world of music. Tango as the first such name is perfectly fitting. It conjures up images of the spirited South American dance with its often-abrupt changes in tempo and movement, which is appropriate because this variety can cope with rapidly changing climate conditions and weather challenges. In analogy to Tango dancers gazing into the distance, Tango sets future standards for hop plant health and sustainability. It is not known if any of these considerations played a role for the hop grower in the Hallertau who came up with the name. Perhaps it is just as likely that the prize of a trip to the International Hop Growers' Convention in 2020 in Argentina has something to do with it.

Figure 6.1: The new Hüll aroma variety Tango – a bunch of cones, a longitudinal cone section, and a cone close-up

Aroma in raw hops and beer

The raw Tango cones already foreshadow the versatility of this variety in the brewhouse. Classic hoppy as well as fruity aromas characterize its sensory profile; and the experts of the GfH Advisory Board agree with this assessment based on their sampling of dried cones.

The chemical analyses (Tab. 6.1) also reveales some of the Tango aspects that brewers tend to look for. Tango has more than twice the total oil content than such Hüll varieties as Perle and Hallertau Tradition, which have proven their worth for decades and are in demand worldwide. Particularly noteworthy is Tango's enormously high farnesen content. There is some debate in the field about the significance of this key aroma substance, which is usually high in members of the Saazer family. However, certain positive synergistic effects of the presence of farnesene on the overall beer aroma are becoming more and more accepted [1 and Schönberger, personal communication]. Next to its high farnesene content, which is comparable to that of Tettnanger, Spalter, and Diamant, Tango also has a high linalool content.

Many scientific studies have already confirmed that oils are the key substance in distinctive "hoppy" aromas [1, 2]. Also typical for Tango are the esters derived from geraniol and geranylic acid. These include geranyl acid methyl ester, geranyl acetate, geranyl isobutyrate, and geranyl propionate. They reflect the fruity side of this new Hüll aroma variety. Geranyl propionate, in particular, is a unique selling point for Tango because this ester is rarely found in other hop varieties.

Several low-molecular and therefore water-soluble, non-terpenoid esters also contribute to Tango's fruity aroma potential (Table 6.1), with the concentration of 2-methylbutyl acetate being remarkably high. This ester can be found in much smaller quantities in other hop varieties, but in Tango it can be considered variety-typical.

Depending on the timing of the harvest, Tango also has a high myrcene content, which humans typically perceive as a hoppy-green-resinous aroma. While myrcene plays no role in beer flavor, when added on the hot side of the brewing process, it has a significant effect after dry-hopping [3].

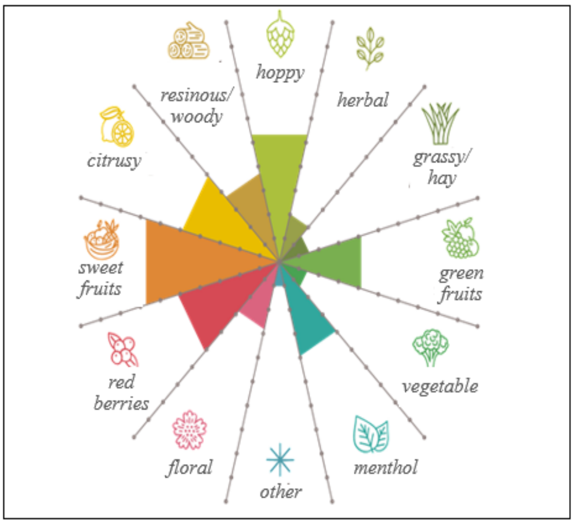


Figure 6.2: Aroma profile of raw Tango

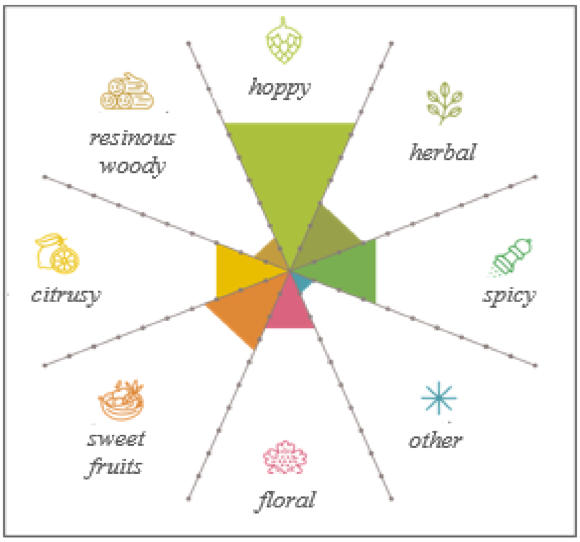


Figure 6.3: Aroma profile of Tango in classic beer styles

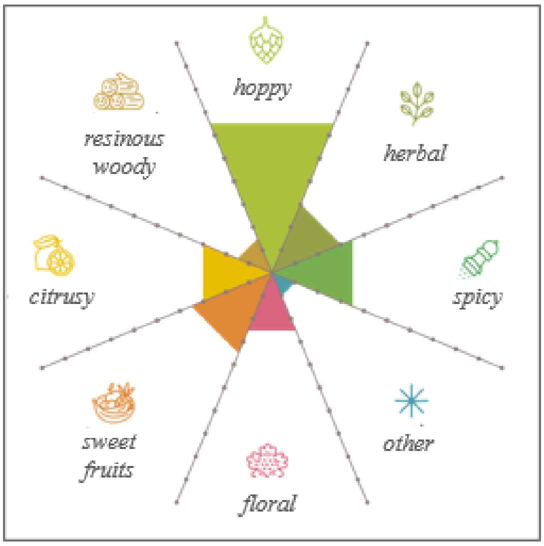


Figure 6.4: Aroma profile of Tango after late- and dry-hopping

The data for bitter substances and oils in Table 6.1 are mean values collected over several years during LfL cultivation tests and tests in commercial hop gardens. The quantitative results are for freshly harvested individual samples of Perle and Hallertauer Tradition in 2019/2020, as well as Tango in 2020 and 2021.

Table 6.1. Analytical data for the substances that are characteristic of the bitterness and aroma of freshly harvested Tango samples compared to Hallertauer Tradition and Perle.

Chemical Compounds	**Tango**	**Perle**	**Hallertauer Tradition**
Total oil (EBC 7.10 in ml/100g)	3.5	1.7	1.2
Bitter substances (EBC 7.7)			
Alpha acids (%)	9.0 (7.5 – 11)	7.4	6.2
Beta acids (%)	8.5 (6 – 10)	5.2	5.0
Ratio beta/alpha ß/α	0.86	0.70	0.80
Cohumulone (as a % of alpha acids)	23 (20 – 25)	30	26
Xanthohumol (%)	0.6 (05 – 0.8)	0.55	0.41
Select mono-and sesquiterpenes (mg/100 g)			
Myrcene	2954	1164	721
ß-Pinene	36	17	9
ß-Ocimene	1	12	2
ß-Caryophyllene	27	106	44
Humulene	49	279	125
ß-Farnesene	163	1	1

Chemical Compounds	**Tango**	**Perle**	**Hallertauer Tradition**
ß-Eudesmene (ß-Selinene)	36	4	3
α-Eudesmene (α-Selinene)	48	6	4
α-Cadinene	24	20	5
Monoterpene alcohols and esters (mg/100 g)			
Linalool	18	7	10
α-Terpineol	2	< 1	< 1
Geraniol	2	1	< 1
Geranyl acid methyl ester	12	10	3
Geranyl Acetate	10	1	1
Geranyl iso-butrate	5	1	1
Geranyl propionate	4	n.n.	n.n.
Non-terpenoid esters (water soluble) (mg/100 g)			
Isobutyl propionate	0.1	0.1	< 0.1
Isobutyl iso-butrate	3	10	5
2-methylbutyl acetate	13	< 0.1	< 0.1
Methylhexanoat	2	1	1
2-Methylbutyl propionate	9	8	5
3-Methylbutyl-isobutyrate = Isoamyl isobutyrate	4	3	1
2-Methylbutyl-isobutyrate	8	29	11
Non-terpenoid esters (water soluble) (mg/100 g)			
Heptane acid methyl esters	18	10	7
Capryl acid methyl esters = Oktane acid methyl esters	14	3	5
Pelargonic acid methyl esters = Nonanonic methyl esters	6	4	2
Total Polyphenols (EBC 7.14)	4.1	4.0	4.5

Brewing quality as determined in numerous brewing trials

Numerous brewing trials with Tango confirm its classic, hop-typical aroma (Figure 6.2) in traditional beer styles, in which brewers have traditionally used Hallertauer Tradition and Perle. The trials confirmed both Tango's delicate but expressive aromatics and its spirited and powerful aroma-intensive aspects. When used in late- or dry-hopping, it imparts an impressively fresh and fruity aroma spectrum dominated by passion fruit (Figure 6.3). These notes can be intensified in beers made with aroma-intensive top-fermenting yeasts. Finally, the pleasantly mild, high-quality bitterness of Tango greatly enhances the finished beer's drinkability. Even in very hop-intensive craft brews, Tango can hold its own with a well-embedded, enjoyable bitterness that is non-obtrusive, thus leaving plenty of space for the brewer to compose a symphony of additional, complex aromatics.

Several expert tasting panels at the Technical University Munich campus at Weihenstephan noticed the finely laced and long-lasting crown of foam in the test beers. Overall, they described the hop note as pleasant, clean, and fresh, with hints of green fruit.

In the brewery, Tango is a multi-purpose hop that can be added to beer at any stage of the process from first-wort hopping to dry-hopping, depending on the brewer's aroma philosophy and hopping technology. Its strength is in replacing older aroma varieties as a substitute without significant changes in classic beer tastes and flavors. At the same time, it opens the door to boundless creativity and aroma diversity.

Environmentally friendly and resource-sustainable cultivation in spite of climate change

The genetic roots of Tango are a mix of Cascade, Hallertauer Tradition, and a few Hüll aroma breeding lines carefully selected by Anton Lutz. This pedigree gives Tango not only excellent brewing qualities, but also several other advantages that are nowadays expected from a modern cultivar (Table 6.2).

Because hop cultivation is resource-intensive and has a potentially significant impact on the environment, the Hüll team has been focused for years on breeding only new varieties that do not require irrigation and that can thrive with a minimum of fertilizers and pesticides. As a result of this "low input" breeding strategy, Tango has been conceived of as a highly nutrient-efficient variety that requires relatively little water throughout the growing season and is highly resistant to many pests and diseases. Yet, Tango delivers stable "high output" yields with both high alpha acid values and high total oil levels. Before the official release of this variety, these advantages had all been confirmed in numerous cultivation trials in the Hallertau, in Tettnang, in Spalt, and in the Elbe-Saale region.

Likewise, extensive greenhouse, laboratory, and field tests demonstrated Tango's remarkable resistance to and tolerance of common hop diseases and pests. Targeted exposures of the new variety to these hazards under "low input" conditions under the survival-of-the-fittest principle led to the selection for further propagation of only those individuals that showed a broad spectrum of resilience. Once again, real-world field trials confirmed the results initially generated under controlled conditions. Therefore, hop gardens planted with Tango can henceforth significantly reduce the need for plant protection chemicals.

Finally, test harvests demonstrated that Tango has an economically favorable ratio of cone yield to residual plant weight (bines and leaves). The relatively small number of leaves is, of course, one of the reasons why Tango requires less water and fertilizer, and fewer pesticides.

This is further proof that the "low input — high output" breeding strategy adopted by the Hüll Hop Research Center to produce Tango makes significant contributions to sustainable hop production. All that remains now is for brewers who frequently expressed their interest in sustainable production methods of raw materials to gradually adapt their recipes to the new aroma varieties. This will allow them to incorporate the breeding progress achieved in Hüll into the finished beers consumers drink.

Because the experimental cultivation of Tango involved growing tests on hectare-size plots in the real world, the trial harvests and their processing has already generated sufficient material for interested brewers to obtain samples for their own experimentation in the brew house, well before the large-scale release of Tango after the 2022 harvest. Many brewery members of the GfH have already responded positively to the offer and numerous brewing trials are still ongoing.

Innovative breeding methods for modern varieties

Tango as a new variety from Hüll is not only modern and forward-looking in all important respects, it also stands for the start of a new breeding method, called genome-based precision breeding. It will supplement the traditional Hüll breeding method of selecting the most promising individual seedlings for further propagation. When Tango was still known just as breeding line 2011/02/04 it was part of the reference hops used to develop molecular selection markers for traits that are important to breed for. Work is currently underway to introduce those selection markers that have been clearly identified into the overall Hüll breeding operation.

Table 6.2: Pedigree of the new aroma variety Tango and its agronomic characteristics

Pedigree	Cascade/Hallertauer Tradition x Hüll Aroma lines
Resistances / Tolerances	Broad resistance or tolerance to diseases and pests
Low Input	Reduced need for pesticides, water, and nitrogen fertilizers
High Output	High yields, high alpha acid levels, high total oil contents
Stress and Climate Tolerance	Excellent with stable high yields and alpha acid levels, no early flowering
Maturity Time Frame	Medium late (between Perle and Hersbrucker Spät)

Milestone on route to an environmentally compatible, climate-stable cultivation of quality hops

Tango is a milestone in the implementation of goals set in the hop and brewing industries with respect to climate adaptation, protection of the environment, resource conservation, supply security, and meeting the German Fertilizer Ordinance. For brewers and hop growers, this variety is an alternative for the future to many well-established, traditional aroma varieties, such as Perle and Hallertauer Tradition.

Availability

The Society for Hop Research (GfH) registered the new Hüll aroma variety under the name Tango with the European Union Community Plant Variety Office (CPVO) in December 2020. Many interested parties have already acquired licenses from the GfH for the cultivation of

Tango. Large-scale cultivation started in the spring of 2021. Until sufficient harvest quantities are available for every brewer everywhere, interested brewers can request trial-size samples directly from the GfH.

Summary

With Tango, a future-oriented aroma variety is reaching the market that will impress both hop growers and brewers. Tango stands for excellent brewing characteristics; consistently high yields even under environmental and climate-related stresses; improved broad-based disease resistance; and sustainable, environmentally friendly hop cultivation. It has moved hop cultivation into the future.

Source (in German): BRAUWELT, Issue No. 46-47 (2020)

6.3 Development of powerful, healthy, high-alpha hops with particular suitability for cultivation in the Elbe-Saale region

Initial Situation

Hop growers in the Elbe-Saale region currently have 1,581 hectares or 7.7% of the total German hop area under cultivation. This makes it the second-largest hop region in Germany after the Hallertau. The region, thus, makes a substantial contribution to both German and global hop production. While in the past, the varieties cultivated in Elba-Saale were mostly the Czech landrace Saazer and the English variety Northern Brewer, the range of varieties has been expanded, especially after German reunification. Today about 80 percent of cultivars grown there are of Hüll origin. For the past 25 years, the main variety has been the robust, high-alpha Hallertauer Magnum. Its share, however, has declined from a peak of 65 percent to today's 39 percent, in part because Magnum, which yields 280 kg alpha acid per ha is no longer competitive compared to the Hüll-bred high-alpha variety Herkules, which produces 500 kg alpha acid/ha. Yet, switching from Magnum to Herkules has not been successful in Elbe-Saale because of this hop's high susceptibility to rot.

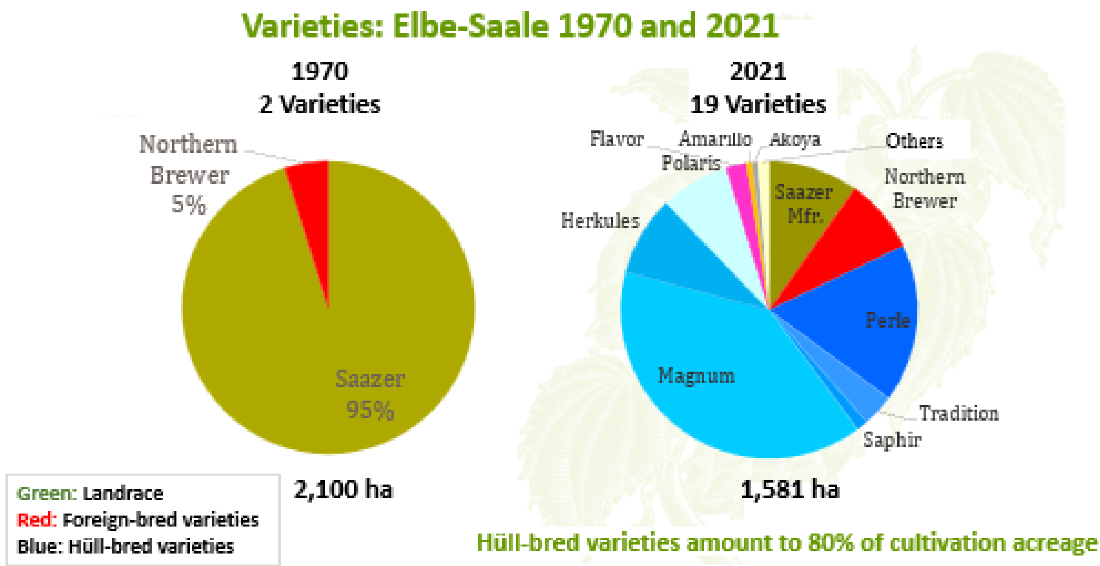


Figure 6.5: Changes in the variety spectrum of hops cultivated in the Elbe-Saale region over the past 50 years

Objective

The aim of this breeding project is to develop new, high-performing, and robust hop varieties which, thanks to their high alpha acid yields and broad disease resistance, especially to rot pathogens, are both economically and environmentally suitable for cultivation under the special climate and soil conditions of the Elbe-Saale region. In addition, the new varieties are expected to meet modern expectations regarding climate adaptation and nutrient efficiency. This work is supported by funds from the agriculture ministries of the three hop-growing states of Thuringia, Saxony-Anhalt, and Saxony.

Implementation and methods

Crosses

- Targeted crosses with pre-selected Hüll breeding material
- Powdery mildew resistance testing of the seedlings or breeding strains, respectively, in the greenhouse and the laboratory
- Seedling tests of individual plants in the greenhouse
- Cultivation tests with reduced amounts of pesticides and fertilizers
- Serial trial cultivation on farms in the Hallertau and in the Elbe-Saale region
- Chemical analysis of the cone contents (IPZ 5d)
- Organoleptic aroma ratings by the breeding team, with support from the GfH expert panel
- Virus testing using the Double Antibody Sandwich Enzyme Linked Immunosorbent Assay (DASELISA) technique (IPZ 5b)
- Testing for *Verticillium* infestation using real-time PCR techniques
- Pathogen elimination via meristem cultivation

Experimental row cultivation with high-alpha strains from Hüll in the Elbe-Saale region

Promising breeding lines from the LfL's high-alpha breeding programs are tested under real-life conditions in the Elbe-Saale region:

- Berthold plant in Monstab, Thuringia
- Agricultural cooperative Querfurt, Saxony-Anhalt
- Lautitz hop estate, Saxony
- Hopfenbau Regner GbR, Saxony-Anhalt

In 2021, in cooperation with the BarthHaas Group, a cultivation trial with breeding line 2011/071/019 (Titan) was started on a large plot on the Regner farm.

Results

Crossing types

Since the start of the project in 2016, there have been more than 245 targeted crossings with parents specially selected from the Hüll breeding material. There were 45 crossings in July 2021 alone.

Seedling preselection

Initially, in the spring of 2021, almost 57,000 seedlings were tested for fungal resistance in the greenhouse in Hüll. Starting in May 2021, more than 2,250 seedlings from that group were selected for further assessment in the vegetation hall to determine their vigor, gender, resistance, and climbing ability under natural infection conditions.

3-year seedling trial

As is done every year, in the spring of 2021, female seedlings from the previous year's crosses that had passed muster in the vegetation hall were planted outside in the test garden in Hüll.

Currently, promising seedlings from previous years are being tested as part of the 3-year seedling test program. These seedlings must prove themselves under conditions of minimal plant protection and reduced amounts of fertilizer for the entire vegetation period. In this process, only the most robust and promising seedlings are examined, based on some 40 selection criteria. Only 47 seedlings from the 2018/2019/2020 vintages were harvested in the fall.

The cone patterns of these plants were chemically analyzed in Hüll by IPZ 5d to arrive at a detailed assessment of cones.

4-year plant trials

Sixteen promising seedlings were selected for the 2021 plant trials at two locations (breeding gardens in Hüll and Stadelhof). There were two repetitions of these tests. Before the start of further propagations, these selected hop plants were tested for virus and *Verticillium* infections. The virus test was carried out in the laboratory of the working group responsible for plant protection in hop growing (IPZ 5b) in Hüll. It was negative. Likewise, the selected plants were *Verticillium*-free, as was confirmed by the genome analysis team in Freising using the highly sensitive real-time PCR technique.

There are currently 54 high-alpha breeding lines in Hüll and Stadelhof in cultivation trials. A total of 46 complete plants that had passed the tests in 2018, 2019, and 2020 were harvested in 2021.

Only after the completion of the 4-year cultivation test in the Hallertau will reliable and meaningful assessments in terms of all selection criteria be possible. Among the most significant assessments are a determination of the yield, the cone compounds, and disease resistance, especially against rot pathogens.

Already, two high-yielding strains with high to very high alpha acid contents proved to be promising candidates for trial cultivation in rows on commercial farms in the Elbe-Saale region. They were planted in spring 2021.

<u>Cultivation in trial rows</u>

Currently, five Hüll high-alpha breeding lines are being test-cultivated at a grower in Thuringia. They are planted next to Hallertauer Magnum, Polaris, and Ariana as comparisons and controls. One high-alpha breeding line has already been cleared because of its insufficient performance potential. It was replaced by two new, more promising breeding lines. Both the LfL and the Thuringian State accompany this cultivation trial with scientific and technical support. In addition, on one farm each in Saxony and Saxony-Anhalt, the two breeding lines are being tested for their local compatibility.

Large-scale cultivation trials with high alpha strain 2011/071/19

From all the trials that are currently in progress, one high-alpha strain (2011/071/019) in particular has emerged that shows a very high alpha acid and yield potential, as well as good stability under stress conditions. Furthermore, this strain also shows a broad spectrum of disease resistances, especially against rot and powdery mildew. This strain has now reached the brewing trials stage, where it also shows promise.

Therefore, at the end of 2019, this high-performance, high-alpha strain was released by the Society for Hop Research (GfH) for field testing on a hectare basis. In the summer of 2020, the strain was planted in the Hallertau on 5.4 ha; and, in 2021, on 0.5 ha in the Elbe-Saale region.

In parallel, an application for approval was submitted to the EU Plant Variety Office (CPVO); and it was given the name Titan. Cultivation trials were extended further into 2022; and a study of the variety's processing characteristics (pellets and extract) is being conducted using the test material harvested in 2021. Also in the planning are further brewing trials in brew houses around the world to hasten the approval for use of the variety in commercial breweries.

Outlook

All the new strains developed in Hüll show promising signs. However, the candidates first need to prove themselves in serial trials on commercial farms in the Elbe-Saale hop region. Since the beginning of the breeding work in 2016, it has become clear that the serial trial cultivation in the Elbe-Saale region could not be completed within the first phase of the project (duration 2016 to 2020). Therefore, it is all the more gratifying that the Thuringian Ministry for 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 have agreed to financially support the breeding and selection work begun by the LfL for another 5 years.

Economic importance of the project results

Through this project, powerful, healthy, high-alpha breeding lines are being developed that combine all the advantages expected of modern varieties with a future: They have to have high and stable alpha acid yields; broad resistances to such pathogens as powdery mildew, downy mildew, and rot; as well as high nitrogen efficiency. By reducing the use of pesticides and fertilizers, they make hop production more environmentally friendly. They also help to save resources and costs.

Finally, the new strains have been selected for their suitability in the special growing conditions of the Elbe-Saale region, which will strengthen the long-term competitiveness of the Elbe-Saale hop-growing region on world markets.

References

Seigner, E. und 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, 28-31.

Seigner, E. und Lutz, A. (2021): Entwicklung von leistungsstarken, gesunden Hopfen mit hohen Alphasäuregehalten und besonderer Eignung für den Anbau im Elbe-Saale-Gebiet. 5. Sachbericht zum Forschungs- und Entwicklungsprojekt.

Properties	Hallertauer Magnum	Herkules	Polaris	Ariana	Tango	Breeding Line 2011/71/19	Breeding Line 2010/75/78	Breeding Line 2015/58/58
Crop year	1998	2001	2012	2016	June 2017	June 2015	May 2019	May 2019
Aroma assessment	pleasant	pleasant	pleasant, fresh	pleasant, fruity	pleasant hoppy, fresh	pleasant	pleasant	pleasant
Alpha acids (%)[1]	**12.9** (10.6 – 16.2)	**13.9** (13.5 – 14.5)	**16.8** (13.7 – 19.4)	**8.8** (8.1 – 10.2)	**7.6** (5.2 – 9.9)	**16.6** (14.3 – 19.8)	**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)		2,230		
Harvest year 2017	2,925	1,950	2,785	4,490		2,930		
Harvest year 2018	2,420	No longer planted due to crown rot	2,255	3,090	2,825	2,395		
Harvest year 2019	2,740		2,555	3,175	4,200	2,335		
Harvest year 2020	2,585		2,515	3,930	4,680	1,955	2,700	3,890
Harvest year 2021	2,970		2,770	3,80	4,340	3,15	2,680	2,735
kg α/ha	**330** (174 – 481)	**325** (221 – 453)	**433** (309 – 537)	**314** (257 – 376)	**314** (137 – 384)	**381** (280 – 466)	**367**	**580**
Plant health	very good	low	very good	very good	very good	good	good	good
Agronomic assessment	robust, vigorous growth	yield reduced due to crown rot	robust, slow growing	robust, broad resistance	robust, broad resistance	powdery mildew resistance, good development	robust, vigorous growth	good development, high yield potential

Table 6.3: Results of the trial row cultivation of Hüll high-alpha strains at one site in the Elbe-Saale region, using Hallertauer Magnum, Herkules, and Polaris as reference varieties; [1]Alpha Acid content in % by weight according to EBC: 7.4

6.4 Leaf test system for assessing the tolerance of hops to downy mildew (*Pseudoperonospora humuli*)

Management: Dr. E. Seigner, A. Lutz

Team: B. Forster

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

During the 2021 season, hop growers faced serious challenges as their crop became infected with the downy mildew fungus (*Pseudoperonospora humuli*). While the downy mildew warning service, which has been operating for almost three decades, was very helpful, the breeding of new hop strains can make significant additional contributions to combatting the downy mildew problem. The breeding goal is to develop hop varieties with significantly improved tolerances to this fungus.

Objective

A standardized test system was established for a "detached leaf assay" in the laboratory. This method is designed to estimate the tolerance to or susceptibility for downy mildew of individual promising breeding strains. The method involved recording the tolerances to secondary infections.

Method

The deliberate infection process involved spraying the underside of hop leaves with a downy mildew sporangia suspension. Five to ten days after inoculation, the reactions of the leaves are assessed visually to check for visible symptoms, chlorosis, necrosis, or sporulation. If the hops do not react adversely, the zoospores released from the sporangia when the air humidity is high grow on the underside of the leaves and form a sporulating mycelium.

Because such a mycelium is a typical symptom in susceptible hop varieties, a systematic assay categorizes the sporulation on a scale of 0 to 5. A score of 0 (highly tolerant) = no symptoms; 1 (tolerant) = 1-10% of leaf area affected; 2 (moderate) = 11-30%; 3 (susceptible) = 31-60%; 4 (highly susceptible) = 61-80%; 5 (extremely vulnerable) = 81-100%. These ratings allow for the construction of a statistical disease index according to Townsend and Heuberger.

On more susceptible, that is, less tolerant, hop varieties, chlorotic leaf spots with clear indications of sporulation appear on the underside of the leaves already after only a few days from inoculation; and dark brown necrosis becomes visible subsequently.

Tolerant varieties, on the other hand, succeed in suppressing sporulation completely or develop smaller necrosis spots on the leaves as a defense reaction, particularly in the early stages of infection (hypersensitive reaction of the host cells).

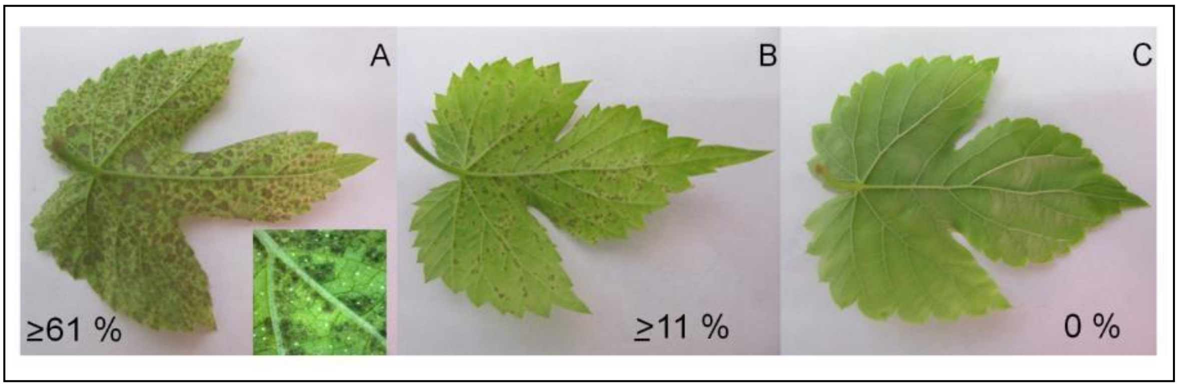


Figure 6.6: Different reactions of hop leaves 6 days after inoculation with downy mildew fungus: susceptible (A), moderately tolerant (B) and highly tolerant (C); % of infected leaf area = sporulation; in photo A there is also a close-up of the Peronospora infestation with black spore areas

Results

In 2021, the test season started in early April. A total of 13 test series were carried out, each with a single variety but six breeding lines. Leaves from Hallertauer Tradition served as a high-resilience reference for downy mildew tolerance; and Polaris, as a low-tolerance reference. Experiments 1 and 2, in which the leaf infestation was found to be too low, were excluded from the statistical evaluation.

After the statistical analysis of the indices for disease severity the following inferences can be drawn:

The statistical evaluations confirmed once again that Hallertauer Tradition from Hüll is highly tolerant of downy mildew, whereas the high-alpha strain 2011/071/019 proved to be susceptible. The susceptibility of all other tested strains to downy mildew proved to be similar to that of Polaris (Figure 6.7).

Therefore, the leaf test system can be considered part of an overall downy mildew tolerance assessment of any given variety. The findings gained in field assessments complements the knowledge gained in the laboratory.

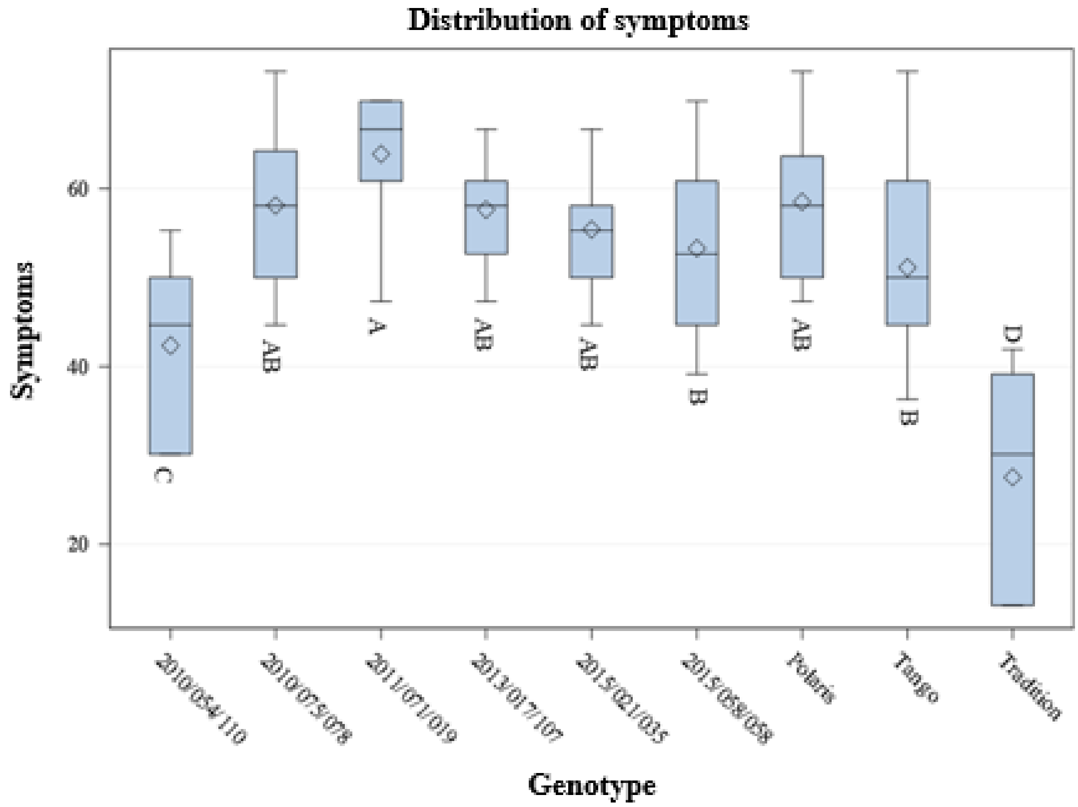


Figure 6.7: Distribution of the reactions of tested hop varieties/strains to downy mildew in the 2021 season. Only hops with different capital letters show statistically significant differences in their downy mildew infestation (Student-Newman-Keuls test with $p<0.05$).

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 severely stunted because of downy mildew infestation) from the hop garden. In the current test season, starting with experiment 10, zoospores from artificially infected leaves that are grown in an incubator were also used.

Outlook

A decisive advantage of the leaf test system is its ability to generate assessments of the disease tolerance of a given hop variety or strain under standardized conditions that are independent of weather and location influences. In recent years, the downy mildew leaf test system has emerged as an important component for assessing tolerance. This means it can also be used to confirm field assessments.

References

Dahmen, H., Staub, Th., and Schwinn, F.J. (1983): Technique for long-term preservation of phytopathogenic fungi in liquid nitrogen. Phytopathology 73: 241-246.

Jawad-Fleischer, M. (2014): Optimierung eines Blatttestsystems (detached leaf assay) zur Testung der Toleranz gegenüber Falschem Mehltau (*Pseudoperonospora humuli*) bei Hopfen. Bachelorarbeit, Hochschule Weihenstephan-Triesdorf, Fakultät Land- und Ernährungswirtschaft.

Mitchell, M.N. (2010): Addressing the Relationship between Pseudoperonospora cubensis and P. humuli using Phylogenetic Analyses and Host Specificity Assays. Thesis, Oregon State University, USA, http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/16301/MitchellMelanieN2010.pdf?sequence=1

Seigner, E., Forster, B., Lutz, A., Eckl, Th. (2019): Detached leaf assay to evaluate downy mildew tolerance of hops. Proceeding of the Scientific-Technical Commission of the International Hop Growers´ Convention, France, 112.

6.5 Research on *Verticillium* problems in hops: Molecular detection of *Verticillium* 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 (*AG Hop Breeding Research Group*) IPZ 5c
Financing:	Erzeugergemeinschaft HVG e. G. *(HVG Hop Producer Group)*
Project Management:	Dr. E. Seigner
Team:	AG Züchtungsforschung Hopfen (*AG Hop Breeding Research Group*): P. Hager, R. Enders, A. Lutz, J. Kneidl
Collaboration:	AG Pflanzenschutz im Hopfenbau (*Plant Protection in Hop Cultivation*): S. Euringer, K. Lutz, Dr. S. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia
Duration:	Since 2008 to October 31, 2023

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

Objective

In addition to other phytosanitary or plant cultivation measures, planting *Verticillium*-free material is a crucial component in being able to provide hop growers with healthy plant material.

Since 2013, the seedlings have been tested for the *Verticillium* fungus using highly sensitive PCR-based detection methods, thus ensuring that only wilt-free hops are distributed.

Method

Based on research by Maurer et al. (2013) a very reliable and sensitive molecular detection technique for *Verticillium* directly in the bines could be established. This detection system, relying on a Multiplex TaqMan®-based real-time PCR method, has been used in practice since 2014.

Results

We are constantly working on optimizing the test system. The aim is not only to test for *V. non-alfalfae* in general in one PCR run, but also to simultaneously differentiate between mild and lethal strains of *V. non-alfalfae*. Differentiating between the various wilt strains is of decisive importance for both hop breeding and cultivation. The multiplex PCR analysis has made this possible.

- **Multiplex TaqMan®-based real-time PCR**

Figure 6.8 shows selected amplification curves of a PCR run. The internal control (green curve), used to detect the Cox DNA of hops, confirms that a PCR has run smoothly, which means that "false negatives" can be ruled out.

As the “FAM” dye coupled to the probe is released, the blue curve increases in fluorescence. This means that the *V. non-alfalfae*-specific sequences are present in the sample extract and have been propagated. Since this primer pair does not differentiate between mild and lethal strains, it can only confirm that the examined bine is infested with *Verticillium*.

At the same time, primers and probes (Cy5-labeled) for lethal strains of *V. non-alfalfae* are also offered in the PCR. The lethal strain of the wilt fungus *V. non-alfalfae* is detected with the increase in the fluorescence signal "Cy5" (purple curve).

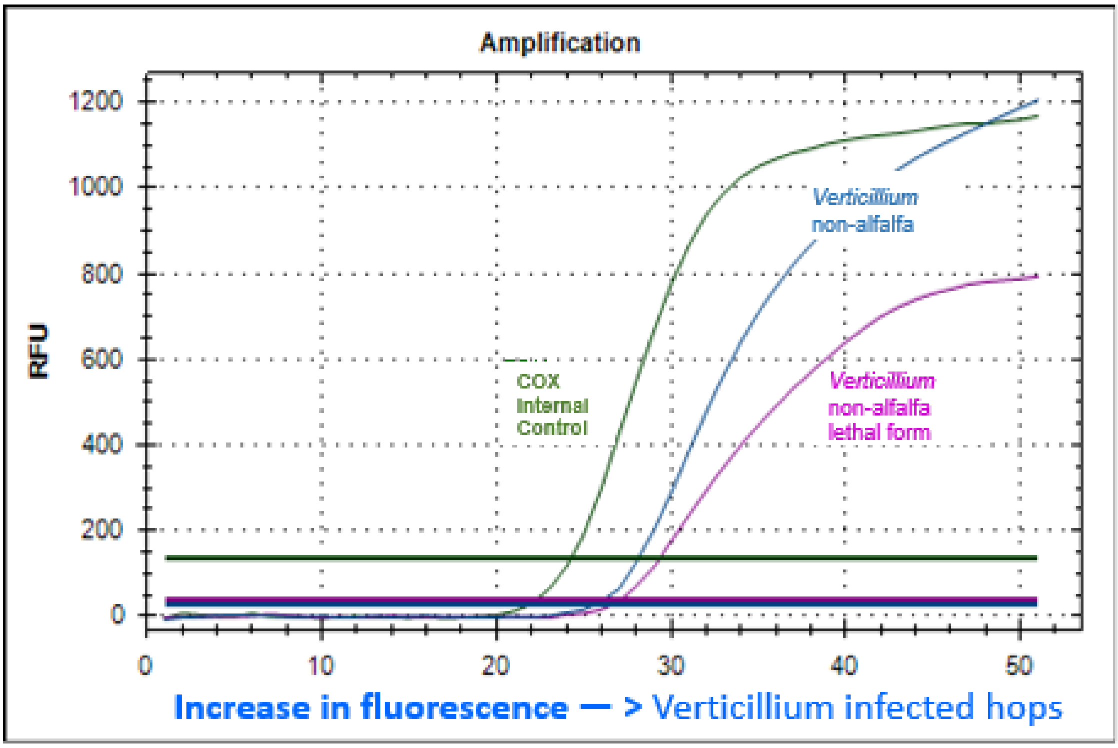


Figure 6.8: Multiplex real-time PCR of a bine sample from a real-world plot, in which a lethal Verticillium *infection was detected*

- **Evaluation of the molecular detection and validation of the detection system**

Advantages of the real-time PCR detection method:

- very specific
- without risk of confusion with other fungal infections (*Fusarium*)
- Even the smallest amounts of fungi are recorded
- Differentiation of mild and lethal strains is possible
- Results are already available after 2 days

Disadvantages of the real-time PCR detection method:

- no clear indication if the detected *Verticillium* fungus can still infect plants or if it is already dead

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

The real-time TaqMan® PCR protocol by Maurer et al. (2013), including some methodology improvements, has been 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 supported by IPS 2c, Virus Diagnostics.

- **Tests for *Verticillium***

Every year, roughly 700 plants are being tested for *Verticillium*. This corresponds to about 2,800 PCR reactions. Since one cannot assume that the wilt fungus is distributed homogeneously in the test material, 2 to 3 samples per plant are taken from different parts of the plant (roots, bine pieces close to the base, etc.). The DNA is then extracted separately from each sample and the DNA extract is analyzed using real-time PCR, both undiluted and diluted to 1:10. If the results are not clear, the real-time PCR test is repeated.

The following were examined this year:

- *Verticillium*-free planting material intended for the LfL's own test sites (breeding gardens in Stadelhof) and for cultivation trials in commercial plots (row and large-plot trial cultivation in the Hallertau, Tettnang, Spalt, and Elbe-Saale)
- Studies of the spread of *Verticillium* infections (lethal strains) in commercial hop gardens in the Hallertau
- Examination of mother plants for GfH propagation operations to ensure that only wilt-free rhizomes reach the grower.
- Mother plants on the propagation farm are checked regularly for wilt infestation. This ensures that *Verticillium*-free plants are made available to the hop growers.
- Examination of Hüll breeding material in LfL breeding gardens and *Verticillium* selection gardens to identify strains/cultivars that are generally not or only slightly affected by *Verticillium*; or that prove to be particularly tolerant to the lethal form.
- Molecular verification of wilt assays in cooperation with S. Euringer and K. Lutz, IPZ 5b. These investigations are also of crucial importance in connection with measures to recover *Verticillium*-infested soils and to sanitize bine shreds, as well as the detection of the fungus in other plant species (intermediate cover crops, weeds).
- Analysis of samples required as part of the so-called Plant Passport 2021
- Establishment of a *Verticillium* reference collection and availability of inoculation material

- **Support for *Verticillium* research through reliable molecular diagnostics**

Since June 2017, the Society for Hop Research has been supporting a research project on the *Verticillium* problem in hops by funding a scientific staff position. This allows for tackling questions with practical relevance to the wilt fungus. All approaches used in this project benefit from the molecular detection of the fungus. Only by means of a PCR analysis can plants that show visual wilt symptoms be verified for a separation between those infected with mild and with lethal strains of the wilt pathogen.

Outlook

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

References

EPPO Bulletin (2020) PM 7/78 (2) *Verticillium* nonalfalfae and V. dahliae: 50 (3): 462-476.

Guček, T., Stajner, N., Radišek, S. (2015): Quantification and detection of *Verticillium* albo-atrum in hop (Humulus lupulus) with real-time PCR. Hop Bulletin 22, 26-39.

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

Seigner, E, Haugg, B, Hager, P., Enders, R., Kneidl, J. & Lutz, A. (2017): *Verticillium* wilt on hops: Real-time PCR and meristem culture – essential tools to produce healthy planting material. Proceeding of the Scientific-Technical Commission of the International Hop Growers´ Convention, Austria, 20-23.

Weller, S.A., Elphinstone, J.G., Smith, N.C., Boonham, N., and Stead, D.E. (2000): Detection of Ralstonia solanacearum strains with a quantitative, multiplex, real-time, fluorogenic PCR (TaqMan) assay. Appl Environ Microbiol. 66(7), 2853-8.

6.6 Meristem culture to produce healthy seedlings

Management:	Dr. E. Seigner, A. Lutz
Team:	B. Haugg
	P. Hager, R. Enders, IPZ 5c
Collaboration:	Dr. L. Seigner und Team der Virusdiagnostik (Virus Diagnostics Team), IPS 2c

Objective

Infestations of *Verticillium*, viruses, and viroids in hops can lead to drastic reductions in yield and quality. However, these diseases cannot be controlled with pesticides. Instead, the meristem culture technique offers a biotechnological method for both recovery and the production of *Verticillium*- and virus-free plant material.

Method

To produce *Verticillium*- and virus-free hop plants, the meristem (the uppermost growth zone of the shoot tips) of infected shoots grown in a greenhouse are surface-sterilized and then treated with heat in vitro for several days.

In this process, it is assumed that any viruses and fungal structures in the meristem are inactivated. After the heat therapy, the meristem is dissected under a microscope, then placed on a special culture medium, and finally regenerated into a complete plant in vitro. To confirm that the meristem step has successfully eliminated all viruses and *Verticillium*, the new plantlets are examined for these at the end of the tissue culture phase.

For this, the IPS 2c working group uses the DASELISA technique or RT-PCR to examine the leaves for the presence of the various hop-typical viruses and, in some cases, also some viroids. Only healthy seedlings are finally planted in the soil.

Results

In 2021, no *Verticillium*-infested hops were found that needed to be treated. Thus, the focus shifted to the elimination of viruses, especially "stubborn" ones, such as apple mosaic virus

(ApMV) and hop latent virus (HpLV). These methods can still be improved. The effects of different heat therapies on the elimination rate of viruses, specifically of ApMV and HpLV, from the trials in 2020 were investigated and confirmed.

After a 3-day in vitro heat adaptation phase at 30 °C, the shoot tips were subjected to a prolonged heat therapy at 35 °C for 7, 9 or 12 days to eradicate viruses, whereby the elimination rate of ApMV leveled out at 95%. For HpLV, the effectiveness of these eradication methods increased from 50% in previous years to 85%.

In the process, the heat therapy damaged some of the meristems and some were lost. Therefore, a "pre-culture" technique was tested, which increased the number of available meristem plants. This involved pre-cultivating the shoot tips initially, after surface sterilization, in the greenhouse, for 3 to 4 weeks after the harvest, under normal conditions, to induce the development of side shoots. This allowed the plants to adapt better to their environment and thereby induce a higher meristem yield (see Figure 6.9, A-D). Results thus far show that there is indeed an increase in the number of meristems. However, it is not clear yet, if this step is worth the extra time.

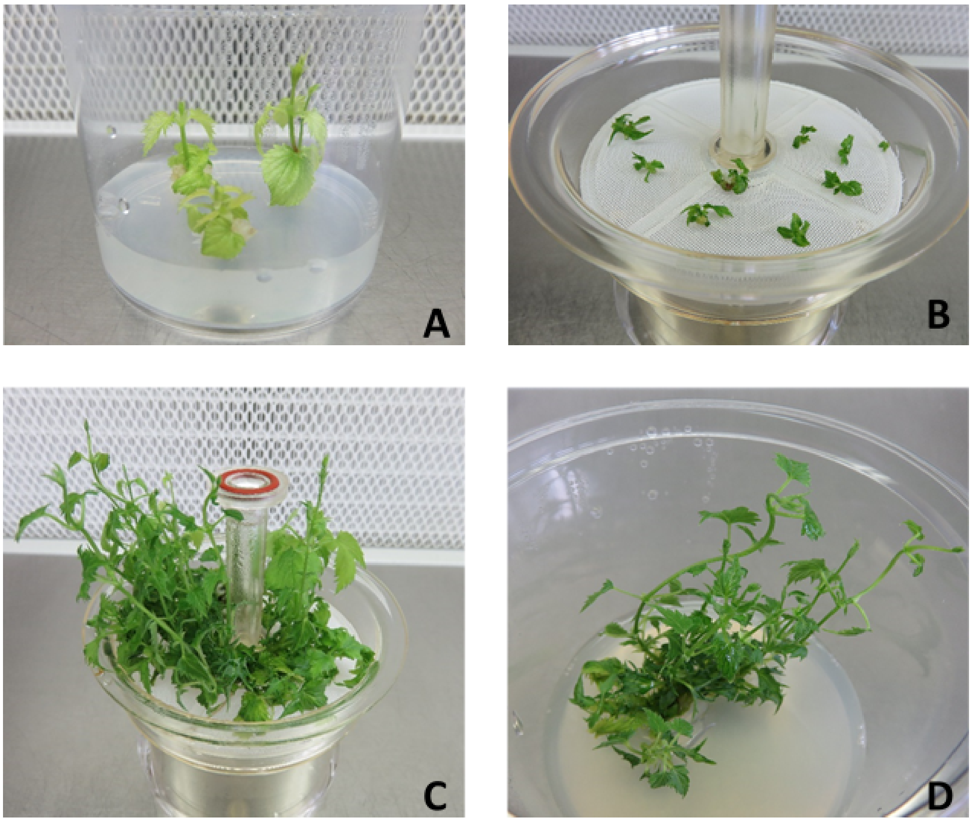


Figure 6.9: Meristem culture with "pre-culture," A) after 3 weeks of pre-culture and completed heat treatment, B) 3 weeks after preparation fresh in the RITA® liquid culture system, C) 10 weeks after preparation in the RITA® liquid culture system and D) isolated plant in a culture vessel

Outlook

Work is underway to further increase the virus elimination rate by optimizing the cultivation and test conditions for meristem culturing. The viroid infestation still poses a major challenge. Truly effective methods are lacking. Therefore, the search for new approaches to viroid elimination or inactivation continues.

References

Faltus, M., Zamecnik, J., Svoboda, P., Patzak J. and Nesvadba, V. (2011): Progress in the Czech Hop Germplasm Cryoconservation. Acta Hort 908: 453-460.

Kazemi, N., Nahandi, F.Z., Habashi, A.A., Masoomi-Aladizgeh, F. (2020): Comparing the efficiency of conventional and novel methods of virus elimination using molecular techniques. European Journal of Plant Pathology 157 (4), 887-897.

Matoušek, J., Trněná, L., Svoboda, P., Oriniaková, P., Lichtenstein, C.P. (1995): The gradual reduction of viroid levels in hop mericlones following heat therapy. Biol. Chem. Hoppe-Seyler 376: 715–721.

Matousek, J., Patzak, J., Orctová, L., Schubert, J., Vrba, L., Steger, G., Riesner, D. (2001): The variability of hop latent viroid as induced upon heat treatment. Virology 287(2):349-358.

Postman, J., DeNoma, J. and Reed, B.M. (2005): Detection and Elimination of Viruses in USDA Hop (Humulus lupulus) germplasm collection. Acta Hort. 668:143-148.

Seigner, E, Haugg, B, Hager, P., Enders, R., Kneidl, J. & Lutz, A. (2017): *Verticillium* wilt on hops: Real-time PCR and meristem culture – essential tools to produce healthy planting material. Proceeding of the Scientific-Technical Commission of the International Hop Growers´ Convention, Austria, 20-23.

7 Hop Quality and Analysis

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

7.1 Overview

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 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).

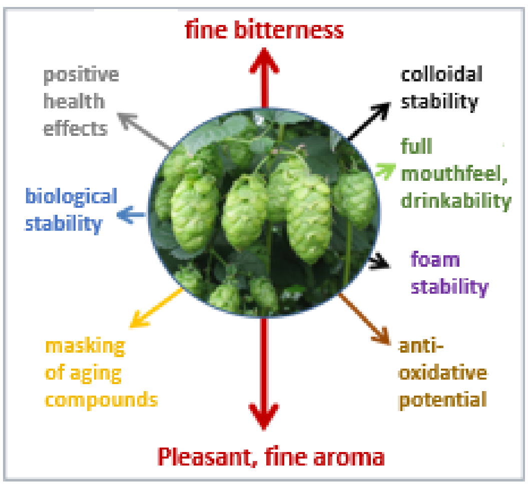


Figure 7.2: The many functions of hops in beer

7.2 Which requirements should hops meet in the future?

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

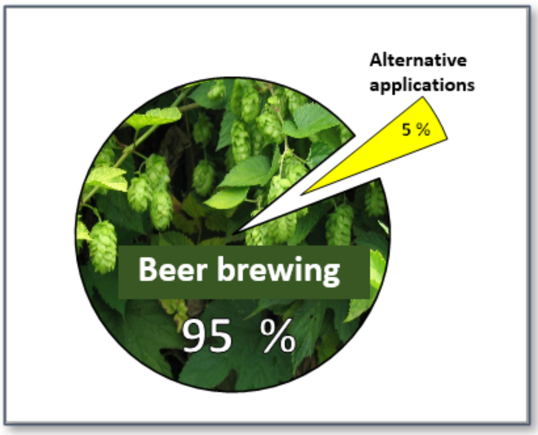


Figure 7.3: Uses for hops

7.2.1 Requirement for the brewing industry

With regard to the use of hops in the brewing industry, there are many different philosophies. Some breweries are interested only in cheap alpha acids, while others select hops deliberately according to variety and cultivation terroir (Fig. 7.4). Yet others rank somewhere in between these two views.

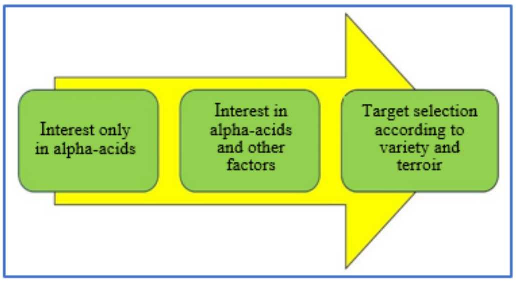


Figure 7.4: Different philosophies regarding the use of hops

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 should produce classic aroma profiles in beer. Polyphenols, on the other hand, have not been considered of great importance in the brewing industry, even though they also contribute to the sensory profile of beer by affecting its mouthfeel, for instance. In addition, polyphenols have many health benefits (see Chapter 7.3).

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 craft brew requirements for hops remain unchanged. They include fruity and floral aromas that 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).

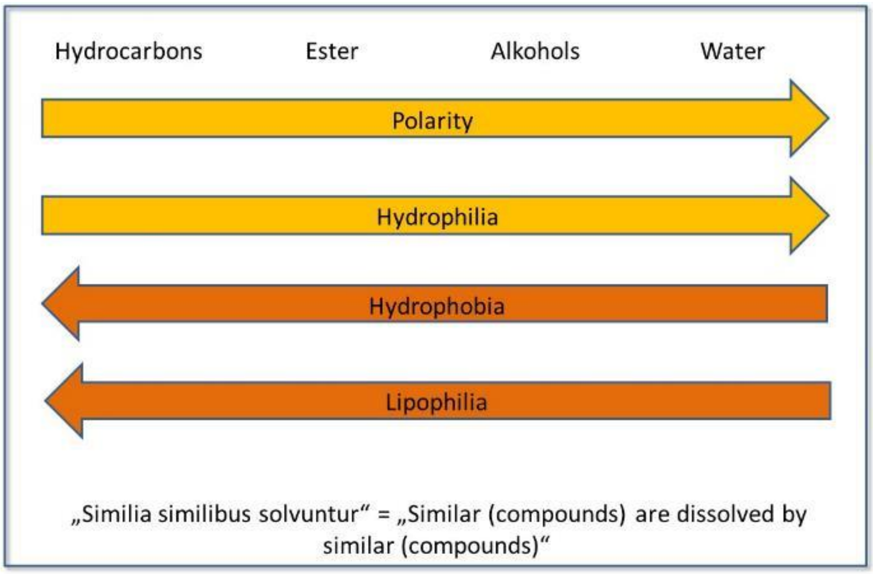


Figure 7.5: The solubility behavior of hop compounds is based on polarity

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

In addition, the group of polyphenols is soluble because of 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%. The legal nitrate limit in drinking water (in Germany) is 50 mg/l, but 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

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

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

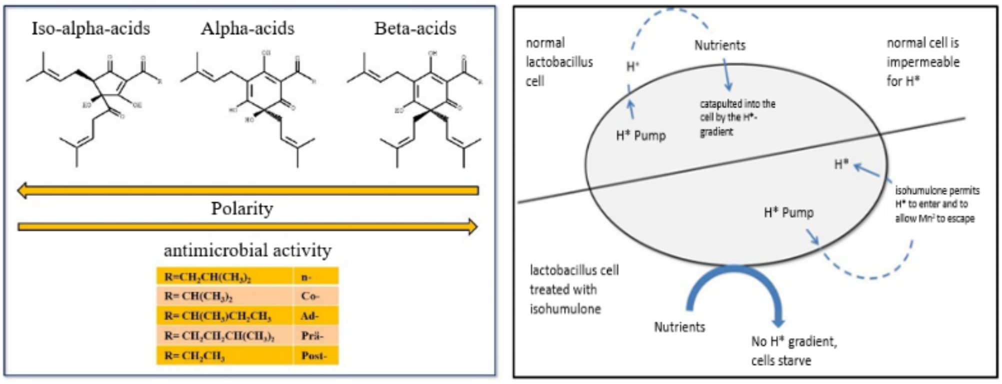


Figure 7.6: Sequence of antimicrobial activity of iso-alpha acids, alpha acids, and beta acids, as well as their effectiveness

The more non-polar a molecule is, the greater is its antimicrobial effectiveness. Hop 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. Some applications based on the antimicrobial activity of hops are listed below.

- Beta acids control gram-positive bacteria (clostridia, listeria, the tuberculosis pathogen mycobacterium tuberculosis)
- Use as a preservative in the food industry (fish, meat products, dairy products)
- Sanitation of biogenic waste (sewage sludge, compost)
- Elimination of mold infestations
- Smell and hygiene improvement of litter
- Control of allergens
- Use as an antibiotic in animal nutrition
- Biological control of bacteria in the sugar and ethanol industry (formalin replacement)

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

Hops are also interesting in the areas of health, wellness, dietary supplements, and functional foods because they contain large amounts of polyphenolic substances. A comprehensive treatise on polyphenols and their importance in beer and health can be found in the next chapter.

7.3 The polyphenols of hops

The 2019 annual report contained more details about aroma substances, while the 2020 annual report contained more details about bitter substances. Therefore, this annual report features more details about polyphenols. These substances fit well into beer because of their polarity. As a sensory element, their importance seems to be still underestimated but could become more recognized in the future.

Polyphenols are secondary plant compounds that are synthesized by the plant as a defense against diseases and pests, as growth regulators, and as pigments. Because of their antioxidant properties and their ability to scavenge free radicals, they have many health benefits. Among the diseases that are based on oxidative processes are cancer, atherosclerosis, Alzheimer's and Parkinson's. Polyphenols can be classified according to the following scheme (Fig. 7.7).

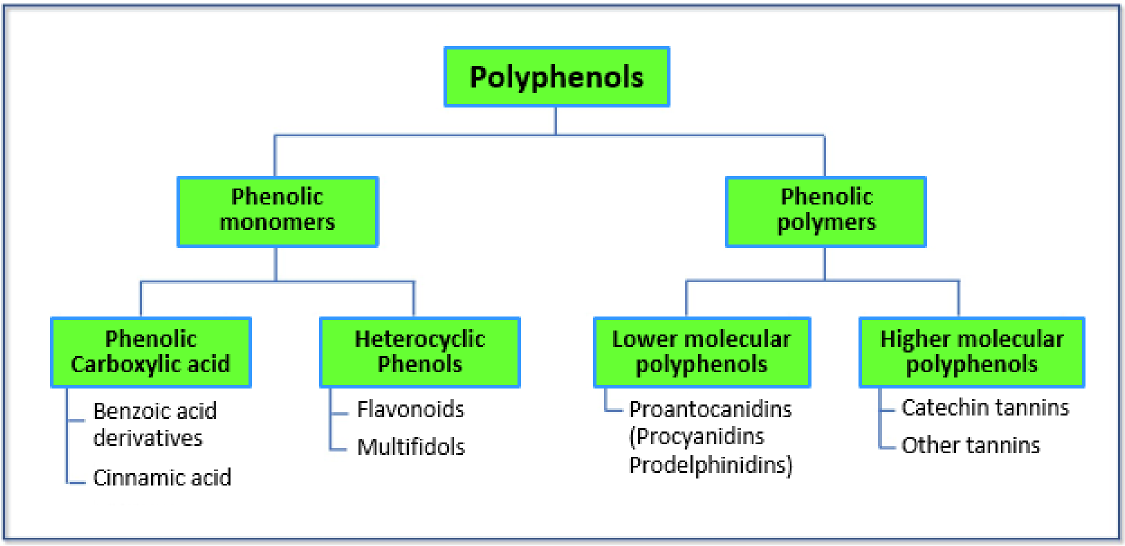


Figure. 7.7: Classification of polyphenols

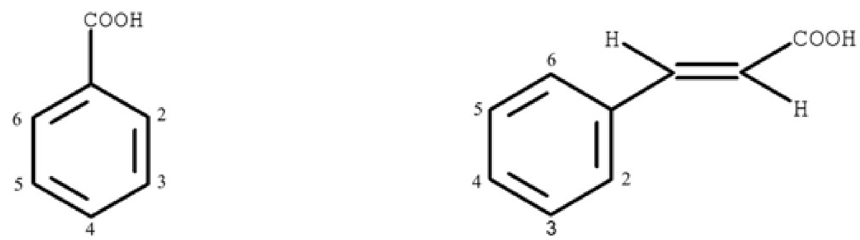
Table 7.1 shows the order of magnitude in which polyphenols are present in hops.

Table. 7.1: Phenolic substances in hops

Substances and Substance Groups	Concentrations
Phenolic Carboxylic acid	
1) Benzoic acid derivatives	< 0.01 %
2) Cinnamic acid	0.01 – 0.03 %
Flavonoids	
3) Xanthohumol (Chalcone)	0.20 – 1.70 %
4) 8,6-Prenylnaringenin	< 0.01 %
5) Quercetin glycoside	0.05 – 0.23 %
6) Kaempferol glycoside	0.02 – 0.24 %
7) Catechin und Epicatechin	0.03 – 0.30 %
8) Acylphloroglucinol derivates (Multifidols)	0.05 – 0.20 %
Higher molecular substances	
9) Oligomeric Proanthocyanidins	0.30 – 1.64 %
10) Catechin and tannins	2.00 – 7.00 %

The following sections provide further explanations of the chemical and analytical structures of hop polyphenols.

7.3.1 Phenolic carboxylic acids



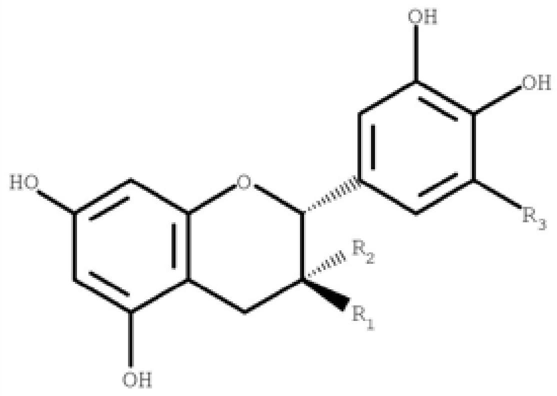
Derivative	Chemical name
Gallic acids	3,4,5-Tridroxybenzoic acids
Protocatechuic acids	3.4 -Dihydroxybenzoic acids
Gentinsin acids	2.4 -Dihydroxybenzoic acids
p-Hydroxybenzoic acids	4-Dihydroxybenzoic acids
Vanillic acids	4-Hydroxy-3-methylbenzoic acids
Syringa acids	4-Hydroxy-3,5-Dimethoxybenzoic acids

Derivative	Chemical name
Caffeic acids	3,4-Hydroxycinnamic acids
p-Coumaric acids	4-Hydroxyzine acids
Chlorogenic acids	5-Caffeoylquinic acids
Ferulic acids	4-Hydroxy-3-methoxycinnamic acids
Sinapic acid	3,5-Dimethoxy-4-hydroxycinnamic acids

Figure 7.8: Benzoic acid and cinnamic acid derivatives

Benzoic acid and cinnamic acid derivatives are ubiquitous in the plant kingdom. They are not specific to hops and their concentrations in hops tend to be relatively low.

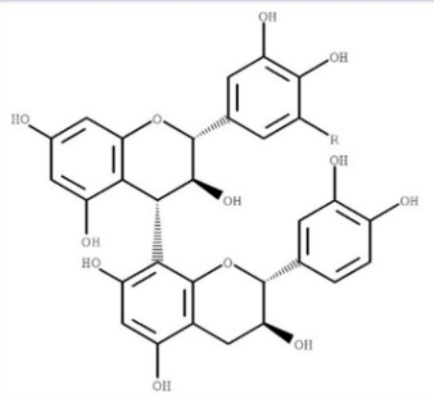
7.3.2 **Catechins (flavanols)**



R1	R2	R3	Trivial name
OH	H	H	(+)-Catechin
H	OH	H	(-)-Epicatechin
OH	H	OH	(-)-Gallic Catechin
H	OH	OH	(-)-Epigallocatechin

Figure 7.9: Catechins (flavanols)

Catechins are widespread in the plant kingdom. Tea and cocoa, for instance, have very high catechin concentrations. There is evidence that catechin-containing plants can promote blood flow through vasodilation (widening of the blood vessels). Catechins are capable of polymerizing themselves to proanthocyanidins. Figure 7.10 shows dimeric, oligomeric, and polymeric proanthocyanidins. However, the larger proportion of catechins in beer certainly comes from malt (barley), not from hops.



R	Trivial name
H	Procyanidin B3
OH	Prodelphinidin B3

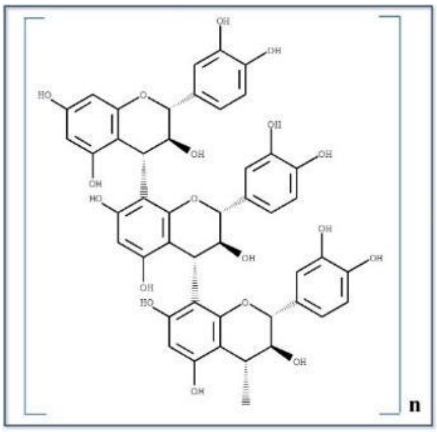


Figure 7.10: Dimeric, oligomeric, and polymeric proanthocyanidins

7.3.3 **Tannins**

Tannins are highly complex compounds of gallic acid and glucose. Figure 7.11 shows a sectional view. Their effect is based on their ability to crosslink proteins three-dimensionally. This is how leather is made from animal skins, for example. The car maker AUDI, incidentally, once investigated using hop tannins for tanning leather for car seats. The project, however, never got off the ground. The astringent effect of tannins also serves to ward off predators.

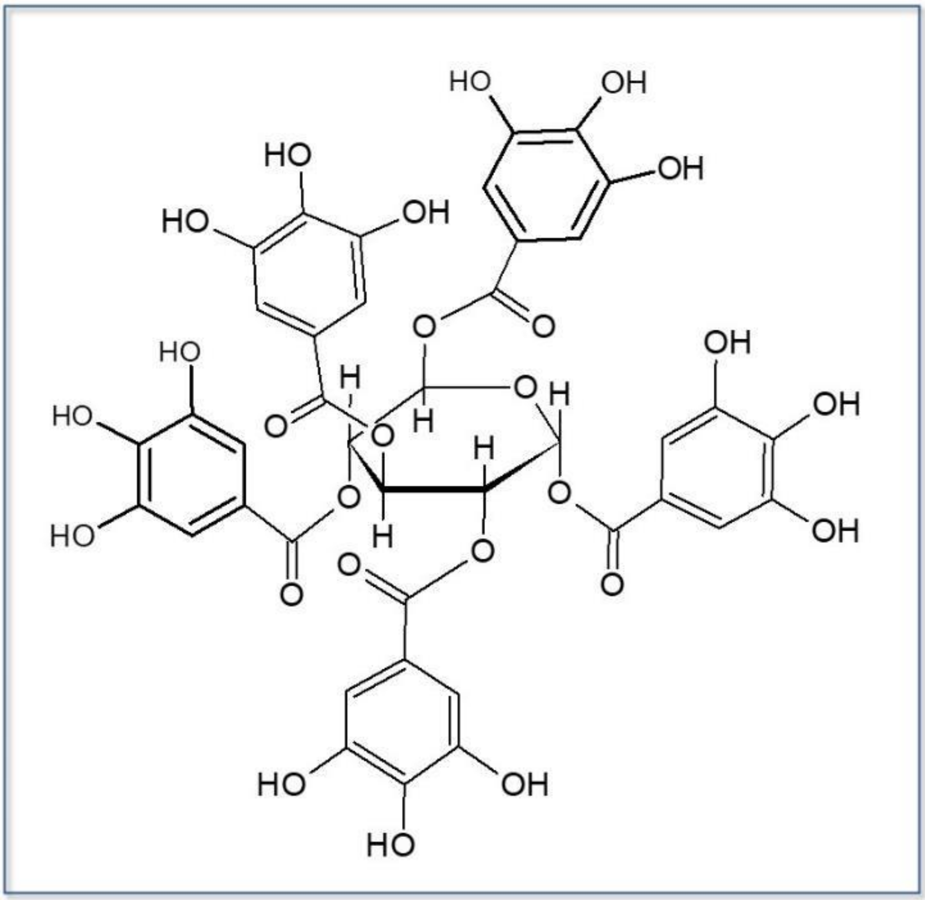


Figure 7.11: Section of a tannin complex

7.3.4 **Analytics**

7.3.4.1 **Methods for determining the total tannin content**

There is currently only one official method for determining the total polyphenol content according to EBC 7.14. This is a non-specific spectrophotometric technique involving a hot water extract from hops that is colored with an Fe^{2+} solution. Fe^{3+} ions form brown complexes with polyphenols that can be measured at a wavelength of 600 nm. The degree of coloration is an indicator of the polyphenol content (Figure 7.10). Aroma hops usually have higher polyphenol contents than do bittering hops. This method is derived from the established EBC method 9.11 for determining the total polyphenol content in beer.

Figure 7.12: Total polyphenols according to EBC 7.14 (staining method)

The catechins and oligomeric proanthocyanidins (flavanols) can also be determined using a staining method derived from the official EBC method 9.12 for flavonoids in beer. However, it is not yet recognized as an official analysis method for hops. It also involves a hot water extract, which is then is treated with dimethyl amino cinnamic aldehyde and acidified. The flavanols react with the dimethyl amino cinnamic aldehyde to form green-colored compounds (Figure 7.13), which are measured spectrophotometrically at a wavelength of 640 nm. Here too, the degree of staining is an indicator of the concentration.

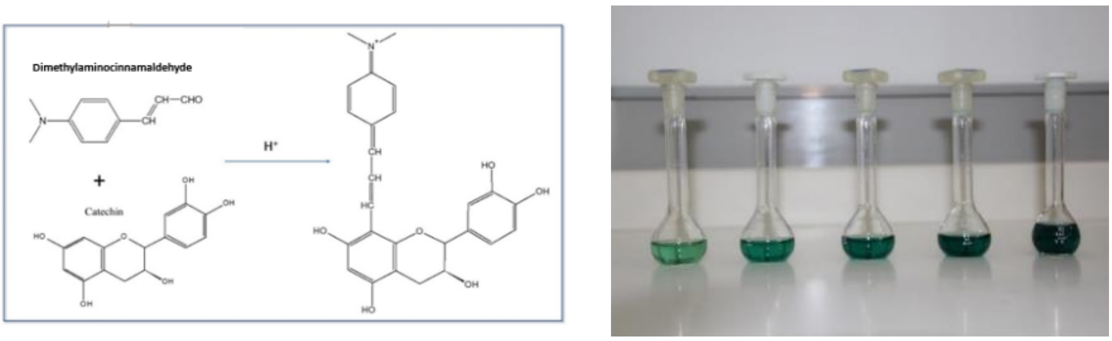


Figure 7.13: Flavanols react with cinnamicaldehyde to form green-colored compounds

7.3.4.2 **Individual compounds with HPLC**

Low-molecular polyphenols can be analyzed very well with HPLC. The substance group of quercetin and kaempferol glycosides (Fig. 7.14) is clearly species-specific.

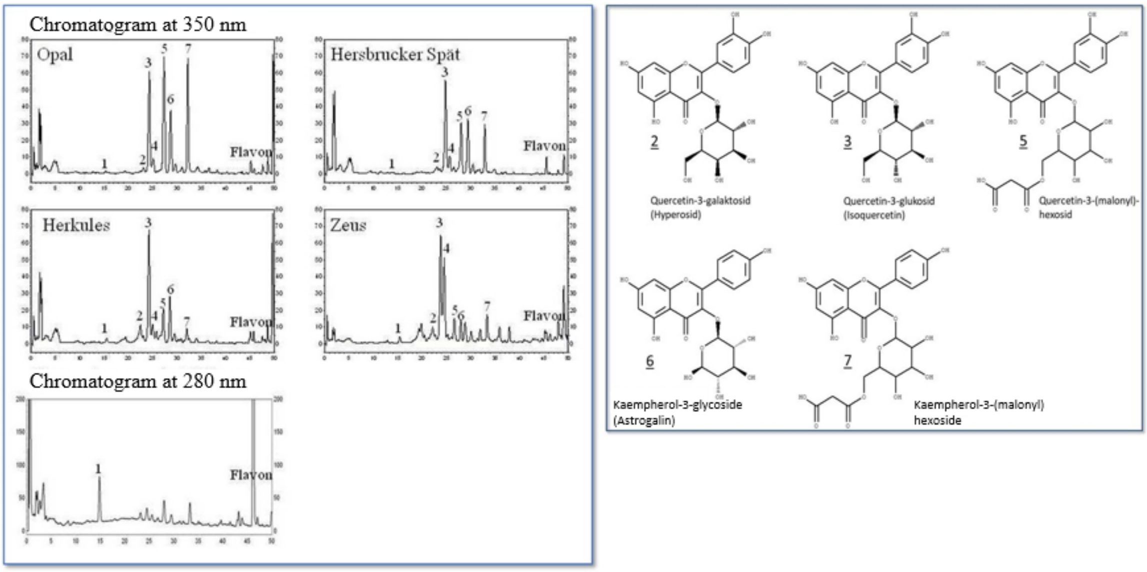


Figure 7.14: Chromatograms of quercetin and kaempferol glycosides and their chemical structures

The quercetin and kaempferol glycosides are measured by HPLC at a wavelength of 350 nm. Multifidol glucosides absorb very well at 280 nm. Figure 7.15 shows the chemical structures of the multifidols.

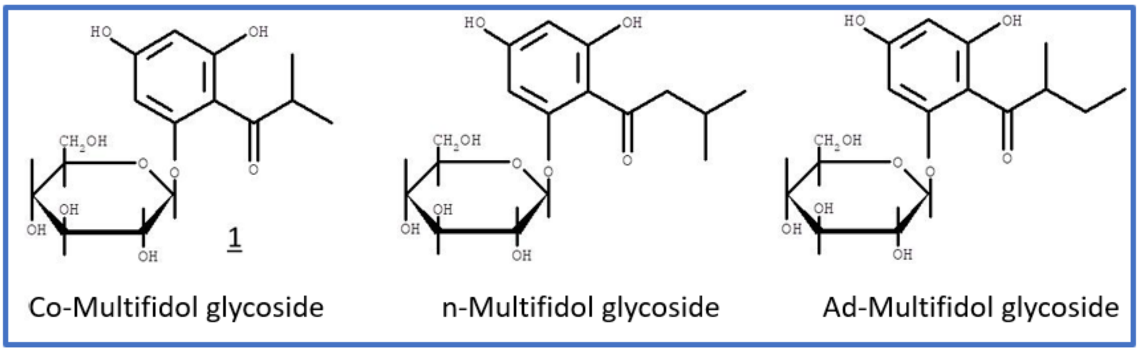


Figure 7.15: Chemical structures of the multifidol glucosides

Analogous to the co-, n- and Adhumulone there is also co-, n- and ad-multifidol glucoside, since these compounds are by-products of the biosynthesis of the bitter substances. In 2020 and 2021, the Scientific Station for Breweries in Munich funded a project on multifidols that is described in the next chapter.

7.3.5 **Isolation, identification, and analysis of multifidols in hops**

This research project was funded to the tune of €10,000 by the Scientific Station for Breweries Munich for the years 2020 and 2021.

Quercetin and kaempferol glycosides, as well as multifidols occur in relatively high concentrations in hops. They are easily soluble in water because of their polarity, and they have low taste thresholds. Table 7.2 shows the taste threshold values of these compounds according to Dr. M. Biendl and S. Cocuzza ("Hard Resins," Hopfenrundschau International, 2016/2017, 60-68).

Table 7.2: Flavor threshold values of low molecular weight polyphenols in hops and the percentage of beers in which this threshold is exceeded.

Lower molecular polyphenols	Taste thresholds in mg/l	Percentage of beers above 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. 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 goal of this project was to develop a suitable preparation and analysis method for samples of multifidol glucosides, followed by quantitative analyses of the most important hop varieties.

A mixture of methanol and water (90:10) has turned out to be an excellent method for extracting multifidols. 5 g of ground hops are extracted with 50 ml of solvent in an ultrasonic bath for 15 minutes. This is then passed first through a pleated filter and then through a nylon syringe filter with a pore size of 0.23 µm, ø 33 mm, by Roth. 5 mL of the filtrate is then added to a 10 mL volumetric flask, to which is added 1 mL of standard before it is topped off to 10 mL. For the HPLC analysis, the samples are filled into 1.5 ml vials.

The HPLC analysis is carried out using a HPLC System Accela 10000 by Thermo Scientific. The EC 125/2 Nucleodur 100-3 C18 column from Macherey-Nagel serves as the analytical column. Fig. 7.16 shows the sample preparation and HPLC analysis.

Figure 7.16: Sample preparation and HPLC analysis of multifidols

The analysis relies on a gradient program:
Solvent A: H2O:methanol (90:10), Solvent B: methanol gradient program:

Time in minutes	Solution A	Solution A	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 min and flavone at 16.6 min (Figure 7.17).

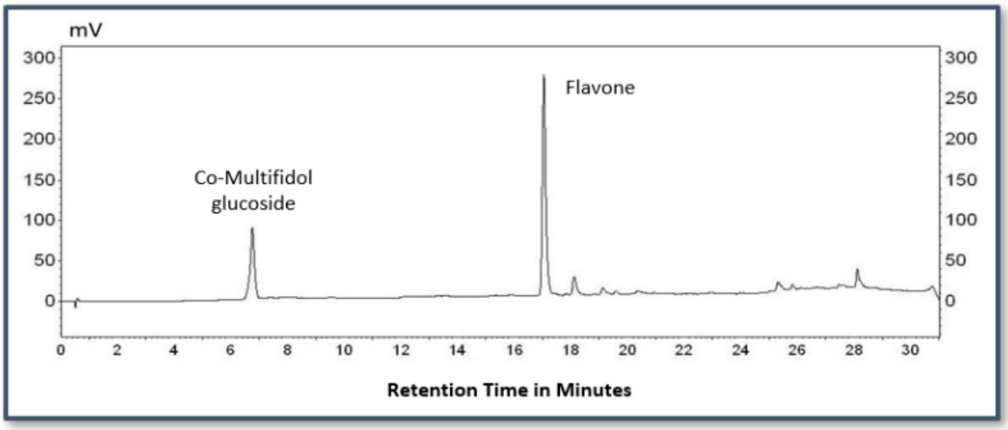


Figure 7.17: Chromatogram of co-multifidol glucoside – flavone

Figure 7.18 shows the UV spectra of co-multifidol glucoside and flavone.

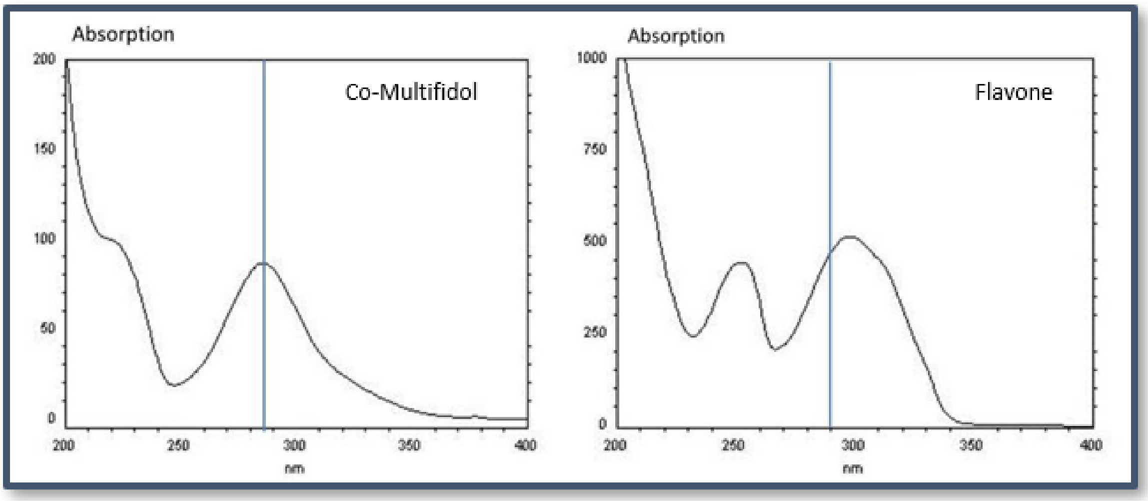


Figure 7.18: UV spectra of co-multifidol glucoside and flavone

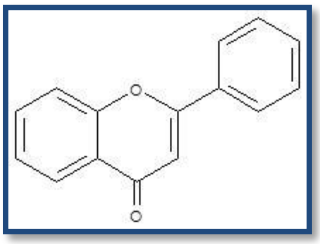


Figure 7.19: Chemical structure of flavone

Co-multifidol glucoside has an absorption maximum at 280 nm and flavone at 300 nm. However, flavone still absorbs very well at 280 nm and is therefore suitable as a secondary standard. Also, flavone (Figure 7.19) does not occur naturally in hops and can therefore be used as an internal or external standard.

Dr. Wietstock from the TU Berlin has isolated co-multifidol glucoside from hops with preparative HPLC in 96% purity and determined the response factors at a wavelength of 280 nm. 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:water (90:10) and then diluted to 1:10. This standard is used for the analytics.

Figure 7.20 shows the results for important hop varieties from the 2019 and 2020 crop years. The varieties have very different levels. Herkules has the highest co-multifidol glucoside content and Hersbrucker Spät the lowest. In 2020, the multifidol content was slightly lower overall, but it has been shown that the variety differences are easily reproducible. The co-multifidol content thus also appears to be genetically determined. Furthermore, after the end of the project, the 2021 harvest year will to be analyzed, too, so that results for three years are available. However, there is no correlation to the alpha acid content. Some varieties with a high alpha acid content, such as Herkules or Polaris, have a fairly low co-multifidol glucoside content. Others, such as the low alpha acid Sapphire, have high levels of co-multifidol glucoside.

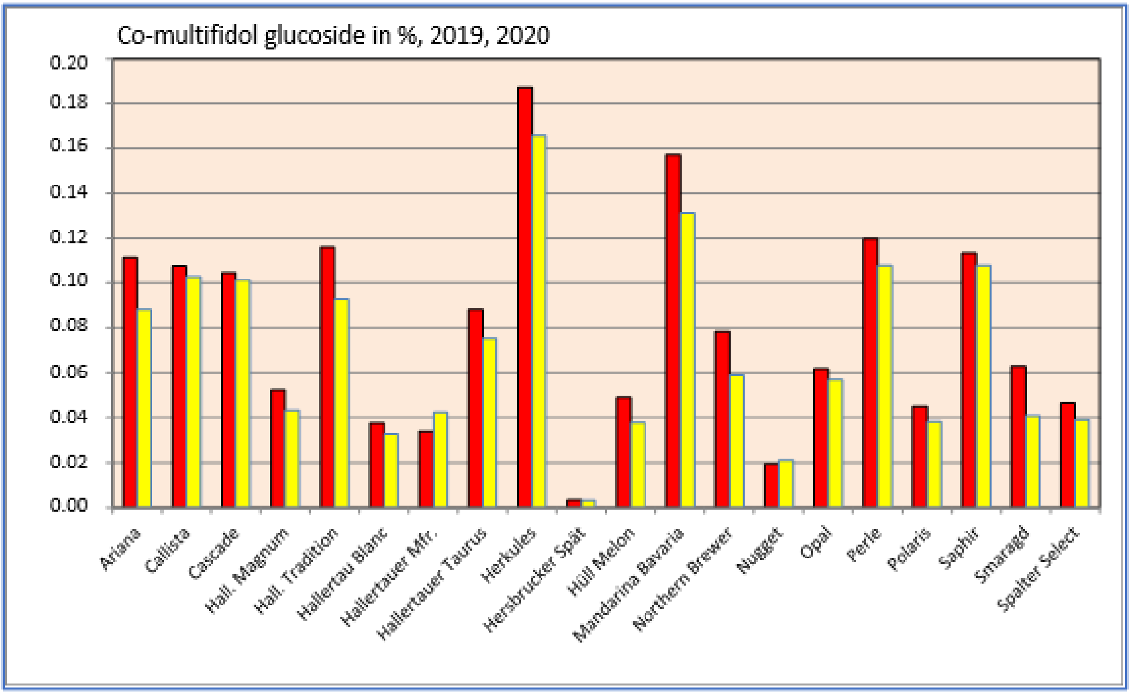


Figure 7.20: Co-multifidol glucoside levels in important hop varieties from the 2019 and 2020 crop years

7.3.6 The importance of polyphenols for beer and health

There is some controversy in the literature about the importance of polyphenols for beer. However, many references in the literature rate low-molecular polyphenols positively because they contribute to the body and mouthfeel of the beer. There is no doubt that polyphenols add antioxidant potential to beer. When polyphenols of higher molecular weight combine with proteins via hydrogen bonds, turbidity occurs (Figure 7.21). Therefore, higher molecular weight polyphenols are generally not desirable and are removed with filter aids such as PVPP (polyvinylpolypyrrolidone).

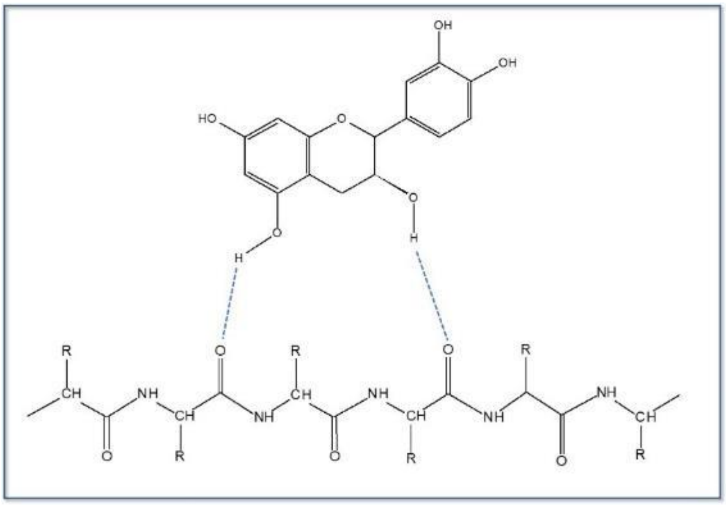


Figure 7.21: Polyphenol-protein complex

The literature on polyphenols and health is almost inexhaustible. In summary, polyphenols have the following properties:

- Polyphenols act as antioxidants in the body
- Polyphenols protect against heart attacks and cancer
- Certain polyphenols such as catechins prevent tooth decay
- Flavonoids prevent cell oxidation
- Polyphenols promote a beneficial intestinal flora

There is a clear consensus that humans should eat a diet that is very high in polyphenols. This means eating lots of fruit and vegetables. Compared to other fruits, hops are very rich in polyphenols.

Of all the hop polyphenols, however, xanthohumol has received the most public attention in recent years, and scientific work on it has exploded. The health-promoting effect of Xanthohumol has already been scientifically proven by the EFSA (European Food Security Authority). This makes health claims for xanthohumol legal and it can be marketed for applications in the field of dietary supplements and functional foods. Extensive information about the history of xanthohumol and its effects can be found on the T.A. XAN Development S.A.M. website https://www.xan.com. Xanthohumol has many benefits (Figure 7.22) but its most important attribute is its anti-carcinogenic effect.

During the brewing process, prenylated flavonoids are constantly being transformed (Figure 7.22). During the kettle boil, xanthohumol is isomerized into iso-xanthohumol demethylxanthohumol, into 8- and 6-prenylnaringenin. This is why desmethylxanthohumol is not found in beer and the concentrations of prenylated naringenins are significantly higher in beer than in hops.

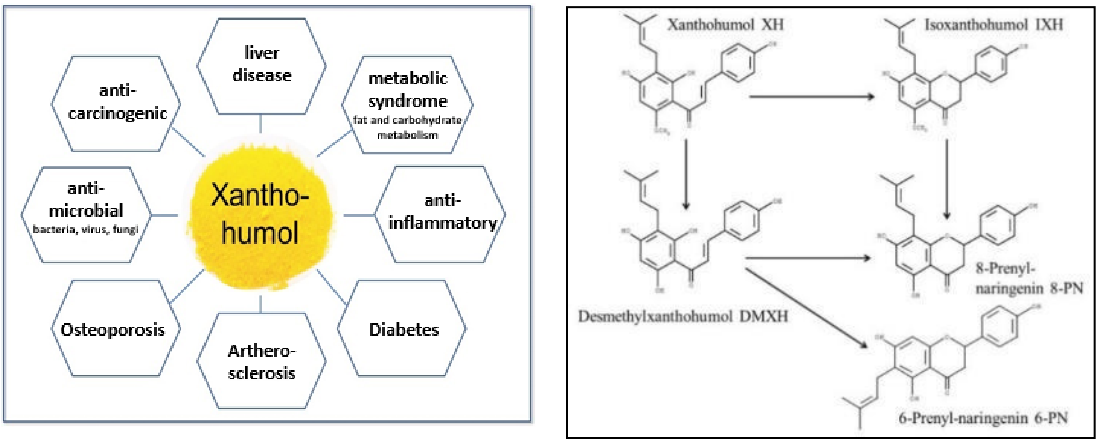


Figure 7.22: Effects of xanthohumol and its transformations in the brewing process

8-prenylnaringenin is one of the strongest phytoestrogens found anywhere in the plant kingdom. The estrogenic effect is the result of 8 prenylnaringenin having a structure similar to that of the female sex hormone 17-ß-estradiol.

Multifidol glucosides have anti-inflammatory properties. In brief, it works as follows. The starting point for inflammation is arachidonic acid, found throughout tissues. If tissue is injured, the enzyme cyclooxygenase first produces prostagladin G2 and then an oxidation of prostagladin H2 (Figure 7.23). An entire cascade of different prostagladins can derived from prostagadin H2. These trigger the various defense reactions of the body, including inflammatory processes.

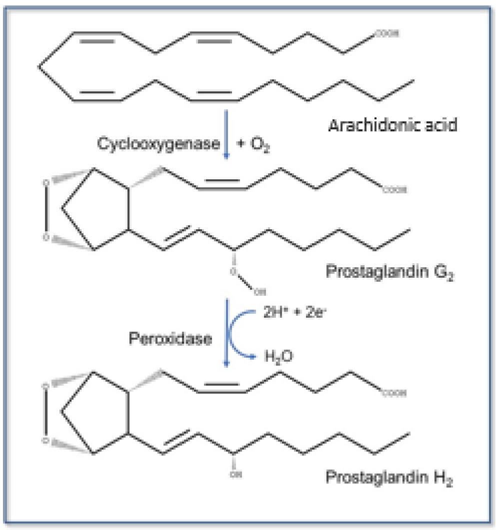


Figure 7.23: Arachidonic acid as a starting point for prostagladin G2 and H2

The mode of action of many well-known painkillers is based on blocking the cyclooxygenase. These include such well-known preparations as:

- Acetylsalicylic acid (Aspirin)
- Ibuprofen
- Naproxen
- Diclofenac (Voltaren)

However, co-multifidol glucoside in hops is also able to inhibit cyclooxygenase.

7.4 World hop varieties (Crop 2020)

Every year, the essential oils from the world hop portfolio are analyzed with headspace gas chromatography and the bitter substances with HPLC. Table 7.3 shows the results for the 2020 crop year. It can be used as a tool to assign unknown hop varieties to a specific variety type.

The constituents of the hop are determined by the DNA of the variety, although many external factors play a role in the expression of the morphological appearance, as well as the constituents (metabolome) (Figure 7.24).

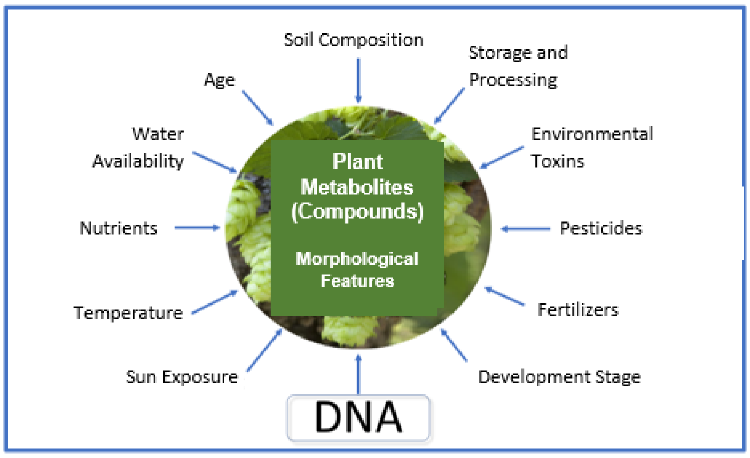


Figure. 7.24: The morphology and the metabolome of hops are determined by many factors

Table 7.2: World hop portfolio (Harvest 2020)

Variety	Myr-cene	2-Metyl-butyl-isobutyrat	Methyl-isohep-tanoate	ß-Oci-mene	Lina-lool	Aroma-dend-rene	Unde-canone	Hu mu-lene	ß-Far-neseen	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß/γ-Ca-dinene	3,7-Seli-nadiene	Gera-niol	α-acids	ß-acids	ß/α	Co-hu-molone	Co-lu-pulone
Admiral	3292	5	0	204	106	0	18	516	0	22	2	5	33	0	0	15,5	5,0	0,32	40,9	74,3
Agnus	688	31	0	20	26	0	9	136	0	21	5	9	48	0	5	11,3	5,3	0,47	30,6	54,3
Ahil	4726	6	96	76	56	0	27	146	125	19	4	8	29	0	7	9,6	3,9	0,41	30,3	54,4
Alliance	872	177	0	9	44	0	14	161	0	18	2	4	45	1	0	4,1	2,1	0,51	26,6	42,5
Ariana	2335	17	220	143	46	0	37	462	0	24	29	62	52	5	2	10,6	5,5	0,52	34,1	54,3
Atlas	4331	95	96	75	52	0	5	161	125	20	6	13	28	0	12	8,8	4,0	0,46	33,2	54,8
Aurora	5412	18	1	470	136	0	92	160	29	17	1	2	29	0	1	9,5	4,0	0,42	21,5	44,8
Aurum	1272	18	7	108	49	0	22	283	0	16	2	3	40	0	1	5,1	4,6	0,90	22,8	42,5
Backa	2301	764	0	98	85	0	23	330	67	21	2	3	54	0	1	6,9	3,9	0,57	48,4	64,2
Belgian Spalter	1163	169	0	87	55	8	21	198	0	22	22	42	36	89	1	4,6	2,8	0,61	17,4	42,2
Blisk	1836	237	67	59	63	0	12	116	160	17	9	16	44	0	11	7,7	3,3	0,42	28,3	54,6
Bobek	2480	387	22	375	167	0	80	156	74	15	2	3	40	0	3	5,6	4,9	0,87	25,3	46,9
Bor	1613	206	1	254	28	0	20	308	0	13	2	3	36	0	3	7,4	3,2	0,43	22,8	44,2
Bramling Cross	1773	370	0	19	64	0	20	428	0	13	1	2	35	0	0	5,0	3,9	0,78	42,3	56,5
Braustern	901	138	0	146	22	0	13	193	0	19	2	4	50	0	2	8,6	4,2	0,49	27,6	49,1
Brewers Gold	1057	102	61	128	38	0	3	166	0	19	6	10	41	0	22	7,4	3,8	0,51	36,1	62,3
Bullion	2079	16	67	169	35	0	4	307	0	18	5	12	38	0	3	8,3	5,1	0,61	37,5	63,7
Callista	3581	33	112	20	153	0	28	531	0	30	33	79	38	0	0	4,1	6,7	1,62	13,3	41,9
Cascade	5569	163	87	66	77	0	11	198	19	31	11	22	84	0	7	6,2	5,7	0,93	31,0	45,7
Centennial	4052	16	238	43	76	0	6	422	0	30	2	5	39	2	24	9,5	2,8	0,29	27,3	51,5
Challenger	2007	443	1	195	63	0	35	373	0	15	34	66	39	1	0	5,2	4,1	0,78	28,2	48,9
Chang bei 1	3158	36	7	11	69	0	41	167	7	24	13	29	28	49	0	2,9	3,6	1,23	10,3	37,2
Chang bei 2	3321	40	4	9	82	0	34	157	13	22	12	27	25	46	0	2,1	3,7	1,74	22,3	41,1
Chinook	1154	6	37	10	22	0	6	339	0	91	11	23	116	39	4	11,4	3,6	0,32	24,4	48,5
Columbus	1328	18	76	15	32	0	4	338	0	74	12	24	128	38	4	13,8	4,6	0,33	29,9	56,7
Comet	1698	32	18	197	26	0	7	30	1	6	32	76	19	23	2	8,8	3,4	0,39	30,4	59,4

Variety	Myrcene	2-Metylbutylisobutyrat	Methylisoheptanoate	ß-Ocimene	Linalool	Aromadendrene	Undecanone	Humulene	ß-Farneseen	γ-Muurolene	ß-Selinene	α-Selinene	ß/γ-Cadinene	3,7-Selinadiene	Geraniol	α-acids	ß-acids	ß/α	Cohumolone	Colupulone
Crystal	1220	153	5	93	68	37	23	275	0	26	23	43	43	75	1	2,4	3,3	1,36	18,9	35,6
Density	1834	340	21	34	60	0	22	432	0	13	2	3	35	0	0	4,6	3,5	0,77	37,8	53,9
Diamant	2561	410	1	36	116	0	39	130	56	16	1	2	41	0	2	7,3	5,0	0,68	20,0	51,2
Dr. Rudi	2332	24	78	108	66	0	27	520	0	22	2	4	31	0	1	5,6	4,0	0,71	34,4	55,4
Early Choice	1311	309	1	72	18	0	17	351	0	15	34	68	40	0	1	2,4	1,3	0,55	26,6	41,6
Eastwell Golding	1012	170	1	96	40	0	15	243	0	16	2	4	41	0	1	4,8	2,4	0,50	22,9	43,5
Emerald	1080	172	19	144	18	0	25	281	0	16	2	3	44	0	2	5,6	4,4	0,78	30,7	47,5
Estera	1304	262	0	38	60	0	18	165	45	17	2	3	41	0	1	2,7	2,4	0,86	26,6	43,2
Ging Dao Do Hua	3531	14	0	11	35	1	19	571	0	62	34	76	83	2	2	4,5	3,8	0,85	45,0	59,0
Golden Star	3853	15	0	12	32	0	17	626	0	54	29	63	70	0	1	3,4	3,7	1,09	48,2	70,9
Granit	1470	198	11	115	19	0	48	273	0	13	5	8	32	0	2	7,4	3,6	0,48	22,4	43,9
Green Bullet	2885	40	24	40	34	0	18	623	0	23	3	6	30	3	0	6,9	4,1	0,60	35,2	57,5
Hallertau Blanc	9502	10	541	100	166	0	28	322	0	32	306	770	81	0	7	11,2	5,3	0,47	19,6	39,5
Hallertauer Gold	1740	255	86	48	69	0	33	347	0	18	2	4	42	0	1	5,4	4,0	0,74	19,4	41,7
Hallertauer Magnum	1586	171	148	112	21	0	14	290	0	15	2	3	37	0	1	13,4	5,5	0,41	23,6	44,4
Hallertauer Mfr.	993	219	40	8	60	0	25	289	0	28	2	4	66	0	2	4,0	3,1	0,78	21,7	40,5
Hallertauer Taurus	2204	82	71	106	94	0	34	323	0	16	38	72	38	0	2	14,2	4,4	0,31	20,1	40,1
Hallertauer Tradition	1417	275	15	34	68	0	27	351	0	19	3	5	73	0	1	5,1	3,5	0,69	29,1	46,1
Harmony	1438	227	3	36	75	0	29	309	0	20	53	100	47	2	1	5,0	4,0	0,80	21,8	44,5
Herkules	3337	91	177	390	30	0	23	517	0	18	2	4	28	0	3	14,4	4,6	0,32	32,7	57,7
Hersbrucker Pure	2126	375	0	118	86	15	47	372	0	21	22	42	32	81	1	3,8	1,7	0,46	19,3	31,6
Hersbrucker Spät	1681	178	4	46	70	35	19	303	0	24	25	44	39	79	1	4,1	4,0	0,99	18,4	36,9
Hüll Melon	5814	5	3	209	75	0	55	186	130	69	254	563	73	213	9	7,2	9,1	1,25	29,6	46,1
Hüller Anfang	658	161	32	7	42	0	26	234	0	29	4	6	63	0	0	1,8	2,8	1,56	13,2	39,3
Hüller Aroma	1057	175	2	11	61	0	24	277	0	23	3	5	48	0	0	3,4	3,0	0,88	22,3	42,2
Hüller Fortschritt	1070	175	30	18	58	0	26	302	0	22	2	4	52	0	0	2,9	3,7	1,26	23,2	41,9
Hüller Start	680	90	4	16	19	0	33	267	0	28	3	5	62	0	0	1,7	2,4	1,44	20,5	41,2
Kazbek	1716	37	66	182	40	0	6	274	0	21	6	14	47	1	3	7,6	4,8	0,63	35,9	60,9

Variety	Myr-cene	2-Metyl-butyl-isobutyrat	Methyl-isohep-tanoate	ß-Oci-mene	Lina-lool	Aroma-dend-rene	Unde-canone	Hu mu-lene	ß-Far-neseen	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß/γ-Ca-dinene	3,7-Seli-nadiene	Gera-niol	α-acids	ß-acids	ß/α	Co-hu-molone	Co-lu-pulone
Kirin 1	3576	12	0	29	35	1	17	572	0	50	27	54	63	0	3	5,2	4,1	0,79	47,2	57,0
Kirin 2	3723	13	0	14	36	1	17	559	0	62	37	85	83	0	2	4,5	4,7	1,03	47,7	70,5
Kitamidori	1069	22	21	155	11	0	10	133	28	27	6	12	40	1	1	9,7	5,1	0,52	20,6	39,1
Kumir	1084	123	3	130	53	0	25	244	0	18	2	4	42	0	1	9,5	3,9	0,41	19,5	35,8
Lubelski	1616	25	6	27	50	0	41	193	88	20	3	6	47	0	2	8,0	4,1	0,52	26,1	44,4
Mandarina Bavaria	7137	166	53	83	93	0	40	509	3	51	95	39	48	0	17	8,2	6,9	0,83	36,3	49,9
Marynka	3729	21	5	313	43	0	27	93	203	14	8	20	24	2	7	11,3	3,6	0,32	20,4	47,1
Mt. Hood	1011	34	60	20	50	0	16	333	0	39	4	9	43	0	3	4,6	4,7	1,01	19,2	39,8
Neoplanta	1042	230	0	154	13	0	13	87	41	17	2	2	39	0	0	7,4	3,0	0,40	33,8	62,6
Neptun	995	226	36	33	51	0	8	192	0	21	2	3	51	0	1	15,2	4,5	0,29	19,9	43,4
Northdown	1043	187	0	134	26	0	12	225	0	16	2	3	42	0	1	6,2	3,7	0,60	26,6	45,6
Northern Brewer	1327	235	2	171	23	0	14	250	0	16	2	3	40	0	3	8,2	3,5	0,43	25,4	48,2
Nugget	922	129	5	106	31	0	14	213	0	16	10	19	37	0	0	10,9	4,2	0,39	26,0	49,0
Opal	1733	237	52	126	99	0	27	319	6	19	2	1	43	0	2	5,9	4,0	0,67	12,5	27,9
Orion	828	147	11	65	40	0	21	187	0	20	2	3	49	0	0	6,7	3,6	0,55	28,5	50,7
Perle	853	150	0	150	12	0	12	233	0	16	2	3	44	0	0	6,0	3,4	0,57	30,8	52,4
Pilgrim	1969	375	1	380	44	0	75	313	0	16	42	86	43	1	12	7,7	3,4	0,43	39,9	63,5
Polaris	2281	59	83	262	16	0	16	351	0	21	1	3	44	0	1	21,1	4,6	0,22	21,8	43,0
Premiant	1222	83	3	84	60	0	28	242	0	18	2	3	43	0	1	9,5	3,6	0,38	16,8	36,7
Pride of Ringwood	1860	36	1	3	15	0	22	31	1	21	74	170	27	0	1	8,0	6,2	0,78	29,1	53,2
Progress	5148	419	162	373	132	27	54	105	0	105	54	104	194	196	15	8,8	3,8	0,44	20,7	41,8
Record	1284	160	1	27	51	0	27	315	0	18	2	4	44	0	0	4,1	5,7	1,39	21,3	40,3
Relax	1872	221	27	28	20	0	33	379	0	23	2	3	41	0	8	0,5	9,3	19,06	37,7	28,0
Rottenburger	1171	174	1	20	49	0	31	325	0	18	2	3	45	0	0	2,6	4,8	1,84	21,3	39,9
Rubin	1615	189	68	113	32	0	11	275	0	20	45	87	46	0	6	12	3,2	0,27	29,4	60,3
Saazer	2197	1	2	18	72	0	56	253	36	28	2	4	64	0	6	3,6	3,1	0,87	23,7	40,7
Saphir	2815	287	6	227	118	8	129	392	0	18	14	28	33	51	2	2,8	4,7	1,69	9,3	38,0
Serebrianker	897	166	27	26	58	0	12	212	0	29	21	37	60	0	5	2,3	2,9	1,27	20,3	37,3

Variety	Myrcene	2-Metyl-butyl-isobutyrat	Methyl-isoheptanoate	ß-Ocimene	Linalool	Aromadendrene	Undecanone	Humulene	ß-Farneseen	γ-Muurolene	ß-Selinene	α-Selinene	ß/γ-Cadinene	3,7-Selinadiene	Geraniol	α-acids	ß-acids	ß/α	Cohumolone	Colupulone
Sladek	1247	109	1	138	64	0	20	258	9	17	2	3	47	0	1	8,7	3,2	0,37	19,6	44,2
Smaragd	2714	76	3	107	84	1	32	542	0	26	4	2	35	3	2	2,8	2,9	1,02	8,4	30,5
Sorachi Ace	2202	7	0	170	25	0	21	120	22	26	2	4	35	0	3	9,6	5,9	0,61	26,8	54,1
Southern Promise	480	71	16	56	0	0	29	232	0	21	12	21	43	49	0	8,8	4,3	0,49	26,2	50,7
Southern Star	706	87	10	17	5	0	18	117	48	22	2	4	51	2	1	11	5,1	0,46	28,7	52,8
Spalter	2026	0	2	26	59	0	48	201	75	25	2	3	59	0	5	3,6	3,5	0,97	23,6	41,2
Spalter Select	8315	185	77	75	263	20	84	366	176	26	16	40	26	71	1	3,9	3,8	0,97	15,5	38,5
Sterling	1484	3	2	148	46	0	12	322	0	19	5	12	28	0	0	12,8	4,4	0,34	30,2	57,3
Strisselspalter	1596	173	2	66	64	32	20	312	0	26	27	51	37	89	1	3,4	3,9	1,16	17,7	35,9
South Africa	1871	18	2	69	10	0	11	448	0	25	38	87	30	2	1	4,6	3,2	0,70	20,6	48,6
Talisman	1578	13	1	222	22	0	12	332	0	19	2	5	30	0	0	9,2	4,7	0,51	27,4	50,1
Tango	11291	384	2	24	213	40	95	58	415	42	107	247	128	265	13	10,2	8,4	0,82	22,1	44,8
Target	3984	7	1	146	96	0	37	422	0	36	5	12	49	16	0	11,4	4,3	0,38	33,8	63,5
Tettnanger	2457	13	5	15	87	0	75	317	25	28	2	4	63	0	13	3,0	2,6	0,86	23,2	40,9
Viking	1933	198	11	259	45	0	49	156	140	17	26	50	46	1	4	6,7	3,7	0,55	22,5	39,8
Vojvodina	1740	335	0	189	20	0	27	344	0	14	1	2	37	0	1	6,1	2,9	0,48	30,5	51,0
WFG	2193	108	2	28	54	0	41	180	120	18	7	13	43	0	3	3,8	3,5	0,92	17,8	37,8
Willamette	1012	146	0	53	44	0	7	85	36	18	2	4	44	1	2	2,8	2,6	0,95	29,7	51,2
Xantia	3332	5	32	513	27	0	18	126	103	19	25	58	27	0	2	13,0	3,9	0,3	25,3	57,8
Yeoman	1005	275	78	65	24	0	14	227	0	14	26	52	36	0	8	10,9	4,3	0,39	25,2	43,1
Zatecki	1241	233	0	69	59	0	17	141	55	17	2	3	40	0	1	3,2	2,5	0,78	25,4	44,6
Zenith	1403	197	1	152	70	0	27	277	0	16	48	102	43	0	2	6,9	2,5	0,37	20,0	46,6
Zeus	917	188	55	64	26	0	2	159	0	53	9	14	95	30	5	15,7	4,9	0,31	33,2	57,0
Zitic	1049	155	64	45	31	0	21	277	0	19	2	3	50	0	4	4,8	3,1	0,65	21,5	39,9

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 analysis for hop delivery contracts

7.5.1 Ring analyses for the 2021 harvest

Since the year 2000 there has been an additional agreement with the hop supply contracts, in which the α-acid content is taken into account. The price agreed in the contract applies if the α-acid content is in a so-called neutral range. If this neutral range is exceeded or undershot, there is a surcharge or deduction. The specifications of the working group for hop analysis specify exactly how the samples are to be processed (sample division, storage), which laboratories carry out the follow-up tests and which tolerance ranges are permitted for the analysis results. In 2021, the IPZ 5d working group again had the task of organizing and evaluating ring analyzes in order to ensure the quality of the α-acid analysis.

In 2021, the following laboratories took part in the chain of tests.

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

The chain tests started in 2021 on September 14th and ended on November 12th, since the majority of the hop batches had been examined in the laboratories during this time. The chain tests were carried out nine times (9 weeks). The sample material was kindly provided by Hopfenring Hallertau. Each sample was only taken from a single bale to ensure the greatest possible homogeneity. On Mondays, the samples were ground with a hammer mill in Hüll, divided with a sample divider (Figure 7.23), vacuum-packed, and taken to the individual laboratories. One sample per day was analyzed during the subsequent weekdays. The analysis results were returned to Hüll a week later and evaluated there. A total of 35 samples were analyzed in 2021.

Figure 7.25: Hammer mill and sample divider

The evaluations were passed on to the individual laboratories as quickly as possible. Figure 7.26 shows an evaluation as an example of what a proficiency test should ideally look like. The numbering of the laboratories (1-7) does not correspond to the list above.

Nr. 6: SIR (22.09.2021)

Laboratory	Measured Value		Mean	S	cvr
1	4.29	4.26	4.28	0.021	0.5
2	4.32	4.27	4.30	0.035	0.8
3	4.27	4.28	4.28	0.007	0.2
4	4.33	4.26	4.30	0.049	1.2
5	4.35	4.37	4.36	0.014	0.3
6	4.32	4.32	4.32	0.000	0.0
7	4.25	4.26	4.26	0.007	0.2

mean	4.30
sr	0.025
sL	0.030
sR	0.039
vkr	0.59
vkR	0.91
r	0.07
R	0.11
Min	4.25
Max	4.37

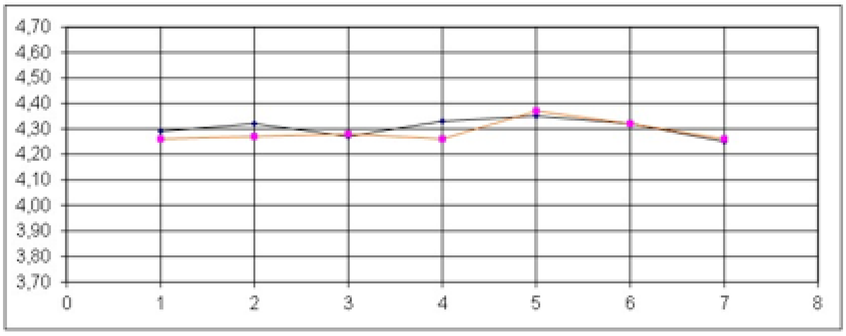


Figure 7.26: Evaluation of a set of chain analyses as an example

The 2020 annual report dealt extensively with the evaluation and mathematical derivation of the various parameters of a proficiency test, which is why there is less information about it in this 2021 report.

The outlier tests are calculated in accordance with DIN ISO 5725. The Cochran test was used within the laboratories and the Grubbs test between the laboratories.

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

With 7 laboratories and a duplicate determination, C must be less than **0.838** at $\alpha = 1\%$ and less than **0.727** at $\alpha = 5\%$, otherwise the data is considered an outlier.

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

With 8 laboratories and a duplicate determination, G must be less than **2.139** for $\alpha = 1\%$ and less than **2.020** for $\alpha = 5\%$, otherwise the data is considered an outlier.

The outliers for 2021 are compiled in Table 7.4.

Table 7.4: Outliers in 2021

	Cochran		**Grubbs**	
Sample	$\alpha = 0{,}01$	$\alpha = 0{,}05$	$\alpha = 0{,}01$	$\alpha = 0{,}05$
22		Laboratory 4		Laboratory 3
Total:	**0**	**1**	**0**	**1**

Since 2013 there have been 5 alpha classes and new tolerance limits. Table 7.5 shows the new classification and the transgressions in 2021.

Table 7.5: Updated alpha acid classes and tolerance limits, as well as their transgressions in 2021

	< 5.0 %	5.0 % - 8.0 %	8.1 % - 11.0 %	11.1 % - 14 %	> 14.0 %
Critical range	+/-0.3 0.6	+/-0.4 0.8	+/-0.5 1.0	+/-0.6 1.2	+/- 0.7 1.4
Transgressions in 2021	0	0	2	0	6

In 2021, the permitted tolerance limits were exceeded 8 times.

In Figure 7.27, all results for the different laboratory analyses are compiled as relative deviations from the mean (= 100%) differentiated according to α-acid contents <5%, >=5% and <10% and >=10%. This graphic shows very well whether a laboratory tends to analyze values as too high or too low.

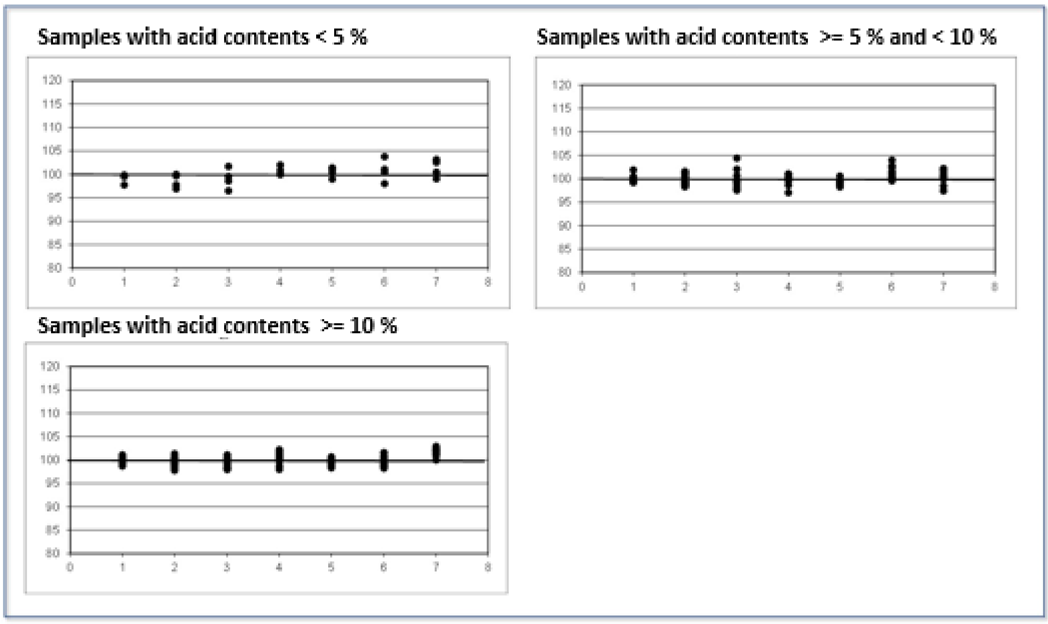


Figure 7.27: Laboratory analyses results relative to the mean

The Hüll laboratory is number 5. This year the α-acid contents were very high and there were many samples with high α-acid contents, so that only four samples with α-acid contents below 5% were available.

7.5.2 Evaluation of check-ups

In addition to the chain tests, control tests have been carried out since 2005, which the IPZ 5d working group evaluates and then forwards to the laboratories involved, as well as to the hop growers' and hops trade association. The first laboratory selects three samples per week, which are then analyzed by three different laboratories in accordance with AHA specifications. The initial examination value applies if the mean value of the follow-up examinations and the initial examination value are within the tolerance limits (Table 7.5). Table 7.6 shows the results for 2021. In all cases, the initial test value was confirmed. Since the 2020 harvest, the BayWa Tettnang laboratory has also been a follow-up laboratory.

Table 7.6: Control evaluation in 2021

Sample name	**Initial test laboratory**	**Initial test value**	**Follow-up tests**			**Mittelwert**	**Results confirmed**
			1	**2**	**3**		
Hallertauer Tradition	Agrolab	6.5	6.0	6.2	6.2	6.12	yes
Hallertauer Mittelfrüher	Agrolab	5.4	5.1	5.2	5.2	5.16	yes
Hallertauer Magnum	Agrolab	15.0	14.7	14.8	14.8	14.78	yes
Sample No. 277, HKS	BayWa	9.1	8.7	9.0	9.1	8.92	yes
Sample No. 301, TET	BayWa	4.2	4.1	4.3	4.4	4.25	yes
Sample No. 306, PER	BayWa	9.1	8.7	9.0	9.1	8.92	yes
HNBR, KW 39-11217	HVG Mainburg	10.4	10.4	10.5	10.6	10.49	yes
HPER, KW 39-10980	HVG Mainburg	8.1	8.1	8.3	8.4	8.27	yes

Sample name	Initial test laboratory	Initial test value	Follow-up tests			Mittelwert	Results confirmed
			1	2	3		
HHMG, KW 39-11623	HVG Mainburg	16.6	16.6	16.7	16.9	16.72	yes
KW 40-PER, Agrolab No. 17124	HV St. Johann	7.7	7.5	7.6	7.7	7.59	yes
KW 40-HMG, Agrolab No. 17362	HV St. Johann	14.4	14.4	14.7	14.7	14.61	yes
KW 40-HKS, Agrolab No. 17358	HV St. Johann	16.7	16.1	16.1	16.6	16.26	yes
KW 41 - PER	HHV Au	10.3	10.2	10.4	10.5	10.37	yes
KW 41 - HMG	HHV Au	16.0	16.0	16.0	16.3	16.11	yes
KW 41 - HKS	HHV Au	20.2	20.0	20.4	20.7	20.36	yes
20483 HAL	Agrolab	5.2	4.8	4.9	5.0	4.91	yes
20885 MBA	Agrolab	9.1	8.8	8.9	9.0	8.89	yes
17885 HKS	Agrolab	19.0	18.9	19.2	19.3	19.15	yes
Sample No. 939, PER	BayWa	9.0	8.9	9.2	9.4	9.16	yes
Sample No. 941, HKS	BayWa	20.2	19.9	20.0	20.0	19.97	yes
Sample No. 943, HMG	BayWa	17.5	17.1	17.2	17.4	17.22	yes
HNUG KW 44 18447	HVG Mainburg	11.1	11.0	11.0	11.2	11.07	yes
HHKS KW 44 17835	HVG Mainburg	17.3	17.3	17.4	18.0	17.571	yes
HPLA KW 44 19455	HVG Mainburg	20.5	20.3	20.4	21.1	20.59	yes
KW 45 – HKS, Agrolab No. 19758	HV St. Johann	16.3	16.1	16.4	16.7	16.40	yes
KW 45 – PER, Agrolab No. 18472	HV St. Johann	7.8	7.4	7.5	7.6	7.51	yes
KW 45 – HMG, Agrolab No. 13428	HV St. Johann	14.2	14.0	14.0	14.3	14.09	yes
KW 46 -NBR	HHV Au	9.8	9.8	9.9	9.9	9.88	yes
KW 46 - HMG	HHV Au	15.7	15.7	15.8	16.1	15.87	yes
KW 46 – HKS	HHV Au	17.7	17.6	17.9	18.0	17.84	yes
Note: KW = calendar week							

7.5.3 Follow-up surveys of the 2021 harvest

The laboratory in Hüll has been involved as a follow-up laboratory since 2019. It evaluates the results. Starting with the 2020 harvest, the BayWa laboratory in Tettnang was also approved as a testing laboratory (Table 7.7).

Table 7.7: Workflow for follow-up laboratories

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

The evaluation of the follow-up examination is sent to the initial examination laboratory as a LfL follow-up examination report within three working days after receipt of the follow-up examination results, which immediately initiates forwarding to the client of the follow-up examination. In 2021 there were a total of 33 follow-up examinations. There was not a single case when the initial test value was not confirmed. Table 7.8 shows the follow-up results in ascending chronological order.

Table 7.8: Follow-up tests in 2021

Sample Name	Initial test laboratory	Initial test results	Follow-up tests			Mean	Results con-firmed
			1	2	3		
DE H HTR Agrolab No. 10777 Lot No. 1059001	HV St. Johann	6.4	6.3	6.4	6.4	6.37	yes
Analysis No. Agrolab 10466 Analysis No. HVG 321/322	HVG Mainburg	5.3	5.4	5.4	5.5	5.43	yes
H DE HMG Analysis No. Agrolab 11052	HV St. Johann	14.1	13.9	14.1	14.2	14.05	yes
DE H HKS Analysis No. Agrolab 15132	HV St. Johann	16.6	16.6	16.6	16.7	16.64	yes
DE H HKS Analysis No. Agrolab 15134	HV St. Johann	15.7	15.6	15.8	15.8	15.73	yes
PER Agrolab-No. 15366	HHV Au	6.9	6.9	7.0	7.0	6.96	yes
DE H HKS Analysis No. Agrolab 17166	HV St. Johann	16.5	16.5	16.5	16.9	16.63	yes
DE H HKS Analysis No. Agrolab 17117	HV St. Johann	15.4	15.0	15.4	15.6	15.33	yes
DE H HKS Analysis No. Agrolab 19295	HV St. Johann	17.6	17.7	17.7	18.1	17.83	yes
DE H HKS Analysis No. 19710	HV St. Johann	17.4	17.9	17.9	18.3	18.03	yes
HHKS Analysis No. Agrolab 15325 Analysis No. HVG 2611/2612	HVG Mainburg	17.7	17.7	17.7	17.9	17.77	yes
DE H HKS Analysis No.-Agrolab 18810	HV St. Johann	16.6	16.7	16.7	17.1	16.79	yes
DE H HKS Analysis No. Agrolab 19733	HV St. Johann	16.7	16.5	16.6	16.9	16.67	yes

Sample Name	Initial test laboratory	Initial test results	Follow-up tests			Mean	Results con-firmed
			1	2	3		
DE H HKS Analysis No. Agrolab 19736	HV St. Johann	14.3	14.1	14.2	15.0	14.43	yes
DE H HKS Analysis No.-Agrolab 21037	HV St. Johann	18.4	18.3	18.6	18.8	18.57	yes
HKS Agrolab-Analysis No. 18921	Agrolab	16.3	16.0	16.2	16.3	16.17	yes
HKS Agrolab-Analysis No. 16409	Agrolab	18.9	18.8	18.9	19.0	18.91	yes
HKS Agrolab-Analysis No. 17562	Agrolab	16.7	16.5	16.5	16.9	16.62	yes
DE H HKS Sample 19775	HV St. Johann	17.3	17.7	17.8	18.2	17.90	yes
SIS SSA Sample 1 Sl 258334	HV St. Johann	8.3	8.2	8.2	8.5	8.29	yes
DE H HKS Sample 18940	HV St. Johann	18.0	18.1	18.4	18.7	18.38	yes
DE H HKS Sample 19062	HV St. Johann	17.2	17.1	17.1	17.5	17.24	yes
DE H HKS Sample 19311	HV St Johann	17.6	17.8	18.1	18.6	18.15	yes
DE H HKS Sample 16420	HV St. Johann	17.3	17.4	17.5	17.6	17.50	yes
DE H HKS Sample 19568	HV St. Johann	17.2	17.1	17.1	17.3	17.18	yes
DE H HKS Sample 18317	HV St. Johann	18.0	17.9	18.0	18.1	18.00	yes
DE H HKS Sample 18233	HV St. Johann	18.1	17.8	17.9	18.0	17.91	yes
DE H HKS Sample 17968	HV St. Johann	14.8	14.4	14.9	15.2	14.82	yes
HNUG Analysis No. Agrolab 19731	HVG Mainburg	10.6	10.6	10.7	11.0	10.75	yes
HMG Agrolab No. 17362	HV St. Johann	14.4	14.4	14.7	14.7	14.61	yes
DE H HKS Agrolab No. 18064	HV St. Johann	16.2	16.1	16.2	16.3	16.19	yes
DE H HKS Sample 19027	HV St. Johann	17.7	17.8	18.1	18.3	18.07	yes
Agrolab-Analysis No. 21163 Lot No. 1304751 Variety HKS	HHV AU	15.0	14.8	14.8	14.9	14.84	yes

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

7.6 Studies of the biogenesis of bitter substances and oils of new breeding strains

With newer breeding lines, extensive biogenesis tests for essential oils and bitter substances are carried out every year to obtain guidance for the correct harvest times. Table 7.9 shows the harvest times, whereby slight shifts in the harvest dates are possible over different years.

Table 7.9: Harvest times of the biogenesis experiments

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

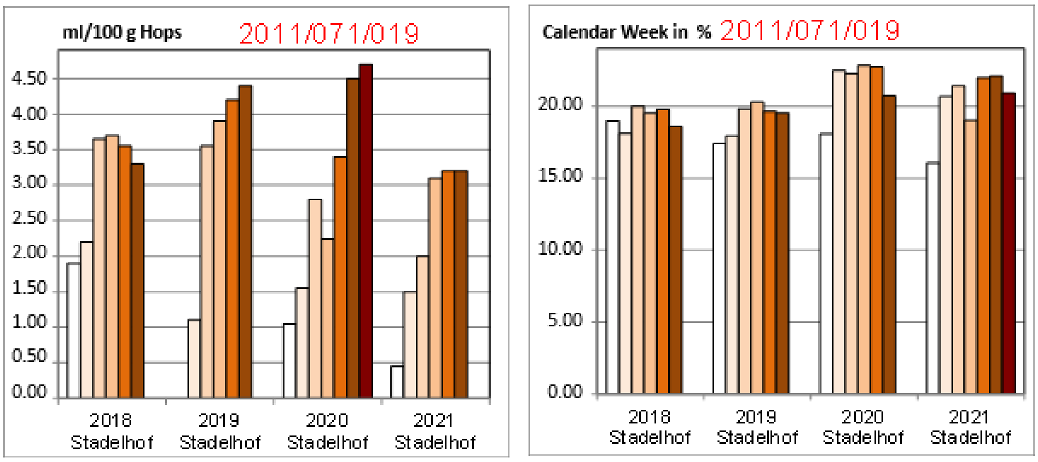


Figure 7.28: Biogenesis of oils and bitter substances in breeding line 2011/071/019

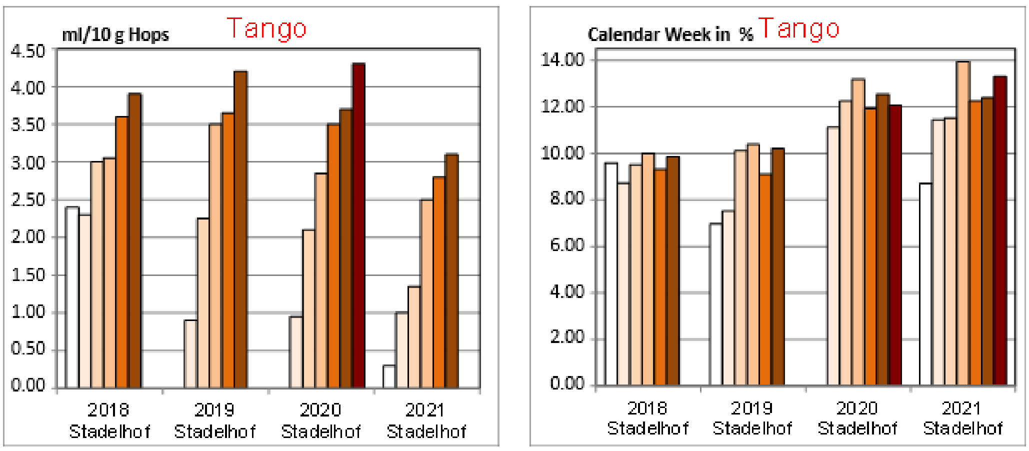


Figure 7.29: Biogenesis of oils and bitter substances in 2011/071/019 = Tango

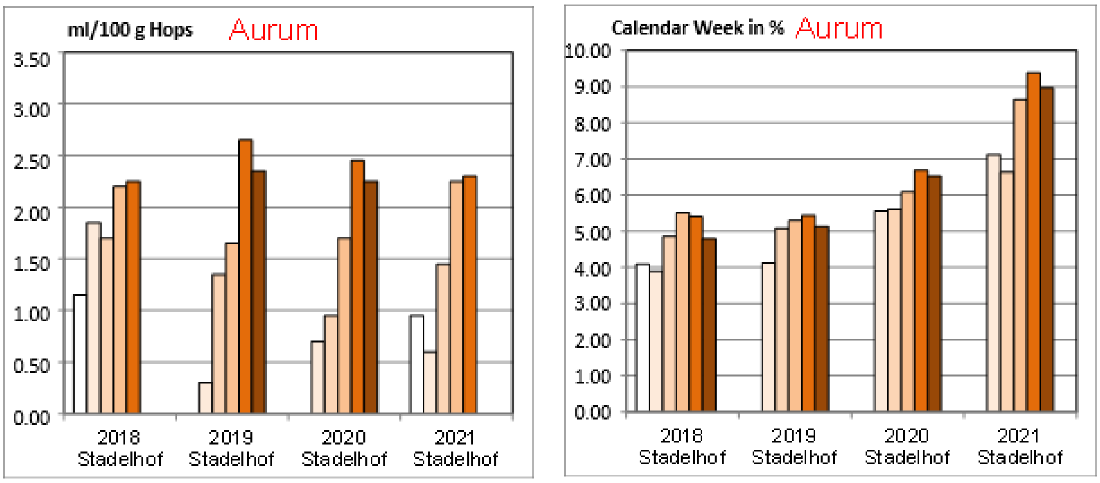


Figure 7.30: Biogenesis of oils and bitter substances in Aurum

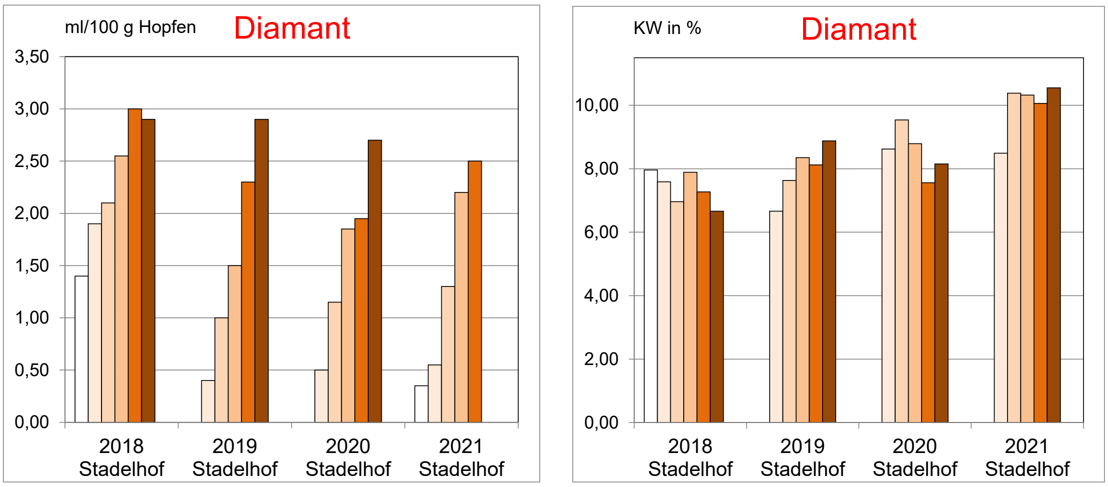


Figure 7.31: Biogenesis of oils and bitter substances in Diamant

The graphics clearly show that the oil content is significantly more dependent on the timing of the harvest than the content of bitter substances. If you want a distinct aroma, you have to harvest later.

The new Tango variety has a very high oil content (2.4 - 4.0 ml/100 g) relative to its alpha acid content (7.5 - 11.0%). The climatic conditions also seem to have different effects on the formation of contents. In dry and hot years, oil concentration even increases. The year 2021 was ideal for the bitter substances, when alpha acid levels were the highest in ten years, but oil levels were lower.

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

The laboratory in Hüll has had a new NIRS device since the spring of 2017. It was financed entirely by the Society for Hop Research (Figure 7.32).

Figure 7.32: NIRS device from Unity Scientific

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

However, work has started on the development of our own calibration for this device based on conductometer and HPLC data. Figure 7.31 shows the correlations of the individual parameters between laboratory values and NIRS values.

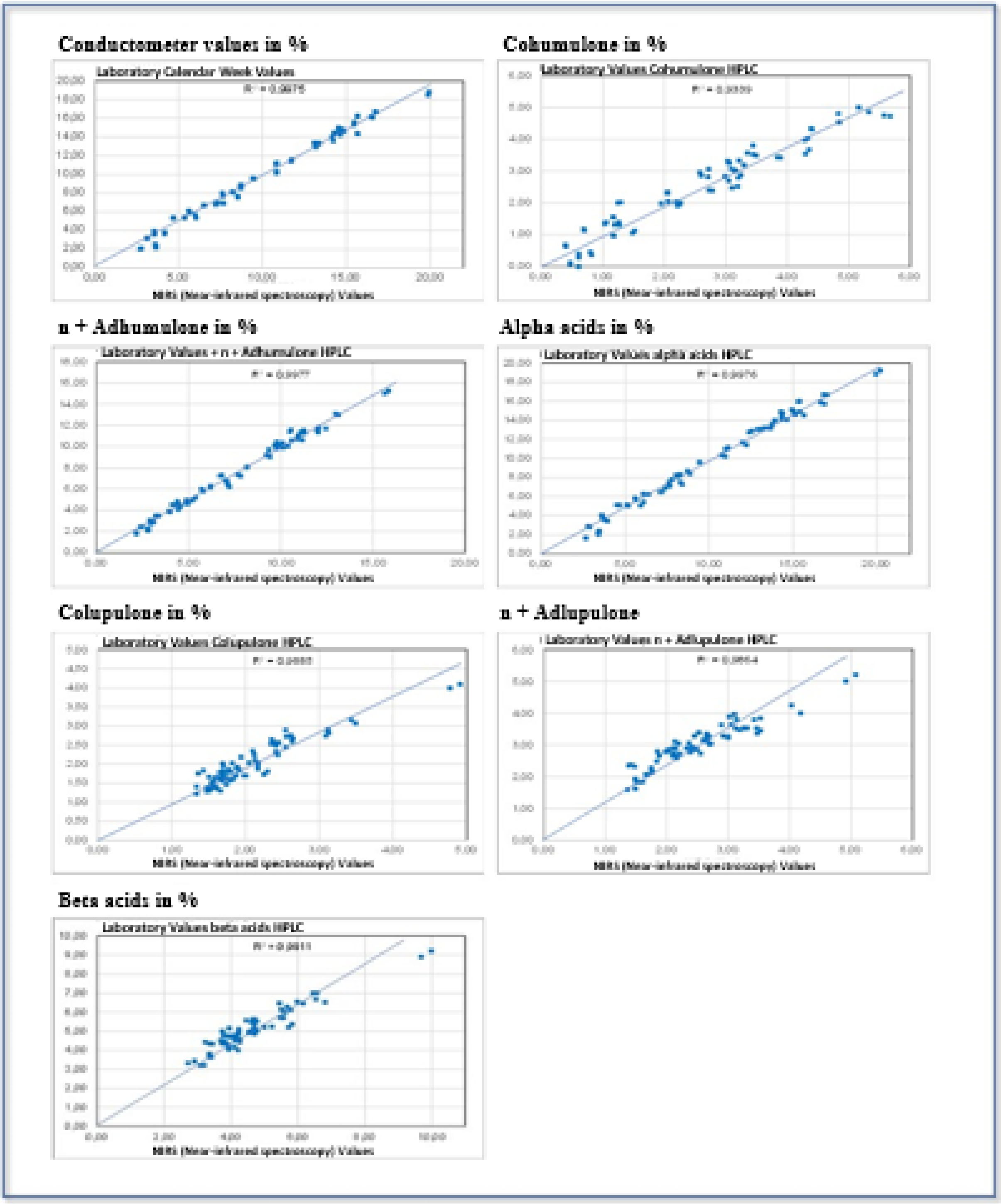


Figure *7.33: Correlations between laboratory values and NIRS values*

Table 7.10: Comparison of the repeat standard deviations (Sr) between standard methods (reference methods) and NIRS methods

Method	Sr – Reference Method	Sr – NIRS-Method	Sr– NIRS/ Reference
Conductometer values	0.0330	0.1182	3.5818
Cohumulone (HPLC)	0.0287	0.0522	1.8188
n + Adhumulone (HPLC)	0.0858	0.1047	1.2203
Alpha acids (HPLC)	0.1173	0.1235	1.0533
Colupulone (HPLC)	0.0367	0.0556	1.5150
n + Adlupulone (HPLC)	0.0464	0.0674	1.4526
Beta acids	0.0782	0.1051	1.3440

A comparison of the repeat standard deviations shows that they are slightly worse with NIRS methods. However, the repeat standard deviations are small overall, which supports the reliability of these methods.

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

Meanwhile, data exists for alpha acids even in the newly-bred Hüll varieties. They were collected from 2012 to 2021. They can be conveniently visualized using Box-Plot representation. Figure 7.34 is an example of such a representation.

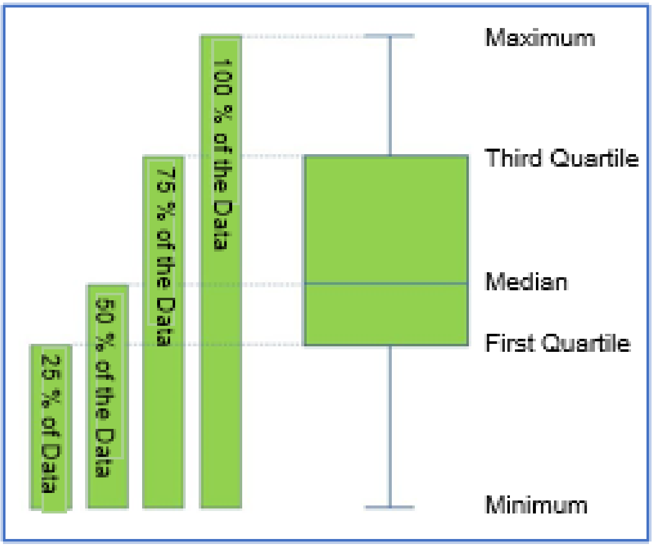


Figure 7.34: Explanation of a box plot display

Figures 7.35 and 7.36 show Box-Plot evaluations of the official AHA results. The illustrations clearly show that the new Hüll cultivars are much more stable with fewer year-over-year fluctuations than, for instance, Perle and Northern Brewer.

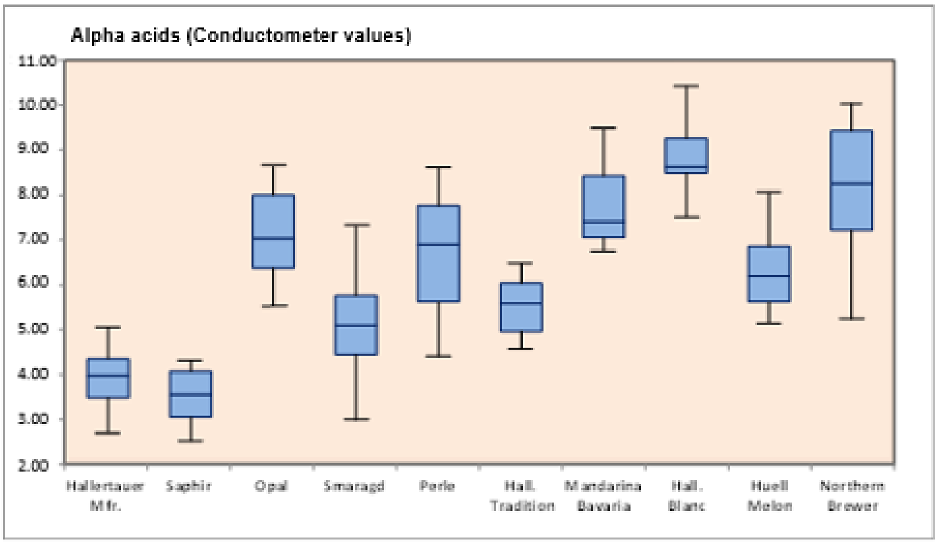


Figure 7.35: Box-Plot evaluation of aroma varieties

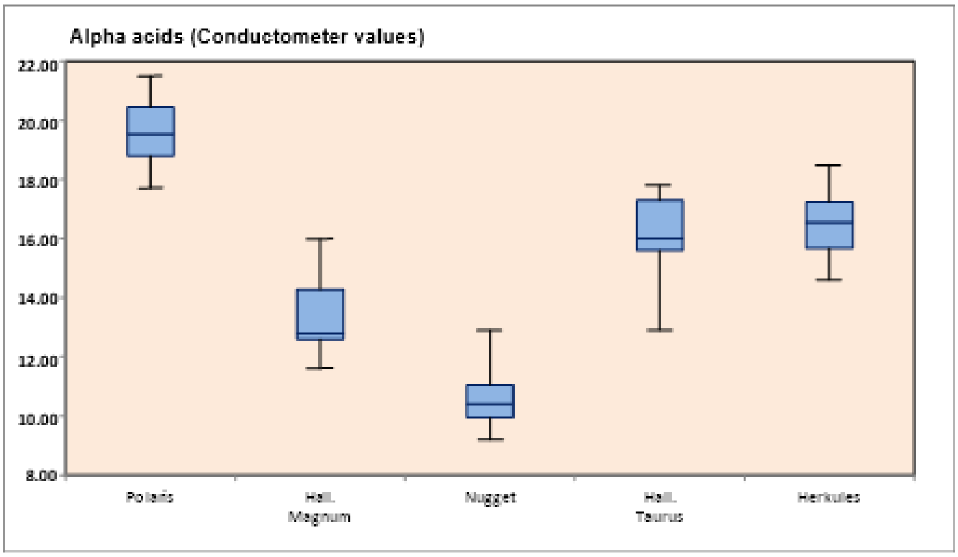


Figure 7.36: Box-Plot evaluation of bitter varieties

7.9 Verification of varietal authenticity in 2021

The working group IPZ 5d has the task to verify the authenticity of the different varieties. This is mandated by the food control authorities.

There were 25 variety checks for the food control authorities (district offices) for the year 2021 and no adverse issues.

8 Ecological Issues in Hop Production

Dr. Florian Weihrauch, Dipl.-Biol.

The task of this Working Group is to conduct applied research, as well as to update the state of knowledge 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. This 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 organic and ecologically 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:	Dr. F. Weihrauch, M. Obermaier, A. Baumgartner, M. Felsl, K. Kaindl, A. Roßmeier, M. Heindl
Collaboration:	Betrieb (*Hop Farm*) Robert Drexler, Riedhof; 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, Institute of Environmental Biotechnology)*
Duration:	March 1, 2014 to December 31, 2022 (project extension)

Objectives

Based on environmental and toxicological assessments, plant protection products containing copper should no longer be used. At the EU level, this active ingredient has received an unfavorable classification in recent years (listing in Appendix I). Thus, it is now permitted to be used 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 countries are, therefore, obligated to work intensely on concepts that allow for the further reduction of the amount of copper in use.

However, organic farms still cannot do without copper as an active ingredient, regardless of the crops they cultivate. First, a four-year test program, lasting from 2010 to 2013, and initiated by the Federal Organic Farming Program (BÖLN) investigated by how much copper quantities in hop cultivation could be reduced without incurring losses. As a result, the currently permissible application rate for hops of 4.0 kg Cu/ha/year was reduced to 3.0 kg Cu/ha/year. After the successful completion of that first project, this follow-up project has the task of critically examining the effects of the new 3.0 kg Cu/ha/year rule, which has now been implemented. It is also tasked to investigate if further reductions in the use of copper are possible.

Approach and results

As in previous years, 14 test sections were created during the 2021 test year. All copper variants were based on Funguran progress, which is the currently approved copper-based crop protection product. The variants consisted of different application rates with different mixing partners as synergists, some of which were also tested as solo variants. The trial was again carried out using the susceptible variety Herkules at the Riedhof site. All treatments were planned with six applications, as is customary in practice, whereby the variants that received just 1 kg of pure copper per ha, 0.5 kg were treated only twice, on the dates of the two middle applications. However, the catastrophic weather conditions in early summer 2021 meant that the plots were impassable for more than five weeks between the first (16 June) and the second (20 July) application. Because the spray schedule could no longer be implemented during the most important phase of the growing season, the entire test had to be abandoned after the third treatment, on August 18th. Instead, the crop was heavily sprayed in order to save at least some of it.

8.2 Development of a catalog of measures that promote biodiversity and networking in hop cultivation

Sponsor:	Bund Ökologische Lebensmittelwirtschaft (BÖLW e.V.) *Organic Food Production Alliance (BÖLW e.V.) and* 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) (Federal Office for Agriculture and Food) über Bundesprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft (*Federal Organic Farming Program including other forms of sustainable agriculture*) (BÖLN-Projekt 2815OE095)
Project Management:	Dr. F. Weihrauch
Team:	Dr. F. Weihrauch, M. Obermaier
Collaboration:	Bund Ökologische Lebensmittelwirtschaft (BÖLW e.V.) *Organic Food Production Alliance (BÖLW e.V.)*
Duration:	August 15, 2017 to December 31, 2022 (project extension)

Procedure and objective

The overall research project seeks to set up six cultivation networks (arable farming, vegetables, hops, potatoes, fruit, and viticulture) focusing on plant health in organic farming, with department coordinators serving as central contacts. Overall coordination is in the hands of BÖLW; while the hop division is coordinated by IPZ 5e in Hüll.

The tasks of the coordinator include building a stable cultivation network of a group of commercial farms, giving advice to farms interested in converting, collecting questions about plant health in the respective crops, recording and disseminating news about innovations; learning about research needs; and formulating cultivation strategies for each crop.

Within the organic hop network, communication takes place mainly in two to three meetings per year, which bring together the relevant players. One of the meetings is a special workshop for farms. In addition, there will be at least one information exchange workshop per year for all the cultivation networks. This ensures the overall coordination of the project.

From the perspective of the hop division, the key events in 2021 were the hop cultivation day as part of the Bioland week (online, February 9th, 2021) and especially the summer visit of the organic hops working group to Alsace (July 27-29, 2021). Because pandemic conditions still prevailed, the number of participants was limited to 22.

A "round table about current plant protection issues in organic hop growing" took place twice in Hüll, in the fall of 2018 and 2019. Unfortunately, it had to be cancelled in 2020 and 2021 because of the pandemic. However, because a lively and direct exchange among practitioners is the intended goal of the project, one meeting was held on April 1st, 2021, on a smaller scale, outdoors in Hüll.

This meeting started with presentations of the experiences by the Fördergemeinschaft Ökologischer Obstbau e.V. (FÖKO) *(Association for the Promotion of Organic Fruit Growing),* which highlighted a demonstration project for the digital recording of plant health in organic fruit growing. A vigorous and heated debate ensued about the transferability of this project to hop cultivation. Despite many positive parallels, the application of the concept in hop cultivation currently seems neither profitable nor easy to implement. Because of the small number of organic hop-growing companies, the data protection law was also considered one of the stumbling blocks. Nonetheless, the discussion served to establish indicators of plant health, which, in addition to their practical use can also help in external communications about organic hops. All companies deemed it important to emphasize the overall organic systems approach instead of just talking about crop protection in the classic sense. This includes raising such issues as soil health and the greening of the hop gardens with cover crops, as well as selecting the right varieties and plant protection agents (approved products and beneficial insects). Also discussed at the round table was the current debate about plant protection measures and different perspectives on land use and the development of markets.

During the summer visit in Alsace, organic hop growers compared their own ideas and measures to those of their counterparts in France. They exchanged ideas and studied a new pelletizing plant for organic hops at the Comptoir Agricole cooperative. They also visited a specialized propagation facility for both common heather (*Calluna vulgaris*) and hops (Figure 8.1) and the breeding program of the Comptoir Agricole. It became clear that the structures in Alsace is significantly different because of the work of the cooperative with its centrally coordinated marketing approach. In Germany, by contrast, in spite of the fact that organic hop growers exchange ideas and cooperate with each other, each farm has to market its own hops.

The main goal of the research project is to pursue targeted management strategies that allow for less reliance on phyto-medically active substances in the cultivation system. The expectations of the BLE or BMEL as sponsor clients are focused on progress and innovation. This involves the development of new management or cultivation systems and a coherent cultivation system as the result, in the form of a “strategy paper,” that concludes the first part of the research project. It will be published in 2022. In December 2020, the BLE approved a two-year extension of the project, which, in a second stage, is intended to support, evaluate, and compare various emerging strategies with concrete data from organic farms.

Figure 8.1: Centrally coordinated propagation of hop plants for the Comptoir Agricole cooperative on the 'Callunas d'Alsace' farm in Alsace.

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 concept of biodiversity is on everyone's mind and the Bavarian state government declared 2019 and 2020 as 'years of biodiversity.' At the beginning of 2018, the EG HVG, together with the LfL, began to initiate measures to stop the loss of species and to promote biodiversity in and around hop cultivation. To includes, for example, the evaluation of possible measures, the creation of a working concept, the formulation individual topics and solutions, the initiation and application for follow-up projects, and the coordination of the implementation of new hop cultivation practices. At the same time, the goal of the project is not to interfere with the productivity of valuable arable land or hop gardens, but to stop the cultivation in marginal, unproductive, or environmentally critical areas, and to redesignate them as protected wild spaces.

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.

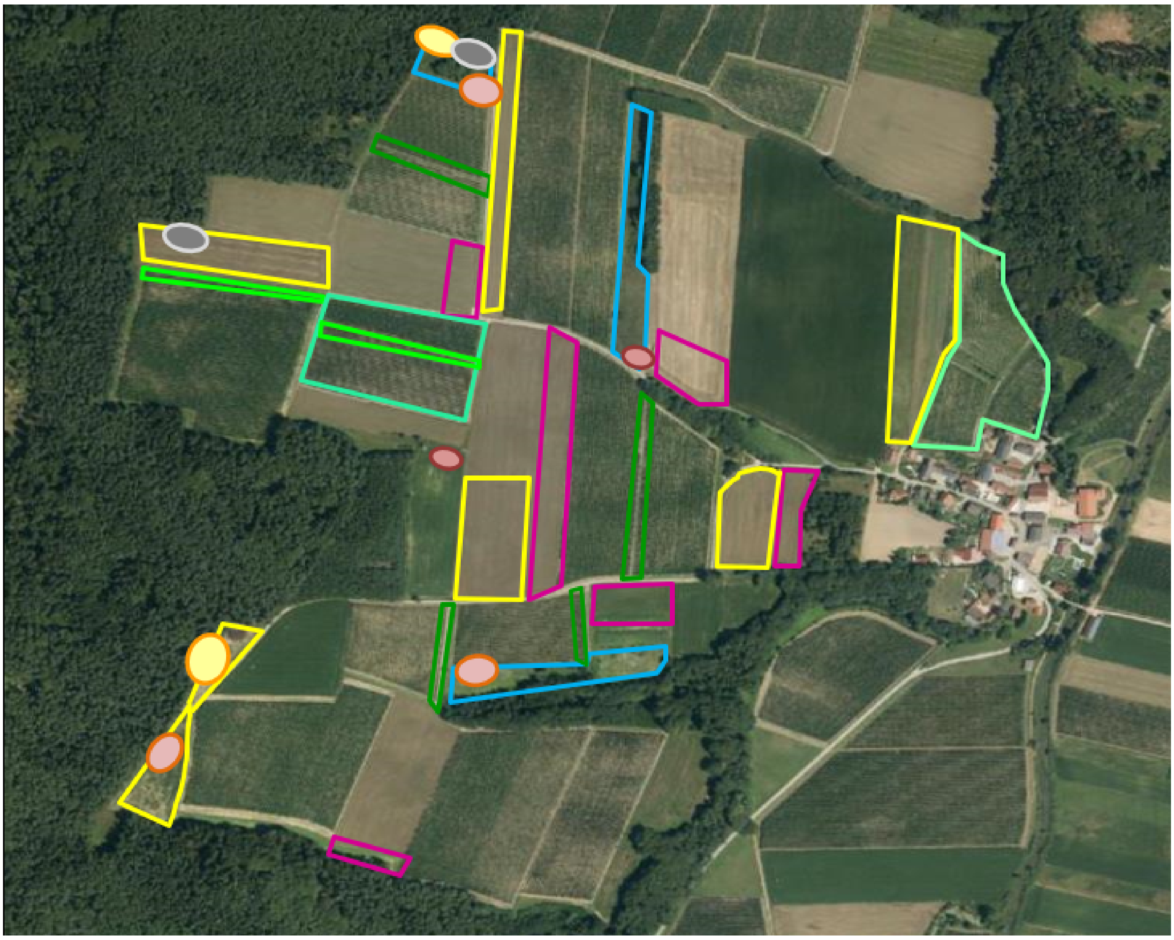


Figure 8.2: Aerial photo of the "Eichelberg biodiversity backdrop" with provisionally planned measures for the promotion of biodiversity and biological plant protection methods.

Concept of the 'Biodiversity Panorama Eichelberg'

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 panorama 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 (Figure 8.3). The starting date for the implementation of these measures was the spring of 2021. The focus of the initial work was on the creation of new living and wintering areas for beneficial insects such as predatory mites. Once these structures are established, they should be infested in the spring of 2022 with predatory mites from viticulture (Figure 8.3).

Figure 8.3: Creation of living and wintering spaces for beneficial insects such as predatory mites in the Eichelberg biodiversity panorama: installation of grape vines on the hop trellises and wild grapes on the anchor wires, in June 2021

8.4 Development of techniques for deploying predatory mites

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: M. Obermaier

Collaboration: Betrieb Blüml GbR, Dürnwind
Koppert Biological Systems

Duration: May 2021 to October 2022

Objective and background

The largest European producer of beneficial insects, Koppert Biological Systems in the Netherlands, is interested in a pilot project in the Hallertau for testing and improving techniques for the release of predatory mites in hops. The aim is the development of an uncomplicated application technique of predatory mites that can help in the control of the common spider mite *Tetranychus urticae*. In terms of costs and personnel requirements, any new technique should not differ significantly from existing acaricide applications. In the 2021 season, initial tests were carried out with a specially designed 'Natutec' device, which is mounted on the rear of a tractor (Figure 8.4). The construction principle was guided by the need for quick and easy mounting of the device without ground contact. This would allow the device to be shared by many companies because the purchase of this device by a single company does not appear to be economically justifiable at this stage.

Figure 8.4: Novel construction by Koppert ('Natutec') for the release of predatory mites in hops; Dürnwind, June 2021

Based on experience by the Hop Research Center during many years of trials, a mixture of two predatory mites, *Neoseiulus californicus* and *Phytoseiulus persimilis*, was used. This proved to be effective. The application timing was also guided by previous experience. The predatory mites were dispersed before the hops reached the tops of the trellises. Also, a pre-assessment ensured that the predatory mites were released well before larger, stable spider mite populations were established.

Method

The newly developed technique was used in several commercial organic hop gardens, with one half of each hop garden receiving predatory mites, while the other half was managed according to usual practice. In addition, a separate trial was carried out by the LfL in a conventionally managed hop plot planted with Herkules, in Dürnwind, near Pfeffenhausen. The trial involved a comparison between an untreated control; two commercial plots, one sprayed with a round of Movento and the other with a round of the acaricide Envidor; and three plots with predatory mites. There were also comparisons with an application of predatory mites on bean leaves, which has been particularly successful in past trial years, whereby the application method was the newly developed Natutec device, supplemented by a later manual application of predatory mites.

Results in 2021

At the beginning of the growing season, the spider mite infestation was low, and the predatory mites could not be released until mid-June. Only shortly before harvest did the number of spider mites increase significantly. Differences among the test variants became discernible only starting in mid-August. As expected, the untreated control had the largest spider mite count per leaf (Figure 8.5).

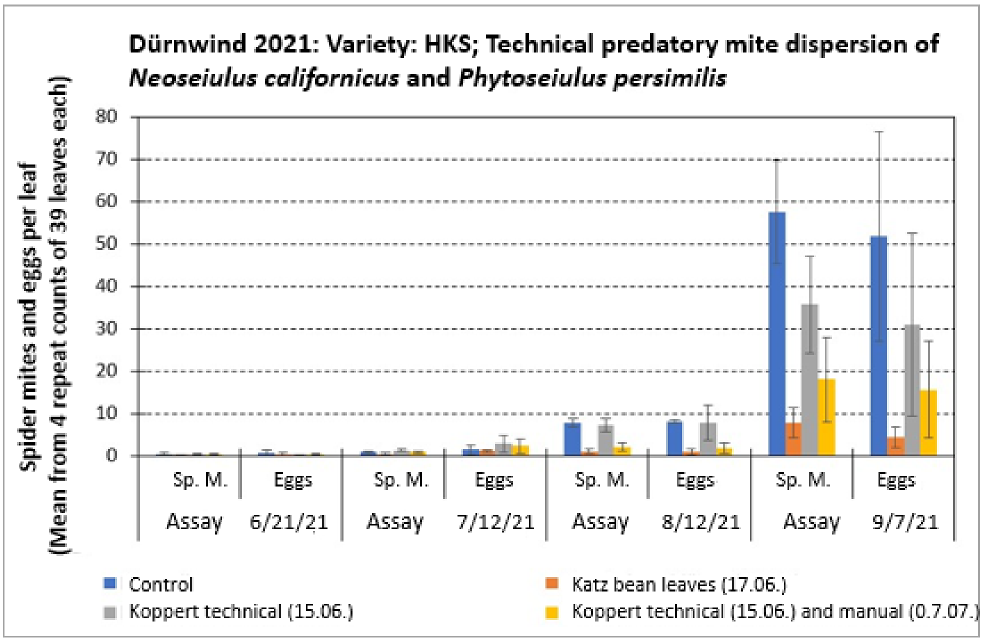


Figure 8.5: Development of the spider mite population with different distribution techniques for predatory mites in the Dürnwind test garden

Although there were some differences between the test variants at the end of the growing season, these are not reflected in the yield or alpha acid content of the crop, neither in comparison to the untreated control nor to the plot with conventional crop protections (Figure 8.6). In addition, a visual examination of some 4,500 cones per variant under a magnifying glass revealed that cone damage differed in severity. The two variants with technical predatory mite applications were only slightly less damaged than the untreated control, whereas the test section with bean leaves did not differ from the sprayed section. Because Herkules is a late-harvest variety, at least minor cone damage is to be expected. However, there was no major damage in any of the variants and, thus, no significant losses in quality.

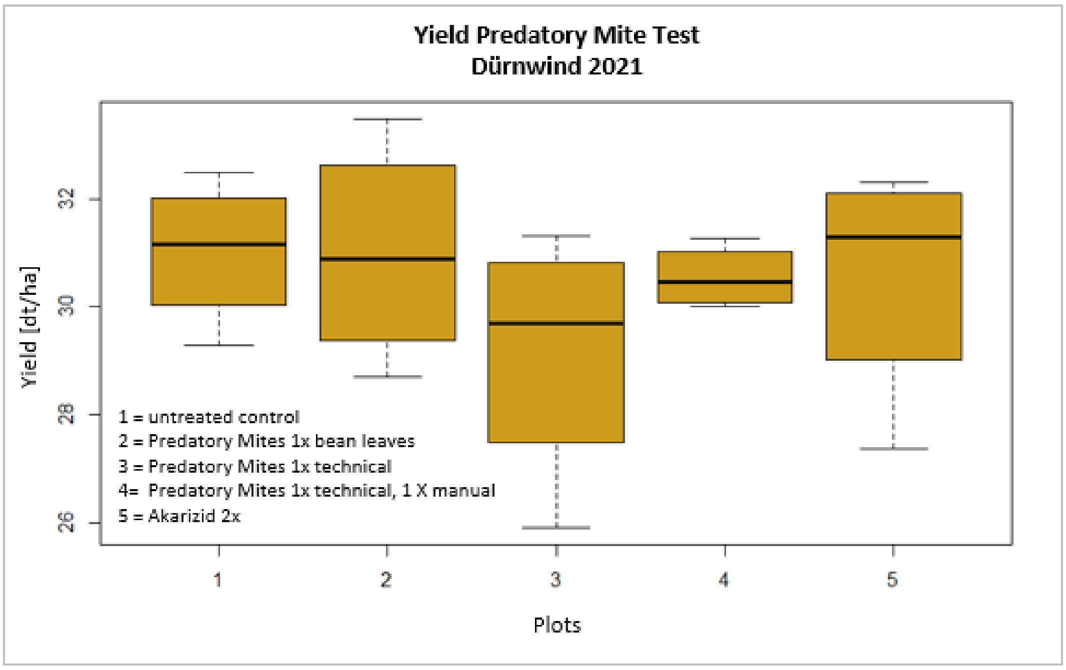


Figure 8.6: The harvested yields of the predatory mite trials on 09/14/21) revealed no differences among the predatory mite variants; nor in comparisons with the untreated control or the conventionally sprayed plots (single-factorial ANOVA)

To understand the results correctly, however, it must be pointed out that the summer months during the 2021 season were generally above-average cool and damp. Thus, 2021 was not a 'spider year.' In other words, there were no economically relevant spider mite infestations in the vast majority of hop gardens in southern Germany. Therefore, no valid conclusions can be drawn from the test hop gardens, in which the method was tested. The weather provides additional, indirect explanations for the lack of impact of the new predatory mite application technique: Because of the extremely bad weather in the spring, which made it very difficult to drive equipment into the hop gardens, the technical application of predatory mites had to be postponed twice. At the time of application, the hop plants had already grown so tall that a large proportion of the predatory mites, which had been distributed via compressed air, failed to land on the plants. An application on younger hops, shortly after training, could have been more targeted; and more predatory mites might have been able to land directly on the plants.

Outlook

For any technical predatory mite application to be competitive with conventional spraying against spider mites, some improvements will still need to be made. In the coming years, further trials in commercial plots are in the planning stage. One of them will be again in Dürnwind, in 2022. At the very least, these tests have shown that a suitable application of predatory mites can achieve results that are comparable with chemical plant protection.

8.5 Establishment of predatory mites in commercial hop plots via under sowing 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 Program 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

A detailed report about this project, which was completed in the spring of 2021, can be found in the 2020 Annual Report.

8.6 Induced resistance to spider mites in hops

Sponsor:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) *[Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Ecology (IPZ 5e)]*
Financing:	Deutsche Bundesstiftung Umwelt (DBU), [German Federal Foundation for the Environment (DBU)] Förderinitiative 'Vermeidung und Verminderung von Pestiziden in der Umwelt', Förderkennzeichen: AZ 35937/01-34/0) *[Funding initiative 'Avoidance and reduction of pesticides in the environment', Funding Reference: AZ 35937/01-34/0)]*
Project Management:	Dr. F. Weihrauch
Team:	M. Obermaier
Collaboration:	20 commercial farms practicing integrated hop production; Arbeitsgruppe IPZ 5d, Hopfenanalytik *[Hop Analytics Working Group]*
Duration:	June 2021 to May 2026

Objective and Background

The common spider mite is the most feared pest in hop cultivation and can build up very large populations very quickly under favorable weather conditions. This can cause enormous losses in quality and yield. With climate change, this hazard is exacerbated by an increased number of dry, hot summer days, which promote mite development. At the same time, society and politics are increasingly focusing on environmental protection and sustainability, and the approval process for effective plant protection products is becoming increasingly difficult. Sustainable alternatives to protect the crop are therefore required for both conventional and organic hop cultivation.

June 2021 saw the start of a new research and innovation project to explore induced resistances in hops to the common spider mite. This is intended to investigate in great detail any potential defenses inherent in the hop plant itself. Such defenses are known to exist in other crops. Observations from various crop protection trials at the Hop Research Center in recent years suggest that hop plants that survive a severe spider mite infestation in one year, can also defend themselves repeatedly and naturally against excessive spider mite infestation in subsequent years (Figure 8.7). The various aspects of this seemingly "learned crop protection" are to be examined in a five-year project.

Figure 8.7: Organic hop garden near Ursbach in two "spider mite years": In 2012, the severe infestation of the still young hop plants led to total loss. In 2018, on the other hand, no relevant spider mite infestation could build up despite suitable weather conditions

Method

The project includes a field trial on 31 commercial plots in 20 hop farms in the Hallertau and Tettnang regions. In each hop garden, a control plot of around 500 m² each was set aside as a "spray window," which was not treated with acaricides or any other agents to combat spider mites over the entire project period. Next to it was one plot that was treated conventionally with plant protection applications just like the rest of the hop garden. In the center of both plots, an area was designated, from which leaves were regularly removed during the growing season to check for spider mite infestations. Test harvests of both plots at the end of the growing season should determine if there are any differences in yield and quality between infested and non-infested areas.

In addition, starting in 2022, the project includes a pot trial under semi-controlled conditions, in which young plants of all four hop varieties, some previously spider mite-infested and some not, are deliberately populated or re-populated with spider mites. Subsequently, the reaction of the plants to these spider mite infestations will be observed and compared to those that had and had not previously been infested. Both parts of that experiment also involve supplementary biochemical analyses of leaf samples.

The selection of cultivars deliberately includes a wide range of economically relevant and widely planted varieties, from traditional landraces to modern high-performance cultivars. These are the landrace Tettnanger (TET) as a very fine aroma variety; the classic Hüll-bred aroma varieties Hallertauer Tradition (HTR) and Spalter Select (SSE); as well as the high alpha variety Herkules (HKS). SSE plays a special role in these experiments because genetically this variety belongs to the Saazer group and thus has a very high aphid tolerance. It is, therefore, particularly well-suited for organic cultivation.

Results 2021

In 2021, the damp weather with only a few hot days in midsummer meant that spider mite populations could not build up quickly either in the Hallertau or in Tettnang. In these commercial plots, therefore, the application of specific plant protection measures to combat spider mites was rarely necessary. If protections were applied, then often only as a side effect of the insecticide Movento, which is used to combat aphids but also provides some protection against the common spider mite. After the test harvests (one harvest per variety from the location most heavily infested with spider mites), there were no detectable difference in yields and alpha acids between treated and untreated plots. However, for HTR, TET, and HKS there were significant differences in yields and alpha acids between untreated and treated plots. For SSE plots, on the other hand, it was not possible to detect lower values in the untreated plots. In fact, the yield in the SSE sprayed trial harvest was even slightly lower than that in the unsprayed plot (Figure 8.8).

The plot trial of the project will start up again after the necessary vernalization of the hop plants in the spring of 2022.

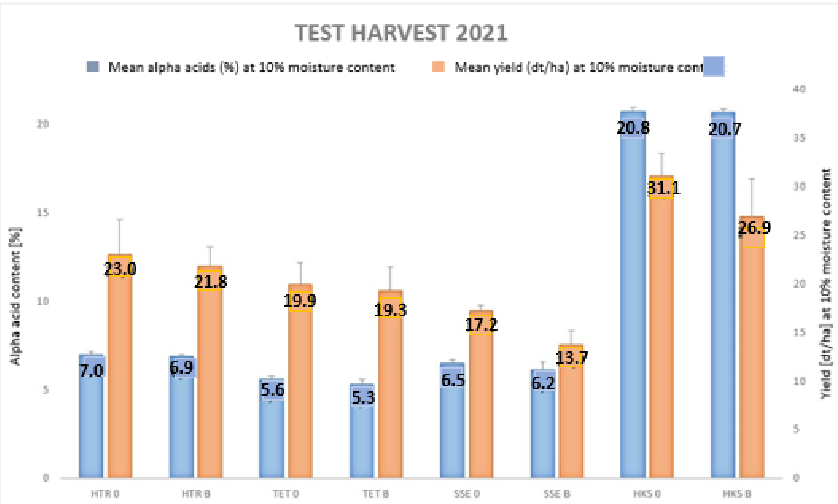


Figure 8.8: Results of the 2021 test harvests that were part of the project on induced resistance to spider mites. Alpha acid content and yield of four tested hop varieties harvested in the most heavily infested sites for the "0" plot untreated against spider mites and the "B" plot treated with pesticides

9 Publications and Technical Information

9.1 Overview of public relations

	Anzahl		Anzahl
Practice-relevant information and scientific papers	34	Guided tours	29
LfL publications	2	Exhibitions/shows and posters	4
Specialist information	18	Expert assessments and opinions	17
Radio and TV broadcasts	5	Internships	7
Internet contributions	6	Participation in working groups	40
Internal events	7	Visited / conducted seminars, conferences, workshops	3 / 5
Seminars, symposia, trade conferences, workshops	7	Lectures and Talks	78

9.2 Publications

9.2.1 Practice-relevant information and scientific papers

Euringer, S., Baumgartner, A.; Kaindl, K.; Obster, R. (2021): Hopfen 2021 - Grünes Heft, Pflanzenschutz. LfL-Information, Editor: Bayerische Landesanstalt für Landwirtschaft (LfL)

Fuß, S. (2021): Pflanzenstandsbericht April 2021. Hopfen-Rundschau, 72. Jahrgang, 05/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 166 - 167

Fuß, S. (2021): Pflanzenstandsbericht August 2021. Hopfen-Rundschau, 72. Jahrgang, 09/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 317

Fuß, S. (2021): Pflanzenstandsbericht Juli 2021. Hopfen-Rundschau, 72. Jahrgang, 08/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 288

Fuß, S. (2021): Pflanzenstandsbericht Juni 2021. Hopfen-Rundschau, 72. Jahrgang, 07/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 232

Fuß, S. (2021): Pflanzenstandsbericht Mai 2021. Hopfen-Rundschau, 72. Jahrgang, 06/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 200

Hagemann, M.H., Seeburger, P., Born, U., Weber, G., Kammhuber, K., Lutz, A., Seigner, E., Wünsche, J.N. (2021): Genetic variation within the promoter of the bitter acid biosynthesis genes of hop partly explain different levels of bitter acids between cultivars. ISHS V. International Humulus Symposium, Editors: Hagemann, M.H. and Wünsche, J.N.

Kammhuber, K. (2021): Ergebnisse von Kontroll- und Nachuntersuchungen für Alphaverträge der Ernte 2020, Hopfen-Rundschau, 72. Jahrgang, 08/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 280 -282

Karer, A., Reindl, A., Portner, J., Fuß, S. (2021): Neues EDV-Tool zur individuellen Berechnung des CO2-Footprints in der Hopfenproduktion. Hopfenrundschau International, 2021, Hrsg.: Verband deutscher Hopfenpflanzer e.V., 70 - 75

Kneidl, J., Weihrauch, F. (2021): Die Grande Dame der internationalen Hopfenforschung geht in Ruhestand: Adieu, Lisa!, Hopfenrundschau International, 2021/2022, Editor: Verband Deutscher Hopfenpflanzer, 66 - 69

Kühne, S., Preißel, S.; Obermaier, M. Weihrauch, F. (2021): Welcher Hopfenschädling ist das? https://pflanzenschutz.oekolandbau.de – Online-Bestimmungshilfe für Schadorganismen im Hopfenbau. Julius Kühn Archiv, 467, 62. Deutsche Pflanzenschutztagung: Gesunde Pflanzen in Verantwortung für unsere Welt; 21.–23. September 2021: Kurzfassungen der Vorträge und Poster, Editor: Julius Kühn-Institut, 485 - 485

LfL, Hopfenring, Verband Deutscher Hopfenpflanzer, LfU, LRA PAF u. KEH (2021): Anforderungen an Anlagen zum Umgang mit wassergefährdeten Stoffen. Hopfen-Rundschau, 72. Jahrgang, 10/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 367 - 370

Obermaier, M., Weihrauch, F. (2021): Raubmilben zur Spinnmilbenbekämpfung im Hopfen? - Ergebnisse eines dreijährigen Forschungsprojektes. Hopfen-Rundschau, 72(05), Editor: Verband deutscher Hopfenpflanzer e.V., 164 - 166

Obster, R. (2021): Pflanzenschutzfachtagung Hopfen - Plant Protection Symposium. Hopfenrundschau International, 2021/2022, Hopfenrundschau International, Editor: Verband Deutscher Hopfenpflanzer e. V., 13 - 16

Portner, J. (2021): 50 % Pflanzenschutzmitteleinsparung durch den *Peronospora*-Warndienst. Hopfenrundschau International, 2021/2022, Editor: Verband Deutscher Hopfenpflanzer e.V., 109 - 115

Portner, J. (2021): Bekämpfung von *Peronospora*-Sekundärinfektionen. Hopfen-Rundschau, 72. Jahrgang, 06/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 194

Portner, J. (2021): Kostenfreie Rücknahme von Pflanzenschutz-Verpackungen PAMIRA 2021. Hopfen-Rundschau, 72. Jahrgang, 08/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 283

Portner, J. (2021): Online-Hopfenbauversammlung 2021. Hopfen-Rundschau, 72. Jahrgang, 1/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 2

Portner, J. (2021): Rebenhäckselausbringung im Herbst künftig unter Auflagen möglich! Hopfen-Rundschau, 72. Jahrgang, 03/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 91

Portner, J. (2021): Rebenhäckselausbringung im Herbst planen! Hopfen-Rundschau, 72. Jahrgang, 08/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 284

Portner, J. (2021): Rebenhäckseluntersuchung als zusätzliche Anforderung in den "Roten Gebieten"! Hopfen-Rundschau, 72. Jahrgang, 08/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 285

Portner, J. (2021): Zwischenfruchteinsaat im Hopfen planen. Hopfen-Rundschau, 72. Jahrgang, 06/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 195

Portner, J. (2021): Übermittlung von Angaben im Hopfensektor. Hopfen-Rundschau, 72. Jahrgang, 05/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 157 - 158

Portner, J., Brummer, A. (2021): Nmin-Untersuchung 2021 und endgültige Nmin-Werte in Bayern. Hopfen-Rundschau, 72. Jahrgang, 05/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 163 - 164

Portner, J., Kammhuber, K. (2021): Fachkritik zur Moosburger Hopfenbonitierung 2021. Hopfen-Rundschau, 72. Jahrgang, 10/2021, Editor: Verband Deutscher Hopfenpflanzer e.V., 358 - 363

Portner, J., Stampfl, J. (2021): Neue LfL-Informationsbroschüre - Tropfbewässerung und Fertigation bei Hopfen. Hopfenrundschau International, 2021/2022, Editor: Verband Deutscher Hopfenpflanzer e.V., 76 - 77

Schlagenhaufer, A. (2021): Effiziente und umweltgerechte Stickstoffdüngung im Hopfenanbau. Hopfenrundschau International, 2021/2022, Editor: Verband Deutscher Hopfenpflanzer e.V., 92 - 97

Seigner, E., Albrecht, T.; Büttner, B.; Lutz, A.; Mohler, V. (2021): Genombasierte Präzisionszüchtung für zukunftsweisende Qualitätshopfen, 1 - 62

Seigner, E., Lutz, A.; Kammhuber, K.; König, W. (2021): Die neue Hüller Aromasorte TANGO mit Klimatoleranz und Nachhaltigkeit fit in die Zukunft. Brauwelt Wissen, BW 44, Brauwelt Wissen, Editor: Fachverlag Hans Carl GmbH, 1128 - 1132

Seigner, E., Lutz, A.; Kammhuber, K.; König, W. (2021): Tango, die neue Hüller Aromasorte - mit Klimatoleranz und Nachhaltigkeit in die Zukunft. Hopfenrundschau International, 30. Ausgabe - 2021/2022, Hopfen-Rundschau - International, Editor: Verband Deutscher Hopfenpflanzer, 82 - 84

Seigner, E.; Lutz, A., Kammhuber, K.; König, W. (2021): Diamant - Environmentally compatible alternative - Breeding success. Brauwelt International - Knowledge, 1/21 - Vol. 39, Editor: Fachverlag Hans Carl, 14 - 18

Weihrauch, F. (2021): Artenvielfalt im Hopfenbau: Das Konzept der ‚Biodiversitätskulisse Eichelberg'. Julius Kühn Archiv, 467, 62. Deutsche Pflanzenschutztagung: Gesunde Pflanzen in Verantwortung für unsere Welt; 21.–23. September 2021: Kurzfassungen der Vorträge und Poster, Editor: Julius-Kühn-Institut, 156 - 156

Weihrauch, F. (2021): Die neue IHB-Sortenliste 2020 wurde veröffentlicht. Hopfen-Rundschau, 72(01), Editor: Verband deutscher Hopfenpflanzer e.V., 16 - 25

Weihrauch, F. (2021): Meeting der Commodity Expert Group (CEG). Hopfen-Rundschau, 72 (12), Editor: Verband Deutscher Hopfenpflanzer e.V., 430 – 430

9.2.2 LfL-Publications

Name(s)	Working Group	LfL-Publication	Title
Arbeitsbereich Hopfen	IPZ 5	LfL-Information	Annual Report 2020 – Specialty Crop Hop
Portner, J.	IPZ 5a	LfL-Information	Hop 2021 - Grünes Heft *(Green Pamphlet)*
Euringer, S.	IPZ 5b	LfL-Information	Hop 2021 - Grünes Heft *(Green Pamphlet)* Pflanzenschutz *(Plant Protection)*

9.2.1 **Internet contributions**

Author(s)	Title	Target Group
Portner, J.	Aktuelle Hopfenbauhinweise und Warndienstmeldungen *(Current hop growing instructions and warning service messages)*	Hop growers
Portner, J.	Veranstaltungen und Hinweise *(Events and notices)*	Hop growers
Seigner, E.	Kreuzungszüchtung mit der Landsorte Tettnanger *(Crossbreeding with the landrace Tettnanger)*	Hop growers and the brewing industry; Ministerium für Ländlichen Raum und Verbraucherschutz, Baden-Württemberg; [*Ministry for Rural Affairs and Consumer Protection, Baden-Württemberg*]; Hopfenpflanzerverband Tettnang e.V. [*Hop Growers' Association Tettnang*]; Gesellschaft für Hopfenforschung e.V.; [*Society for Hop Research, e.V.*]
Seigner, E.; Lutz, A.	Tango, die neue Hüller Aromasorte – Aroma "meets" Klimatoleranz *(Tango, the new Hüll aroma variety - Aroma "meets" climate tolerance)*	Hop and brewing industries
Euringer, S.; Lutz, K.	Arbeiten zum Citrus Bark Cracking Viroid (CBCVd) in der Hallertau *(Work on Citrus Bark Cracking Viroid (CBCVd) in the Hallertau)*	Hop growers
Euringer, S; Lutz, K.; Weiß, F.	Feldhygiene im Hopfengarten *(Field hygiene in the hop garden)*	Hop growers

9.2.2 **Posters**

Author(s)	Title	Target Group
Euringer, S.	Citrus Bark Cracking Viroid	Hop growers, vlf field trip
Seigner, E.	Downy Mildew Forecasting System	ABInBev
Seigner, E.	The New Hüll Aroma and High Alpha Hop Cultivars - Progress in Breeding	ABInBev
Seigner, E.	Climate tolerance, Resistance & Sustainability - Ready for the Future	ABInBev

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

9.3.1 Seminars, symposia, trade conferences, workshops

Date	Speakers	Event	Venue	Target Group
January 28, 2021	Lutz, A., Obster, R., Portner, J., Schlagenhaufer, A., Stampfl, A.	Hop growers conference	Online	Hop growers
February 4, 2021	Münsterer, J.	Seminar: Thermal imaging technology in dry-hopping	Online	Farmers, ssociation members, interested parties
April 1, 2021	Weihrauch, F.; Obermaier, M.	Round table: Crop protection for organc hops	Hüll	Organic hop growers, expert advisers
July 27, 2021	Weihrauch F.; Obermaier, M	Summer field trip: Working group on organic hops	Obernai, Alsace, France	European organic hop growers
August 20, 2021	Portner, J.; Fischer, E.	State Garden Show – Hops for Special Beers	Ingolstadt	Visitors
October 21, 2021	Weihrauch, F.	Session of the Commodity Expert Group: Minor uses for hops	Hüll + Online	International crop protection experts

9.3.2 Attendance at seminar, symposia, conferences, workshops

Date	Title	Target Group	Place
January 11, 2021	Discussion: PSM-Monitoring for hops	Expert panel	Wolnzach
January 28, 2021	Master examination committee meeting in Upper Bavaria (Oberbayern)	Members of the master examination committee	Online
February 18, 2021	DB Fertilizer Ordinance	AELF, IAB 2	Online

9.3.3 Internal events

Date	Title	Event Type	Place
January 11, 2021	Discussion about PSM-monitoring for hops	Working Group meeting	Wolnzach
January 15, 2021	Discussion of investment and future program	Working Group meeting	Wolnzach
March 4, 2021	Review of „Green Book“	Working Group meeting	Hüll
April 1, 2021	Round table on crop protection for organic hops	Practitioner information event	Hüll
June 16, 2021	Discussion of material flow in hops	Working Group meeting	Wolnzach
August 26, 2021	Meeting AK Hops	Working Group meeting	Buch
October 25, 2021	Discussion of N-efficiency of hop fertilization with ECOZEPT	Working Group meeting	Wolnzach

9.3.4 Education, training, continuing education

Date	Event/Partner	Type	Target Group	Place
January 26, 2021	Calculation of economics of *Verticillium* remediation/Euringer S, Lutz K	Other training	Farmers	Online event
February 19, 2021	Master's examination – topics concepts AP in hops / Portner, J.	Master course	Farmers	
June 10, 2021	Master examination AP (oral) Hops / Portner, J.	Advanced traning exam	Farmers	Wolnzach
October 6, 2021	Master's examination - topic concepots AP / Portner, J.	Master course	Farmers	
October 11, 2021	Lessons for students at the agricultural school / Münsterer, J.	Other training	Farmers	Pfaffenhofen
October 13, 2021	Lessons for students at the agricultural school / Münsterer, J.	Other training	Farmers	Pfaffenhofen
November 4, 2021 to November 25, 2021	BiLa – hop cultivation / Portner, J.	Adult education	Farmers	Abensberg

9.3.5 Expert opinions and assessments

Date	Expert	Title	Clent
January 15, 2021	Portner, J.	Funding facts for the funding guideline in the investment and future program	BMEL, JKI, StMELF, IPS
January 18, 2021	Euringer, S.	Expert opinion regarding the application for Art. 53 Luna Sensation VdH	Verband dt. Hopfenpflanzer
January 20, 2021	Weihrauch, F.	Expert opinion regarding the use of Quassia 2020 in organic hop production	Organic Food Production Alliance (BÖLW e.V.)
January 28, 2021	Euringer, S.	Expert opinion regarding Art. 53 Movento SC100 VdH	German Hop Growers Association
February 23, 2021	Euringer, S.	Expert opinion regarding the application for Art.53 Exirel VdH	German Hop Growers Association
February 24, 2021	Weihrauch, F.	Peer review	„Crop Protection“ Magazine
March 29, 2021	Euringer, S.	Expert opinion regarding the application for Art. 53 Danjiri Sumi Agro	Sumi Agro Germany
April 6, 2021	Euringer, S.	Brief regarding approval extension Beloukha	German Hop Growers Association e.V.
April 15, 2021	Portner, J.	EU Hop Harvest Report 2020	BMEL und StMELF
April 22, 2021	Euringer, S., Lutz, K.	Expert opinion regarding the storage of Rebenhäcksel re: sanitation	Center for Agroecology, Pfaffenhofen AELF Paf

Date	Expert	Title	Clent
May 5, 2021	Euringer, S., Geiger, P., Doleschel, P.	Expert opinion regarding the hygienization of bine shreds by pyrolysis (biochar production)	Hopsteiner
May 25, 2021	Geiger, P., Euringer, S.	Expert opinion regarding a letter from HopSteiner about "Vegetable Charcoal"	LfL
July 7, 2021	Euringer, S.	Expert opinion regarding the application for Art. 53 Luna Sensation VdH (Update)	German Hop Growers Association
August 24, 2021	Fuß, S.	Official hop harvest estimate in the Hallertau cultivation area 2021	The Bavarian State Ministry for Food, Agriculture and Forestry (StMELF)
September 28, 2021	Weihrauch, F.	Export opinion about a project outline	German Federal Foundation for the Environment (DBU)
November 9, 2021	Portner, J.	AU measure to dispense with herbicides in hop cultivation	The Bavarian State Ministry for Food, Agriculture and Forestry
December 3, 2021	Weihrauch, F.	Supervision and grading of an M. Sc. Internships with final examination for Wageningen University & Research	Wageningen University & Research

9.3.6 Specialist Information

Euringer, S., Lutz, K.: 'Feldhygiene im Hopfenbau: CBCVd', Hüll, 01.04.2021 (Expert Advice)

Euringer, S., Lutz, K.: 'Feldhygiene im Hopfenbau: Virosen', Hüll, 01.04.2021 (Expert Advice)

Euringer, S., Obster, S. Kaindl, K.: 'Auswahl der in D zugelassenen PSM für den Hopfenbau', Hüll, 01.03.2021 (Expert Advice)

Lutz, A., Seigner, E.: 'Blogbeitrag über Diamant, Aurum und Tango ', Hüll, 19.02.2021, Riley Schmalhaus (Expert Advice)

Lutz, K., Euringer, S.: 'Feldhygiene im Hopfenbau: *Verticillium'*, Hüll, 01.04.2021 (Expert Advice)

Portner, J., Stampfl, J.: 'Fachexkursion Hopfenbewässerung', Forchheim, Wolnzach, 17.08.2021, LfL und HVG (Excursion)

Portner, J.: 'Aktuelle Hopfenbauhinweise und Warndienstmeldungen' (Internet contribution)

Portner, J.: 'Auflagen und Regelungen bei der Bewirtschaftung von Hopfenanlagen an Gewässern!', Online- Hopfenbauversammlung (Video)

Portner, J.: 'Hopfen 2021', Wolnzach (Expert Advice)

Portner, J.: 'Veranstaltungen und Hinweise', 26.11.2021 (Internet contribution)

Seigner, E., Lutz, A.: 'The New Hüll Aroma and High Alpha Hop Cultivars - Progress in Breeding - Resistance, Climate Tolerance and Sustainability', 28.08.2021, ABInBev (Poster)

Seigner, E., Lutz, A.: 'Kreuzungszüchtung mit der Landsorte Tettnanger', 23.02.2021 (Internet contribution)

Seigner, E., Lutz, A.; Kneidl, J.; Ismann, D.; Kammhuber, K.: 'Climate tolerance, Resistance & Sustainability - Ready for the Future - The new Hüll Aroma Hop Cultivars', 28.08.2021, ABInBev (Poster)

Seigner, E.: 'Downy Mildew Forecasting System - Reduction of Plant Protection Chemicals', 28.08.2021, ABInBev (Poster)

Seigner, E.: 'Genombasierte Präzisionszüchtung für zukunftsweisende Qualitätshopfen - 4. Zwischenbericht', 15.04.2021 (project intermediate reprot)

Seigner, E.; Lutz, A.: 'Kreuzungszüchtung mit der Landsorte Tettnanger', 22.02.2021 (project final report)

Seigner, E.; Lutz, A.: 'Tango, die neue Hüller Aromasorte – Aroma "meets" Klimatoleranz' (Internet contribution)

Seigner, E.; Lutz, A: 'Entwicklung von leistungsstarken Hoch-Alpha-Sorten mit besonderer Eignung für den Anbau im Elbe-Saale-Gebiet - 5. Sachbericht', 16.06.2021 (Project intermediate report)

9.3.7 Lectures

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Doleschel, P.	GfH *(Society for Hop Research, e.V.)* annual meeting 2021 - personnel development and projects	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	Board and guests of the Society for Hop Research	Wolnzach-Hüll, November 24, 2021
Doleschel, P., Portner, J.; Euringer, S.; Seigner, E.; Lutz, A.; Kammhuber, K.; Weihrauch, F.	The LfL work in hops in 2020/2021	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	Members, board and guests of the Society for Hop Research	Wolnzach-Hüll, March 24, 2021
Doleschel, P., Vahl, W.	The challenge of climate change – Situation and approaches to solutions in crop growing	LfL	Participants of the LfL annual conference: "Climate change and digital concepts in crop production"	Grub/online, December 1, 2021
Euringer, S.	CBCVd updates	German Hop Growers Association	Members of the Advisory Board of the German Hop Growers Assn.	Wolnzach, October 14, 2021
Euringer, S.	News about the CBCVd in the Hallertau	LfL	Farmers	Geisenfeld, August 3, 2021
Euringer, S.	News about the CBCVd in the Hallertau	LfL	Farmers	Geisenfeld, August 5. 2021
Euringer, S.	News about the CBCVd in the Hallertau	LfL	Hop growers	Online event January 28, 2021
Euringer, S.	QM-CBCVd-Monitoring 1	LfL	Employees/ Temporary workers	Hüll, June 29, 2021
Euringer, S.	QM-CBCVd-Monitoring 2	LfL	Employees/ Temporary workers	Hüll, June 30, 2021
Euringer, S.	Dealing with CBCVd in hop growing	LfL	Master student PAF	Hüll, July 8, 2021
Euringer, S., Obster, R.	Results of the official means test	Commodity Expert Groups CEG	Commodity Expert Groups members	Hüll, October 21, 2021
Euringer, S., Obster, R.	Trial design AMP Hüll	Commodity Expert Groups CEG	Commodity Expert Groups members	Hüll, April 20, 2021
Euringer, S., Weiß, F.	CBCVd Monitoring 2019-21	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	Brewers, Associations	Hüll, November 24, 2021

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Euringer. S., Obster, R.	Urgent PS questions in hop growing 2021	German Hop Growers Association	Federal agencies, Government, Associations	Online, March 19, 2021
Kammhuber, K.	Isolation, identification and analysis of multifidols in hops	Scientific Station for Breweries in Munich e.V.	Brewers	Munich September 15, 2021
Kammhuber, K.	Experiences of the Hüll laboratory as a reference laboratory for alpha acid analysis for hop supply contracts	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	Board and guests of the GfH	Wolnzach-Hüll, November 24, 2021
Lutz, A.	Flowering and ripening times of hop varieties in the Hallertau	LfL	Hop growers	Geisenfeld, August 5, 2021
Lutz, A.	Hop breeding and aroma assessment	Weihenstephan Alumni Brewers Association	Weihenstephan Alumni Brewers Association	Online, April 28, 2021
Lutz, A., Seigner, E.	"*Humulus lupulus*" - hop varieties and development	TUM	Brewers and those interested in beer	Online, April 13, 2021
Lutz, A., Seigner, E.	"*Humulus lupulus*" - hop varieties and development	TUM	Brewers and those interested in beer	Online, June 15, 2021
Lutz, A., Seigner, E.	Flowering and ripening times of hop varieties in the Hallertau	LfL	Young Hop Growers e.V.	Geisenfeld, August 3, 2021
Lutz, A., Seigner, E.	Tango – the new Hüll aroma variety	LfL	Hop growers	Geisenfeld, August 5, 2021
Lutz, A., Seigner, E.	Tango – the new Hüll aroma variety	LfL	Young Hop Growers e.V.	Geisenfeld, August 3, 2021
Lutz, A., Seigner, E.; Kneidl, J.	Tango – the new Hüll aroma variety	LfL	Hop growers	Hüll, January 28, 2021
Lutz, A.; König, W., Seigner, E.	Breeding of resistant hop varieties	Spalter Hopfenpflanzer	Brewers	Spalt, October 12, 2021
Lutz, A.; Seigner, E.	New Hüll varieties - efficient, extensively tested, and fit for the future	Young Hop Growers e.V.	Young Hop Growers e.V.	Online, March 31, 2021
Lutz, Anton	German Hop Champion	German Hop Growers Association e.V.	Hop growers	Kloster Scheyern, July 16, 2021
Lutz, K.	Current information on hop wilt	German Hop Growers Association e.V.	Members of the Advisory Board Association of German hop grower	Wolnzach, October 14, 2021
Lutz, K.	Field hygiene in the hop garden: *Verticillium*-wilt	Interest Group Niederlauterbach (IGN)	Members of the IGN regulars' table	Niederlauterbach, December 20, 2021

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Lutz, K.	Research project on hop wilt	Hopfenring e.V.	Members of the Hopfenring e.V.	Online event, January 25, 2021
Lutz, K.	Research project on hop wilt	LfL	Hop growers	Online-event, January 28, 2021
Lutz, K.	GfH project for hop wilt	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	Technical-scientific committee of the GfH	Hüll, March 24, 2021
Lutz, K.	Research on *Verticillium* in hop	LfL	Members of the Commodity Expert Group (CEG)	Online event, April 20, 2021
Lutz, K.	Dealing with *Verticillium*-wilt in hop growing	Pfaffenhofen Winter School	Protégé, PAF	Hüll, July 8, 2021
Lutz, K., Weiß, F.	Citrus Bark Cracking Viroid Update	German Brewers Association	Members of the Agricultural Committee	Hüll, August 26, 2021
Lutz, K., Weiß, F.; Euringer, S.	Expert Talk: Citrus Bark Cracking Viroid	LfL	Representatives of the hop industry, RjH, HVG and Association of German Hop Growers	Hüll, August 19, 2021
Münsterer, J.	Technical drying and measures for optimizing drying using hops as an example	LLG Saxony-Anhalt, FNR, Saluplanta e.V.	Practicioners, farmers, companies	Online-Veranstaltung, February 23, 2021
Obermaier, M.	(Organic) Hops - Green Gold or the Soul of Beer	Schwarz Services	Employees at the specialist and manage-ment level of the HR group	Online, November 11, 2021
Obermaier, M.	Current projects of the working group on ecological issues of hop growing	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	Editors and influencers from the fields of beer/beverages/ food	Hüll, September 17, 2021
Obermaier, M.	Organic hops, biodiversity and sustainability in hop cultivation	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	Students of agricultural and food sciences at ETH Zurich	Hüll, September 16, 2021
Obermaier, M., Weihrauch, F.	Establishment of predatory mites in hop-growing practice undersown	Bioland e.V.	Participants from organic hop growing (Organic farmers, expert advisers)	Online event, February 9, 2021

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Obster, R.	Plant protection in hop growing	Winter School, Pfaffenhofen	Students in master programs	Hüll, July 8, 2021
Obster, R.	Plant protection in German hop cultivation	German Brewers Association	Members of the Agricultural Committee	Hüll, August 28, 2021
Obster, R., Baumgarnter, A.; Euringer, S.; Kaindl, K.	Tactile test for common spider mites	LfL	Producers of crop protection agents	Digital, July 9, 2021
Obster, R., Baumgarnter, A.; Kaindl, K.	Residue studies Fluopicolide	CEG	Commodity Expert Group members	Hüll, October 21, 2021
Obster, R., Euringer, S.	Current pesticide problems in German hop growing	German Hop Growers Association e.V.	Federal authorities, crop protection companies, representatives from the industry	Pfaffenhofen a. d. Ilm, July 15, 2021
Obster, R., Euringer, S.	Experiment meeting 2021	LfL	Hop Ring consultants and IPZ 5a	Wolnzach, December 13, 2021
Obster, R., Euringer, S.	Presentation of test results	Commodity Expert Groups	Commodity Expert Groups	Hüll, April 20, 2021
Obster, R., Euringer, S.; Fuß, S.	Plant protection in hop growing	LfL	Hop growers	Online event January 28, 2021
Obster, R., Euringer, S.; Portner, J.	Integrated crop protection in hop growing	IVA/ German Hop Growers Association	Federal authorities, crop protection companies, industry representatives, politicians, press	Buch, July 22, 2021
Portner, J.	Current hop growing tips	Young Hop Growers e.V.	Hop growers	Geisenfeld, August 3, 2021
Portner, J.	Current hop growing tips	VlF Kelheim	Hop growers	Geisenfeld, August 5, 2021

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Portner, J.	Current hop growing tips	Hop Growers Association Spalt	Hop growers in the Spalt growing region	Spalt, July 16, 2021
Portner, J.	Arguments for hop irrigation	LfL and HVG	Hop growers	Ilmendorf, Augut 23, 2021
Portner, J.	Experiences with undersowing in hops to protect against erosion	Market in Siegburg	Hop growers in Niederumels-dorf	Niederumelsdorf, July 15, 2021
Portner, J.	Expert discussion on hop irrigation	StMUV	Representative in the field of irrigation at StMELF, StMUV, LfU, TUM	Online, December 15, 2021
Portner, J.	Expert criticism hops	City of Moosburg a. d. Isar	Award winners and guests	Moosburg a. d. Isar September 24, 2021
Portner, J.	Innovative crop protection technology hop cultivation	Hop Growers Association Hallertau	Representatives of the PS industry and federal and state authorities	Eja, July 15, 2021
Portner, J.	Innovative crop protection technology hop cultivation	Hop Growers Association Hallertau, IVA	Officials and representatives of the press	Buch, July 22, 2021
Portner, J., Euringer, S.	Occurrence and distribution of the citrus bark cracking viroid (CBCVd) in hops in the Hallertau	Association of German Hop Growers and HVG	Board members and advisory boards	Tettnang, July 29, 2021
Portner, J., Schlagenhaufer, A.	Material flow summary in hops	Association of German Hop Growers and HVG	Board members and advisory boards	Tettnang, July 29, 2021
Portner, J., Stampfl, J.	Irrigation and fertigation of hops	LfL	Water management officials	Forchheim, Wolnzach, August 17, 2021
Seigner, E.	Genome-Based Precision Breeding for Quality Hops (GHop)	LfL, IPZ 5c, and University of Hohenheim	GHop project partner; University of Hohenheim, HVG, LfL	Online-Meeting, August 13, 2021
Seigner, E., Büttner, B.; Lutz, A.; Kammhuber, K.	New breeding methodology for LfL hop breeding	University of Hohenheim	GHop - Project association partner	Wolnzach, October 6, 2021

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Seigner, E., Lutz, A.	Crossbreeding with the local variety Tettnanger	Ministry of Rural Affairs and Consumer Protection	Ministry for Rural Areas and Consumer Protection, Baden-Württemberg; Hop Growers Association Tettnang; University of Hohenheim	Online, February 23, 2021
Seigner, E., Lutz, A.	Powdery mildew resistance breeding in hops	Hop processing cooperative HVG	HVG Supervisory Board	Wolnzach, October 13, 2021
Seigner, E., Lutz, A.	Tango, the new Hüll aroma variety	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	Technical-scientific committee of the GfH	Hüll, March 24, 2021
Seigner, E., Lutz, A.	Breeding - Research - Climate Adaptation	German Hop Growers Assn; Agriculture Industry Assn.; Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	Agriculture Industry Association, BVL, JKI, German Hop Growers Association	Buch - Aiglsbach, July 22, 2021
Weihrauch, F.	Development of a catalog of measures to promote biodiversity in hop growing	AELF Pfaffenhofen	Authority management AELF Pfaffen-hofen a.d.Ilm	Pfaffenhofen a.d. Ilm, February 8, 2021
Weihrauch, F.	Research projects 2020 at the LfL on the subject 'Copper Minimization in Organic Hops' and 'Hops and Biodiversity'	Bioland e.V.	Participants from organic hop growing (Organic farmers, expert advisers)	Online event, February 9, 2021
Weihrauch. F.	Biodiversity in hop growing: The concept of the 'biodiversity setting Eichelberg'	Julius Kühn Institute	National participants in the field of plant protection	Online event, September 21, 2021
Weihrauch. F.	Experience with regulating hop fleas *Psylliodes attenuatus* in organic hop production	LfL	Scientists and consultants in the ecological farming	Online event, March 16, 2021
Weihrauch. F.	Presentation of the „biodiversity setting Eichelberg“	IGN	Member companies of the Interest Group Niederlauterbach (IGN) e.V.	Eichelberg, April 19, 2021

Speaker(s)	Subject/Title	Event	Target Group	Venue/Date
Weihrauch. F., Obermaier, M.	Research projects 2021 in Hüll in the field of ecology and crop protection in hop growing	Biobetrieb Bentele	Converting and existing organic hop farms in Tett-nang and Alsace, France	Tettnang-Well-muths-weiler, July 1, 2021
Weihrauch. F., Obermaier, M.	Induced resistance to spider mites in hop cul-tivation: Analysis and utilization as a building block in the integrated crop protection	German Federal Foundation for the Environment (DBU)	Scientists from the field of crop pro-tection	Osnabrück, Sep-tember 16, 2021
Weihrauch. F., Obermaier, M.	"Biodiversity setting Eichelberg": Biodiver-sity in harmony with hop growing	Gesellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	Board of the Ge-sellschaft für Hopfenforschung (GfH) *(Society for Hop Research, e.V.)*	Hüll, November 24, 2021
Weihrauch. F., Obermaier, M.	"Biodiversity setting Eichelberg": Biodiver-sity in harmony with hop growing	LfL	Hop growers	Geisenfeld, Au-gust 5, 2021
Weihrauch. F., Obermaier, M.	"Biodiversity backdrop Eichelberg": Biodiver-sity in harmony with hop growing	Young Hop Growers e.V.	Hop growers	Geisenfeld, Au-gust 3, 2021

9.3.8 Radio and TV Broadcasts

Broadcast Date	People	Title	Series	Channel
May 26, 2021	Lutz, A.; Obermaier, M.; König, W.	Together – Getting hands-on in Hop Research Center	Together – Getting hands on in the region	TV Ingolstadt
July 23, 2021	Lutz, A.; Obster, R.	Crop protection in hop growing causes problems	Current news	TV Ingolstadt
August 12.2021	Lutz, A.	Homeland stories in the Hop Re search Center Hüll	Homeland Sto-ries	TV Ingolstadt
September 19, 2021	A. Lutz	New hops from Upper Bavaria	Schwaben und Altbayern	BR
November 5, 2021	Lutz, A.; Obster, R.	Panel Discussion about the state of German Hops– CBC 20201, recorded October 13, 2021	BEER CULTURE SUMMIT 2021	Online podcast USA

9.3.9 Internships

Theme	Supervisor	Intern(s)	Start	Finish
Hop research	Kammhuber, K.	Student	September 21, 2020	February 12, 2021
Hop research	Lutz, A.	Student	March 1, 2021	July 30, 2021
Hop research	Lutz, A.; Lutz, K.	Student	June 14, 2021	June 18, 2021
Hop research	Lutz, A.	Student	February 15, 2021	July 9, 2021
Hop research	Weihrauch, F.	University student	June 1.2021	September 30, 2021
Hop research	Lutz, A.	Student	July 19, 2021	July 23, 2021
Hop research	Lutz, A.	Student	February 15, 2021	July 9.2021

9.3.10 Guided tours (No. = number of participants)

Date	Name	Subject/Title	Guest(s)	No.
June 11, 2021	Doleschel, P. Kammhuber, K.; Lutz, A.; Seigner, E.	LfL hop research, hop breeding, hop analysis, beer tasting	Alumni of the German Rural Youth Association, Mr. Opperer	30
March 24, 2021	Doleschel, P. Lutz, A. Weihrauch, F. Kammhuber, K.; Lutz,K.	Hop breeding, ecological issues in hop growing, hop analysis, crop protection in hop growing	President of the LfL, S. Sedlmayer	5
August 2, 2021	Euringer, S.	Crop protection trials, hop pruning, Beloukha	Belchim Crop Protection (Belgium)	5
September 16, 2021	Kammhuber, K.	Hop research in Hüll with a focus on analytics	Retired food chemists	20
July 30, 2021	Lutz, A.	LfL hop research, hop breeding, hop varieties, and beer tasting	President of the LfL, S. Sedlmayer, and the board of directors of Remonte Bräu Schleissheim, e.G	8
October 11, 2021	Lutz, A.	LfL hop research, hop breeding, and hop varieties	ABInBev	3
October 14, 2021	Lutz, A.	LfL hop research, hop breeding, hop varieties, hop aroma, and beer tasting	Ratsherrn Brauerei	4
July 21, 2021	Lutz, A.	Hop Varieties	Agricultural technical school, Pfaffenhofen	15
Aug.18, 2021	Lutz, A.	Hop varieties and harvest dates	ISO-Hop farms	105
April 29, 2021	Lutz, A.	Hop breeding and Hüll varieties	TUM, Research brewery	5
July 19, 2021	Lutz, A.	Hop breeding and varieties	Brauerei Planck	2
July 22, 2021	Lutz, A.	Hop breeding and varieties, beer tasting	Horticultural Society Wolnzach	20

Date	Name	Subject/Title	Guest(s)	No.
May 12, 2021	Lutz, A.	Hop breeding and new varieties from Hüll	Brewer	1
August 3, 2021	Lutz, A.	Hop breeding, hop varieties and aroma, beer tasting	Machinery and Industry Group Ilmtal	20
August 18, 2021	Lutz, A.	Hop breeding, hop varieties, harvest date	Hopfenring eV, Trial Supervisor	5
July 24, 2021	Lutz, A.	Hop breeding, varieties and beer tasting	Horticultural association, Niederlauterbach	20
August 25, 2021	Lutz, A.	Hop breeding, varieties, hop ripening time	BayWa Group (BayWa AG)	10
July 8, 2021	Lutz, A. Seigner, E. Kammhuber, K.	LfL hop research, hop breeding, hop varieties and their use in beers, hop analysis	Doemens students	25
July 20, 2021	Lutz, A. Seigner, E. Kammhuber, K.	LfL hop research, hop breeding, hop varieties and their use in beers, hop analysis	Brewing technology students at TUM, Doemens	30
September 15, 2021	Portner, J.	Guided tour of the House of Hops and discussion of hop topics with the hop organizations	President S. Sedlmayer	6
September 9, 2021	Seigner, E.	LfL hop research, hop breeding, hop varieties, downy mildew prognosis system, hop harvest	BreweryArco-Valley	10
August 30, 2021	Seigner, E.	Hop research, hop breeding, varieties, forecasting systems	ABInBev	45
September 23, 2021	Seigner, E.	Hop research of the LfL, hop breeding, hop varieties, plant protection, disease forecasting systems, hop harvest	Molson Coors Beverage Company, Christian Hansen Group - Biotechnology	3
September 30, 2021	Seigner, E.; Euringer, S.	Hop research of the LfL, hop breeding, hop cultivars, hop aroma, plant protection	ABInBev - Financial Management Group	19
September 1, 2021	Seigner, E.; Forster, B.	Biotechnology and genome analysis in LfL hop research	Doemens, Dr. Plapperer	1
September 9, 2021	Seigner, E.; König, W., GfH	LfL hop research, hop breeding, Pero warning system, Hop harvest, beer tasting	KUS, District of Pfaffenhofen	11
August 25, 2021	Seigner, E.; Lutz, A.	Hop research, hop breeding, varieties, aroma evaluation	Erdinger Weissbier Brewery	3
September 10, 2021	Seigner, E. Obermaier, M. Kammhuber, K.	LfL hop research, breeding, varieties, harvest, organic hop cultivation, hop analytics	Brewers and influencers	20
August 19, 2021	Weihrauch, F.	Presentation of the ‚Biodiversity setting Eichelberg;‘ hops and biodiversity	KUS District Pfaffenhofen	12

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)
Lutz, K.	Gesellschaft für Hopfenforschung, e.V.	Society for Hop Research, e.V.
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
	EU Commodity Expert Group Minor Uses Hops	EU Commodity Expert Group Minor Uses Hops
	JKI - Fachbeirat Geräte-Anerkennungsverfahren zur Beurteilung von Pflanzenschutzgeräten	JKI Advisory Committee — equipment approval procedure for assessing plant production equipment
	Meisterprüfungsausschuss Regierung von Oberbayern für den Ausbildungsberuf Landwirt	Boards of Examiners Lower Bavaria, Upper Bavaria East, Upper Bavaria West, for Qualified Agriculturalist
Seigner, E.	Gesellschaft für Hopfenforschung, e.V.	Society for Hop Research, e.V.
	Gesellschaft für Pflanzenzüchtung, e.V.	The Society for Plant Breeding e.V. (GPZ)
Member	**Organization (Native language)**	**Organization (English)**

Weihrauch, F.	Arbeitsgemeinschaft Bayerischer Entomologen e.V.	Working Group of Bavarian Entomologists
	British Dragonfly Society	British Dragonfly Society
	DGaaE, AK Neuropteren	DGaaE, German Society for General and Applied Entomology, AK Neuroptera
	DPG, Deutsche Phytomedizinische Gesellschaft	DPG, German Phytomedicinal Society
	DgaaE, AK Nutzarthropoden und Entomopathogene Nematoden	DGaaE, Study Group Beneficial Arthropods and Entomopathogenic Nematodes
	DgaaE, Deutsche Gesellschaft für allgemeine und angewandte Entomologie	DGaaE German Society for General and Applied Entomology
	DgfO, Deutsche Gesellschaft für Orthopterologie	DGfO, German Society of Orthopterology
	EU Commodity Expert Group (CEG) Minor Uses in Hops	EU Commodity Expert Group (CEG) Minor Uses in Hops
	Gesellschaft deutschsprachiger Odonatologen e.V.	Society of German-speaking Odonatologists e.V.
	Gesellschaft für Hopfenforschung e.V.	Society for Hop Research, e.V.
	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
	Wissenschaftlich-Technische Kommission des Internationalen Hopfenbaubüros	Scientific and Technical Commission (WTK) of the International Hop Growers’ Convention (IHB)
	Worldwide Dragonfly Society	Worldwide Dragonfly Society

10 Our Team

For the State Institute for Agriculture - Institute for Plant Production and Plant Breeding - Hüll / Wolnzach / Freising were active in 2021 (AG = working group):

IPZ 5

Coordinator: Direktor, LfL, Dr. Peter Doleschel

Alexandra Hertwig
Birgit Krenauer

IPZ 5a

AG Hopfenbau, Produktionstechnik

(*Hop Cultivation, Production Technology*)

Managing Director: LD Johann Portner

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

IPZ 5b

AG Pflanzenschutz im Hopfenbau

(*Plant Protection in Hop Cultivation*)

Head: Simon Euringer

Anna Baumgartner
Maria Felsl
Korbinian Kaindl
Kathrin Lutz
Marlene Mühlbauer
Regina Obster
Johann Weiher
Florian Weiß (since October 25, 2021)

IPZ 5c

AG Züchtungsforschung Hopfen

(*Hop Breeding Research*)

Head: Bureau Director (RD) Dr. Elisabeth Seigner (until November 30, 2021)

Acting: LR Anton Lutz (from December 1, 2021)

Brigitte Brummer
LTA Renate Enders
CTA Brigitte Forster
Stephan Gast (until March 31, 2021)
CTA Petra Hager
LTA Brigitte Haugg
Maximilian Heindl
Agr.-Techn. Daniel Ismann
LTA Jutta Kneidl
Katja Merkl
Sonja Ostermeier
Ursula Pflügl
Andreas Roßmeier
Maximilian Schleibinger (since June 7, 2021)

IPZ 5d

AG Hopfenqualität und -analytik

(*Hop Quality and Analytics*)

Head: Bureau Director (RD) Dr. Klaus Kammhuber

Sandra Beck (since August 16, 2021)
MTLA Magdalena Hainzlmaier
CL Evi Neuhof-Buckl
Dipl.-Ing. agr. (Univ.) Cornelia Petzina (until April 30, 2021)
CTA Silvia Weihrauch
CTA Birgit Wyschkon

IPZ 5e

AG Ökologische Fragen des Hopfenbaus

(*Ecological Issues in Hop Cultivation*)

Head: Dipl.-Biol. Dr. Florian Weihrauch

M.Sc. Maria Obermaier