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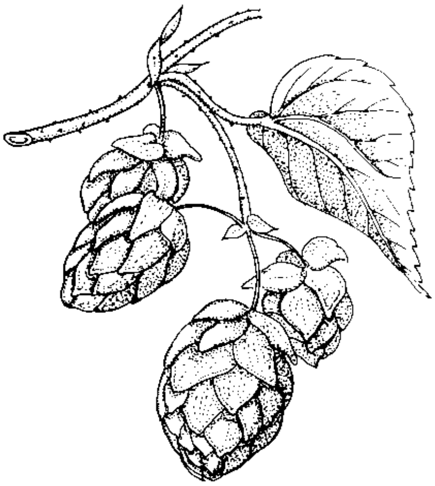
Annual Report 2019

Special Crop: Hops



Bavarian State Research Center for Agriculture

- Institute for Crop Science and Plant Breeding -

and

Society for Hop Research e.V.

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Annual Report 2019

Special Crop: Hops

Foreword

Climate change has by now become an undeniable fact, and it presents major challenges for hop cultivation in the future. In the Hallertau, summers will henceforth be much warmer and drier. Based on social pressures, the permitting of pesticides and their use will also become much more restrictive. The Fertilizer Ordinance will be strengthened again in 2020. This means that new strategies and approaches in the cultivation, processing technologies, sanitary and phytosanitary measures, as well the breeding of hops, need to be considered.

The Working Group IPZ 5a is now working on a “fertigation”-focused irrigation project. In addition to managing the water requirements of the hop plant during dry phases, this technology should also allow for more targeted, needs-based methods of fertilization with the result of a more efficient utilization of nutrients. In addition, the project studies the nitrogen dynamics in hop soils, and carries out tests in the composting and recycling of spent hop bines with the aim of optimizing the nutrient efficiency of organically bound nitrogen.

In some hop gardens, in 2019, the *Citrus bark cracking viroid* CBCVd has been detected for the first time, which, if not dealt with properly, has the potential of becoming a serious threat to hop cultivation in the Hallertau region.

Modern hop varieties such as Mandarina Bavaria, Ariana, Callista, Hallertau Blanc, as well as Polaris and Herkules have demonstrated in 2019 that they can produce stable alpha-acid yields. These Hüll cultivars also offer solutions that allow for the implementation of the Fertilizer Ordinance. Because these varieties were raised with reduced nitrogen additions throughout their entire development from the seedling stage onward, the result was a selection of individuals with the most efficient uptake of nutrients. Finally, resistance breeding to cope with such pests as powdery mildew, peronospora, and aphids has been a top priority of our work. In the future, hop cultivation will remain successful only with varieties that have a broad spectrum of natural resistances. A highlight of the Hüll breeding effort was the market launch of the Spalter offspring Diamant as part of the annual hop inspection tour. The subsequent beer tasting also confirmed the breeding success at Diamant.

The IPZ 5e Working Group will certainly play a key role in the future because of societal demands to reduce the use of chemicals in hop gardens.

The LfL hop research effort is well positioned and ready to accept and overcome the challenges faced in growing hops in Bavaria and in Germany in the future. This annual report presents the large variety of activities of the Hop Research Center in Hüll. Obviously, a successful hop research program would not be possible without the hard work of the Center’s committed and creative staff. Therefore, we would like to take this opportunity to thank all employees in Hüll, Wolnzach and Freising.

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

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

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1 Statistical Hop Production Data

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

1.1 Acreage data

1.1.1 Structure of hop production

Tab. 1.1: Number of hop farms and their acreages in Germany

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

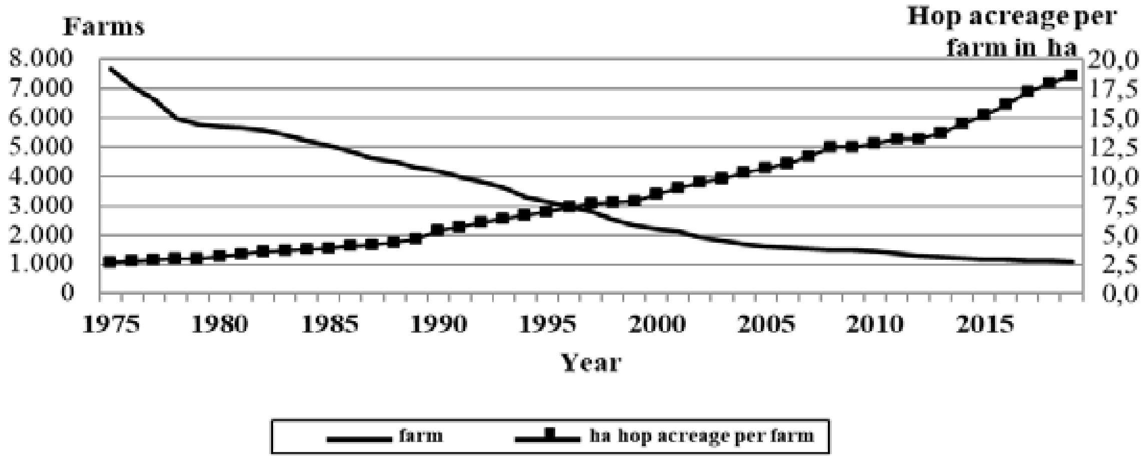

Fig. 1.1: Number of hop farms and their acreages in Germany

Tab.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		Increase + / Decrease - 2019 to 2018				Increase + / Decrease- 2019 to 2018			
	2018	2019	ha	%	2018	2019	Farms	%	2018	2019
Hallertau	16,780	16,995	215	1.3	903	886	- 17	- 1.9	18.58	19.18
Spalt	404	415	11	2.8	55	52	- 3	- 5.8	7.34	7.98
Tettnang	1,397	1,438	41	2.9	132	128	- 4	- 3.1	10.58	11.23
Baden, Bitburg and Rhineland-Palatinate	22	22	0	± 0	2	2	± 0	± 0	11.00	11.00
Elbe-Saale	1,541	1,547	6	0.4	29	29	± 0	± 0	53.13	53.35
Germany	**20,144**	**20,417**	**274**	**1.4**	**1,121**	**1,097**	**- 24**	**- 2.2**	**17.97**	**18.61**

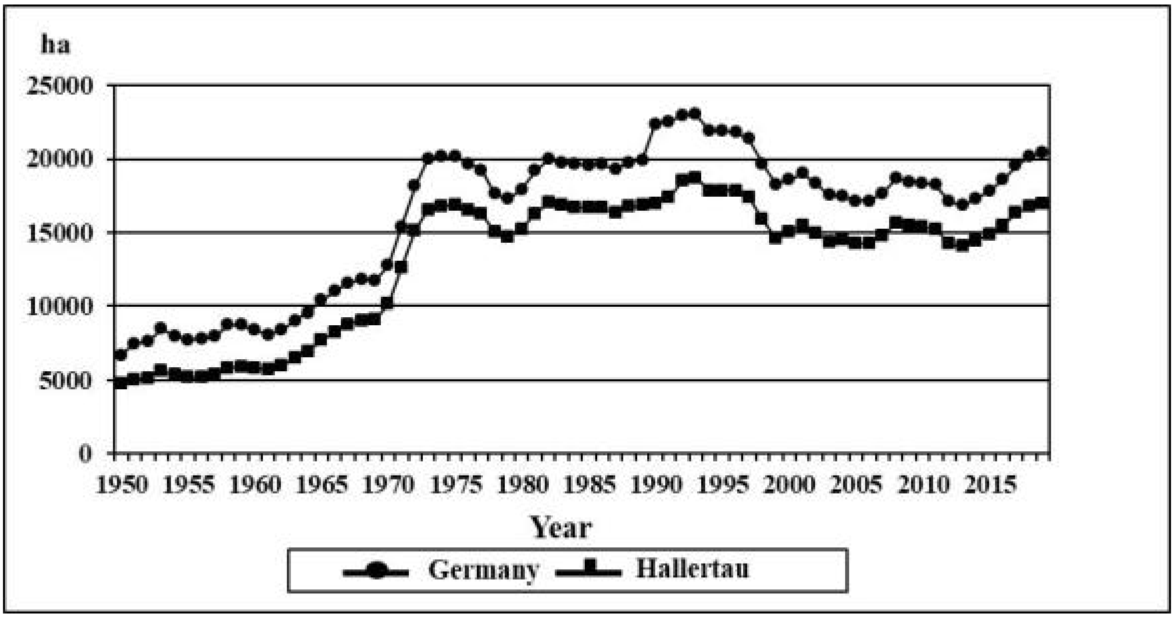

Fig. 1.2: Hop acreage in Germany and in the Hallertau

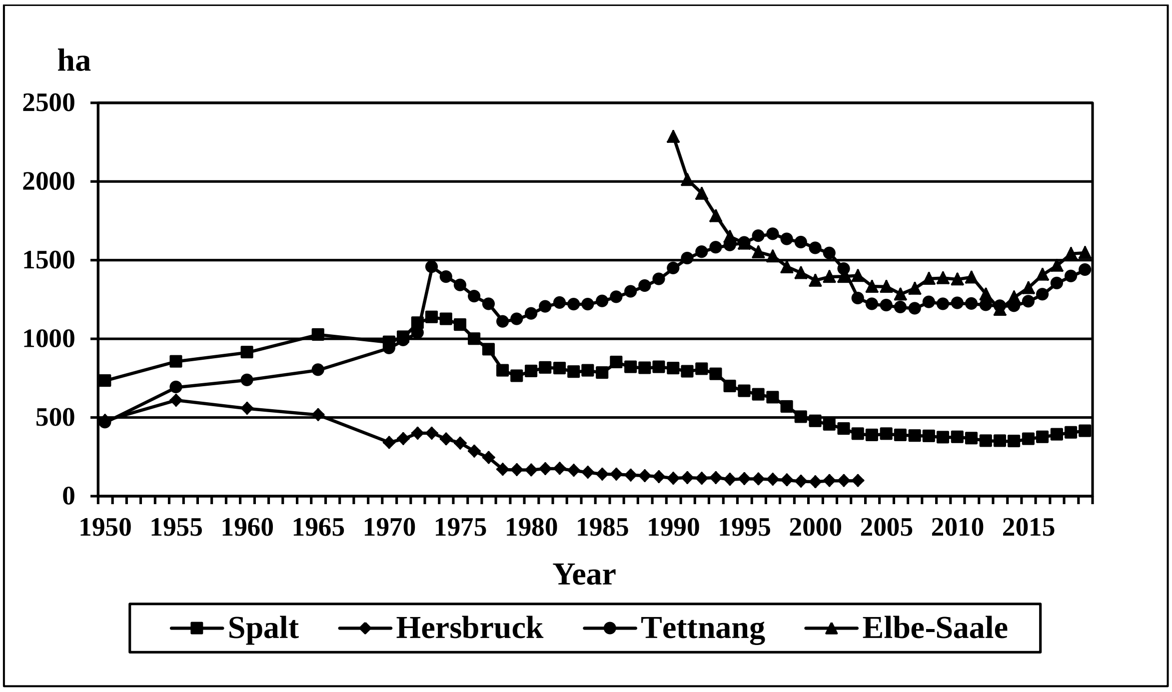

Fig. 1.3: Hop agreage in Spalt, Hersbruck, Tettnang and Elbe-Saale

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

1.1.2 Hop varieties

In 2019, the German hop acreage increased for the 6th time in a row, this time by 274 ha, to a total of 20,417 ha.

The proportion of **aroma varieties** is 55%. In addition, flavor varieties have been counted separately in recent years, and Brewers Gold has been included internationally in this group for the first time. The area of flavor hops under cultivation has declined once again. This applies especially to Amarillo, a variety that has been cultivated in Germany for a few years. Its acreage has declined by almost one-third as a result of unexpectedly high yields.

The cultivation acreages of such old landraces as Hallertauer Mittelfrüh and Tettnanger, as well as of such classic aroma varieties as Saphir (Sapphire) and Northern Brewer, also report declines. By contrast, such already strong, traditional aroma varieties as Perle, Hallertau Tradition and Spalter Select experienced once again substantial increases in acreages of 145 ha, 59 ha and 33 ha, respectively.

The **bitter hop acreage** increased again, too, and now accounts for 45%. As with aroma varieties, older bitter varieties, such as Hallertauer Magnum and Taurus are experiencing declines. On the other hand, Herkules (+245 ha) and Polaris (+ 51 ha) were able to increase their areages again. Today, Herkules is by far the most-planted hop variety in Germany (6,554 ha), occupying almost one-third of the entire hop acreage.

Tab. 1.2: Hop varieties in German growing regions in hectares in 2019

Aroma varieties

Variety	**Hallertau**	**Spalt**	**Tettnang**	**Elbe-Saale**	**Other areas**	**Germany**	**Varieties in %**	**Changes in ha**
Amarillo	183		7	16		**206**	**1.0**	**-94**
Ariana	66	5	5			**76**	**0.4**	**8**
Brewers Gold	18					**18**	**0.1**	**2**
Callista	50	1	9	5		**66**	**0.3**	**-6**
Cascade	69	5	4	9	1	**87**	**0.4**	**1**
Comet	8		0			**8**	**0.0**	**0**
Hallertau Blanc	140	3	13	12		**167**	**0.8**	**-1**
Hallertauer Gold	4	3				**7**	**0.0**	**0**
Hallertauer Mfr.	506	31	140		1	**678**	**3.3**	**-9**
Hallertauer Tradition	2,637	32	58	39	4	**2,770**	**13.6**	**59**
Hersbrucker Pure	1	2				**3**	**0.0**	**0**
Hersbrucker Spät	911	7	0			**918**	**4.5**	**-6**
Hüll Melon	94	5	12	12		**123**	**0.6**	**-17**
Mandarina Bavaria	265	3	12	18		**298**	**1.5**	**-23**
Monroe	23		4			**26**	**0.1**	**-4**
Northern Brewer	145			135		**279**	**1.4**	**-13**
Opal	143	1	1			**146**	**0.7**	**5**
Perle	2,778	36	75	251	8	**3,148**	**15.4**	**145**
Relax	4					**4**	**0.0**	**-1**
Saazer	7			149		**156**	**0.8**	**0**
Saphir	410	19	43	20		**492**	**2.4**	**-23**
Smaragd	64	1	17			**83**	**0.4**	**1**
Spalter	0	118				**118**	**0.6**	**-2**
Spalter Select	489	98	20	4		**611**	**3.0**	**33**
Tettnanger			732			**732**	**3.6**	**-18**
Total (ha)	**9,017**	**370**	**1,152**	**669**	**15**	**11,222**	**55.0**	**37**
Percentage (%)	**44.2**	**1.8**	**5.6**	**3.3**	**0.1**	**55.0**		**0.2**

Bitter Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Hallertauer Magnum	1,320	3		628	3	**1,954**	**9.6**	**-38**
Hallertauer Merkur	10	3				**12**	**0.1**	**-2**
Hallertauer Taurus	213	1	0	14		**228**	**1.1**	**-30**
Herkules	6,122	37	262	128	5	**6,554**	**32.1**	**245**
Nugget	111			12		**123**	**0.6**	**-5**
Polaris	160		19	96		**275**	**1.3**	**51**
Record	1					**1**	**0.0**	**0**
Others	42	1	4	1		**48**	**0.2**	**16**
Target					0	**0**	**0.0**	**0**
Total (ha)	**7,978**	**45**	**286**	**878**	**8**	**9,195**	**45.0**	**237**
Percentage (%)	**39.1**	**0.2**	**1.4**	**4.3**	**0.0**	**45.0**		**1,2**

All Varieties

Variety	Hallertau	Spalt	Tettnang	Elbe-Saale	Other areas	Germany	Varieties in %	Changes in ha
Total (ha)	**16,995**	**415**	**1,438**	**1,547**	**22**	**20,417**	**100.0**	**274**
Percentage (%)	**83.2**	**2.0**	**7.0**	**7.6**	**0.1**	**100.0**		**1.3**

1.2 Harvest volumes, yields and alpha-acid contents

The German 2019 hop crop was 48,472,220 kg. Significantly, it exceeded the previous year's crop, which was 41,794,270 kg, by 16%. Despite an acreage increase of 274 ha and a higher proportion of high-yielding varieties in several growing regions, such a large crop had not necessarily been expected, mostly because of unfavorable weather conditions including long periods of heat without precipitation. While the insufficient rainfall and a storm shortly before harvest time caused a significant drop in hop yields in the wine-growing region of Spalt, the Tettnang region experienced sufficient rainfall and thus a record harvest.

For all of Germany, the average yield of 2,374 kg/ha is well above the previous year's 2,075 kg/ha, which puts it into record-breaking territory.

In 2019, the alpha-acid content of most of Germany's important aroma varieties was generally above the average of the last 5 years, but below that of the last 10 years. Among the bitter varieties, Hallertauer Magnum was disappointing. Its alpha-acid content did not even come close to the 5-year average. The high-alpha varieties Hallertauer Taurus and Herkules, however, were a pleasant surprise. Their alpha contents were mostly on a par with the averages over the past 10 years. Overall, the total amount of alpha acid produced in Germany in 2019 are estimated to be some 5,260 metric tons (MT), which is about 1,260 MT or almost one-third more than the previous year.

Tab. 1.3: Harvest volumes and yields per hectare of hops in Germany

	2014	2015	2016	2017	2018	2019
Yield kg/ha	2,224	1,587	2,299	2,126	2,075	2,374
Acreage in ha	17,308	17,855	18,598	19,543	20,144	20,417
Total harvest in kg	38,499,770	28, 336,520	42,766,090	41,556,250	41,794,270	48,472,220

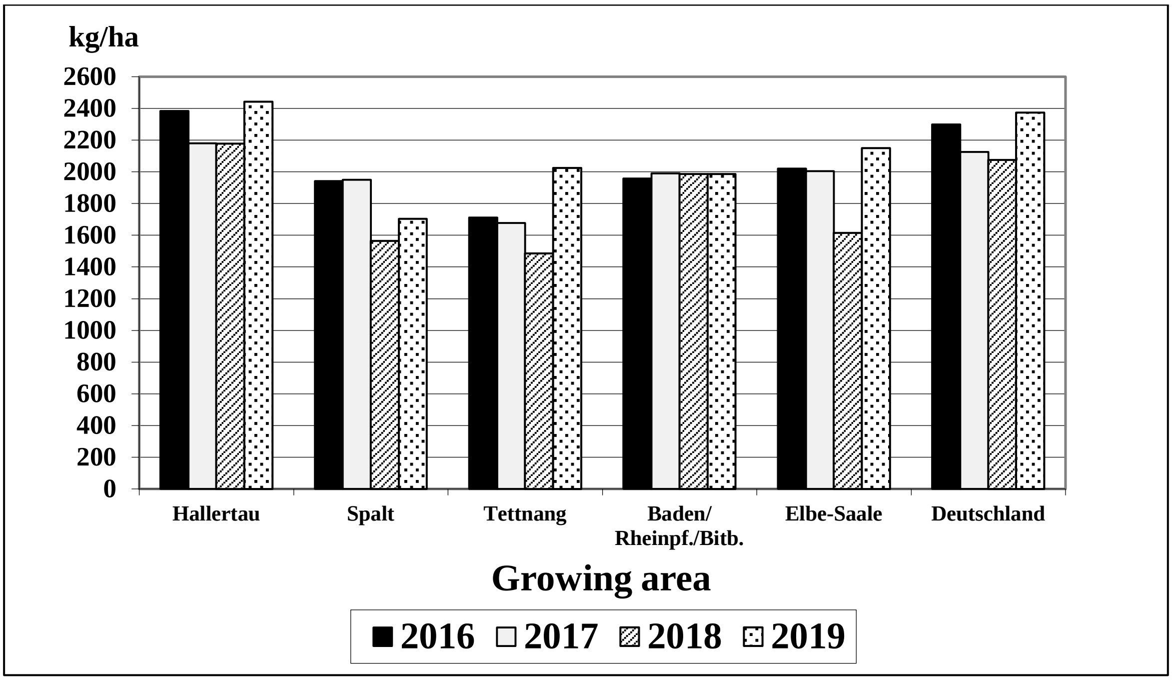

Fig. 1.4: Average yields of the different growing regions in kg/ha

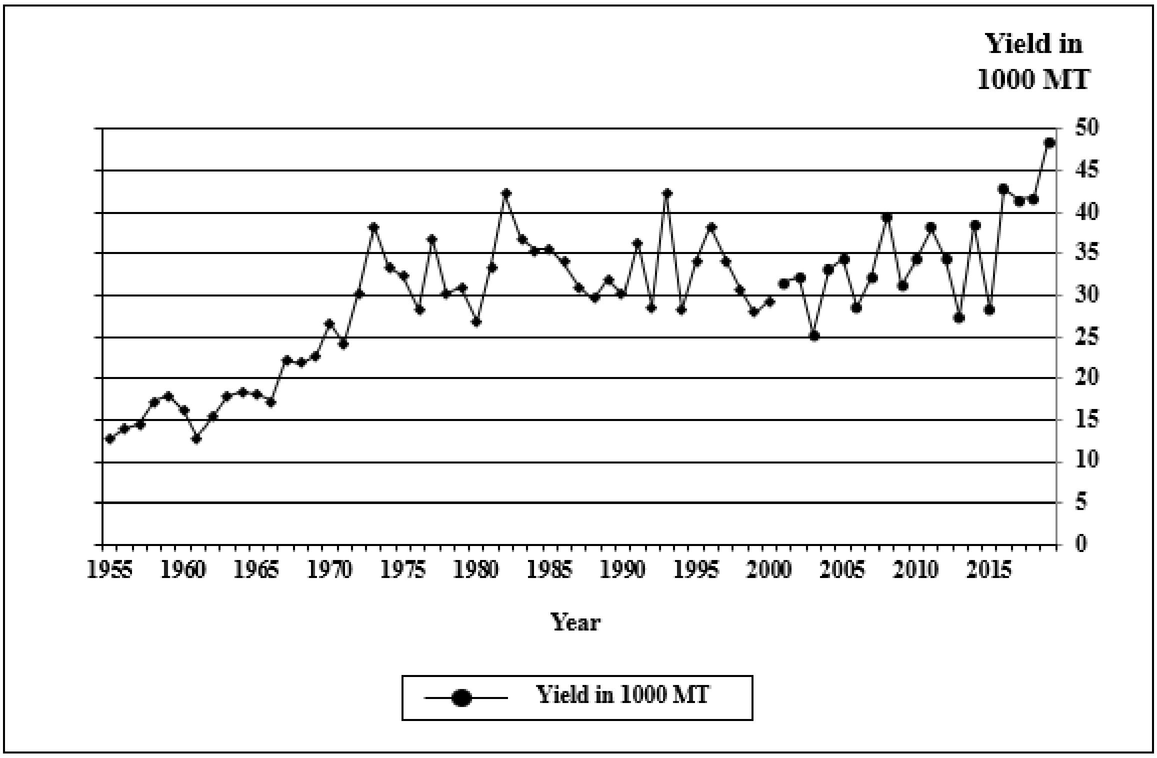

Fig. 1.5: Harvest volumes in Germany

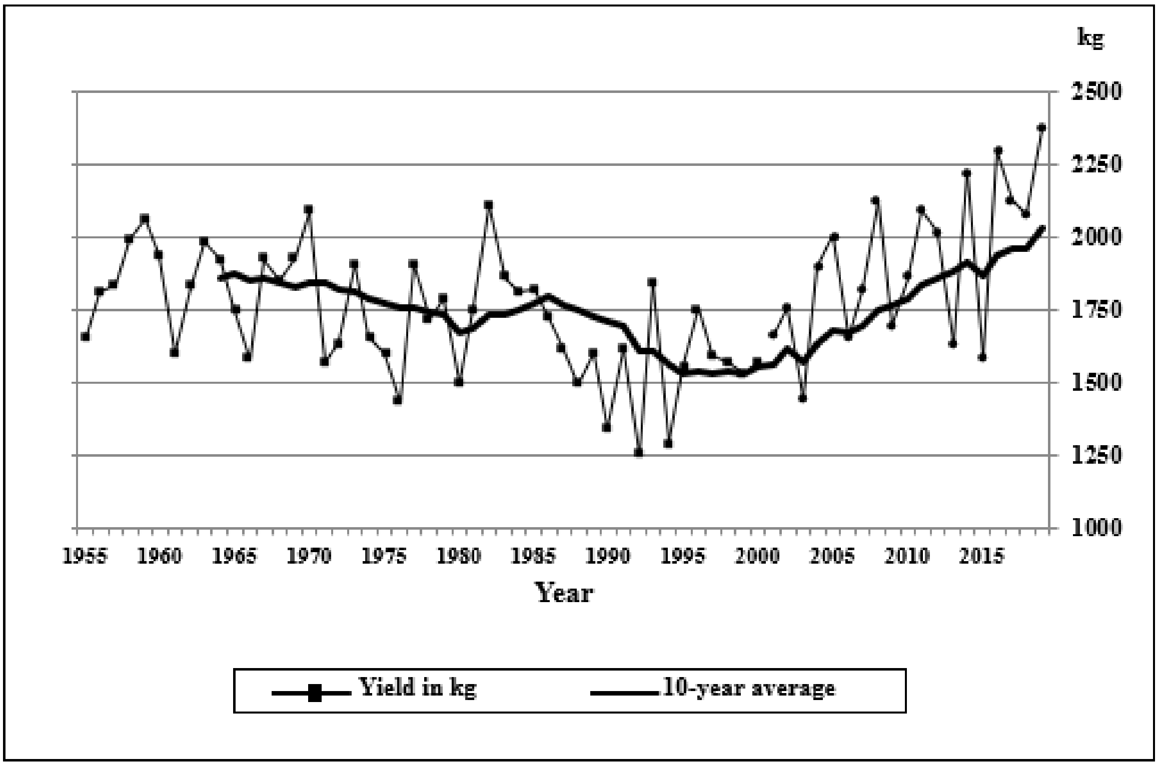

Fig. 1.6: Average yield per hectare in Germany

Tab. 1.4: Yields per hectare in German cultivation areas

Growing area	Yield in kg/ha total area								
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Hallertau	2,151	2,090	1,638	2,293	1,601	2,383	2,179	2,178	2,441
Spalt	1,759	1,383	1,428	1,980	1,038	1,942	1,949	1,564	1,704
Tettnang	1,460	1,323	1,184	1,673	1,370	1,712	1,677	1,486	2,024
Baden/Rhineland-Palatinate/ Bitburg	2,202	2,353	1,953	2,421	1,815	1,957	1,990	1,985	1,985
Elbe-Saale	2,071	1,983	2,116	2,030	1,777	2,020	2,005	1,615	2,150
Æ Yield/ha Germany (kg)	**2,091**	**2,013**	**1,635**	**2,224**	**1,587**	**2,299**	**2,126**	**2,075**	**2,374**
Total yield Germany (MT)	38,111	34,475	27,554	38,500	28,337	42,766	41,556	41,794	48,472
Acreage Germany (ha)	18,228	17,124	16,849	17,308	17,855	18,598	19,543	20,144	20,417

Tab. 1.5: Alpha-acid values of individual hop varieties

Growing area/variety	2010	2011	2012	2013	2014	2015	2016	2017	2018	**2019**	**Ø 5 Year**	**Ø 10 Year**
Hallertau Hallertauer	3.8	5.0	4.6	3.3	4.0	2.7	4.3	3.5	3.6	**4.1**	**3.6**	**3.9**
Hallertau Hersbrucker	3.5	4.5	3.0	1.9	2.1	2.3	2.8	2.3	2.0	**2.5**	**2.4**	**2.7**
Hallertau Hall. Saphir	4.5	5.3	4.4	2.6	3.9	2.5	4.0	3.0	3.3	**3.3**	**3.2**	**3.7**
Hallertau Opal	8.6	9.7	9.0	5.7	7.3	5.9	7.8	7.2	6.4	**7.3**	**6.9**	**7.5**
Hallertau Smaragd	7.4	8.0	6.0	4.3	4.7	5.5	6.2	4.5	3.0	**5.0**	**4.8**	**5.5**
Hallertau Perle	7.5	9.6	8.1	5.4	8.0	4.5	8.2	6.9	5.5	**6.7**	**6.4**	**7.0**
Hallertau Spalter Select	5.7	6.4	5.1	3.3	4.7	3.2	5.2	4.6	3.5	**4.4**	**4.2**	**4.6**
Hallertau Hall. Tradition	6.5	7.1	6.7	5.0	5.8	4.7	6.4	5.7	5.0	**5.4**	**5.4**	**5.8**
Hallertau Mand. Bavaria			8.8	7.4	7.3	7.0	8.7	7.3	7.5	**7.9**	**7.7**	
Hallertau Hall. Blanc			9.6	7.8	9.0	7.8	9.7	9.0	8.8	**9.0**	**8.9**	
Hallertau Hüll Melon			7.3	5.3	5.4	5.8	6.8	6.2	5.8	**6.6**	**6.2**	
Hallertau North. Brewer	9.7	10.9	9.9	6.6	9.7	5.4	10.5	7.8	7.4	**8.1**	**7.8**	**8.6**
Hallertau Polaris			20.0	18.6	19.5	17.7	21.3	19.6	18.4	**19.4**	**19.3**	
Hallertau Hall. Magnum	13.3	14.9	14.3	12.6	13.0	12.6	14.3	12.6	11.6	**12.3**	**12.7**	**13.2**
Hallertau Nugget	11.5	13.0	12.2	9.3	9.9	9.2	12.9	10.8	10.1	**10.6**	**10.7**	**11.0**
Hallertau Hall. Taurus	16.3	17.4	17.0	15.9	17.4	12.9	17.6	15.9	13.6	**16.1**	**15.2**	**16.0**
Hallertau Herkules	16.1	17.2	17.1	16.5	17.5	15.1	17.3	15.5	14.6	**16.2**	**15.7**	**16.3**
Tettnang Tettnanger	4.0	5.1	4.3	2.6	4.1	2.1	3.8	3.6	3.0	**3.8**	**3.3**	**3.6**
Tettnang Hallertauer	4.2	5.1	4.7	3.3	4.6	2.9	4.4	4.3	3.8	**4.3**	**3.9**	**4.2**
Spalt Spalter	3.7	4.8	4.1	2.8	3.4	2.2	4.3	3.2	3.5	**3.9**	**3.4**	**3.6**
Spalt Spalter Select	5.6	6.4	4.6	3.3	4.5	2.5	5.5	5.2	2.9	**4.1**	**4.0**	**4.5**
Elbe-S. Hall. Magnum	13.1	13.7	14.1	12.6	11.6	10.4	13.7	12.6	9.3	**11.9**	**11.6**	**12.3**

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

2 Weather and Growth Development 2019

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

2.1 Weather and growth development

The hop year 2019 started out with warm and dry spring weather resulting in promising early growth, which slowed down only at the end of April and the beginning of May when cooler temperatures prevailed. This created an opportunity to clean out the bines early and train them around the wires, which in the Hallertau started on April 24 and lasted until mid-May. The delays in the growth and development of the plants were subsequently compounded by a period of high heat in June and July, which affected flowering and cone formation all the way to the ripening stage. Compared to several other recent years, the hop harvest began a few days later this year, in early September.

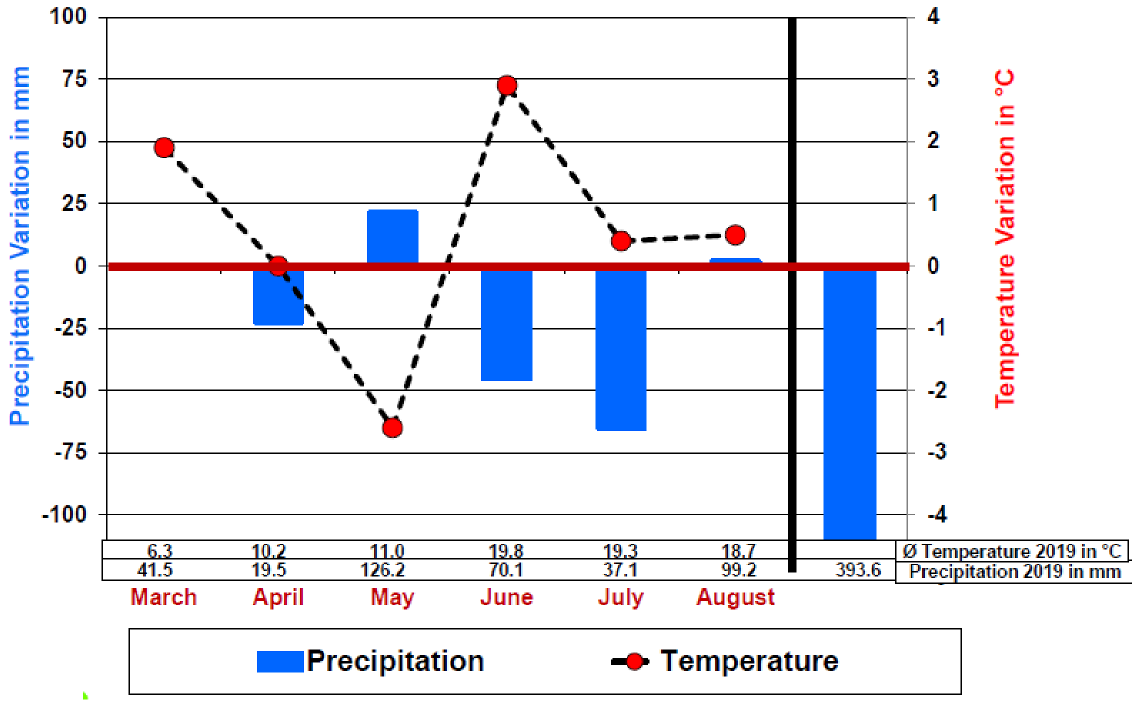

Fig. 2.1: Weather patterns in Hüll during the 2019 vegetation period expressed as monthly deviations from the 10-year average

This year, violent thunderstorms with large amounts of precipitation were rare, short and only local, and as a result, there was no major erosion damage to report. In Hüll, only about one-half of the usual amount of precipitation fell in June; and only one-third in July. In areas with light soils and even less rainfall, the hop plants reacted with drought stress and reduced yields. Only in August did sufficient rainfall with moderate temperatures return, which was, however, too late for many hop gardens. Especially in non-irrigated sites or in soils with insufficient water retention capacity, yields and qualities were disappointing. Later-maturing hop varieties, especially in favorable locations, however, still benefited from the late, life-giving weather and produced good to even above-average yields.

2.2 Problems resulting from disease and pest infestations

Because pesticides to control soil pests were not available this year, with the exception of Karate Zeon, there were local problems with infestations by hop flea beetles (*Psylloides attenuatus*) and alfalfa snout beetles (*Otiorhynchus ligustici*), also known as lovage weevils.

Peronospora primary infections have been reported only in rare cases, while the risk of Peronospora secondary infections arose only at the beginning of June, after the rainy May, when temperatures became increasingly warm, causing the zoosporangia count as measured in spore traps to exceed the control threshold. Because of the subsequent heat and drought later in June and in July, however, the risk of infection quickly decreased. The danger returned not until the end of July, as well as in August, as precipitation — and with it, the count of zoosporangia — increased. This called for 3 additional rounds of spraying.

The fight against powdery mildew, by contrast, was more extensive this year. The first infestations were reported in mid-May. Despite numerous control measures, powdery mildew kept reappearing throughout the season, especially in dense stocks of bitter hops such as Herkules. An objective quality assessment of disease and pest infestations suggests that mildew infestations were by far the most frequently noticed pathogen in 2019.

The much-dreaded verticillium wilt also appeared this year. The first symptoms, including dying leaves, could be observed starting in mid-June. The infestation intensified shortly before harvest time, when many diseased hop gardens could already be recognized from a distance as being affected.

Infestations of hop aphids and common spider mites could be kept in check this year with relatively little effort, thanks to an emergency approval of Movento SC 100. This allowed for timely control measures against these pests. In some cases, however, when spider mite infestations were discovered too late, cones still turned red right around harvest time, which led to losses in yield and quality.

2.3 Special events in 2019

In crop year 2019, there were no unusual events to report in the Hallertau region. Only the delayed development cycle and the relatively late maturation of the hop plants were significant. In all other respects, 2019 will be remembered as an average year, apart, of course, from the erratic weather pattern. Locations without irrigation and with less water-retentive soils suffered losses in yield and quality and, thus, could not always fulfill their contract requirements. Although the dry weather eliminated the need for most fungicide measures against peronospora, which resulted in cost savings, this advantage was offset by the high cost of combating powdery mildew.

Weather data for 2018 (monthly mean, maximum and minimum values) compared to 10-year * and 50-year ** mean values

Month		Temperature at 2m elev. Mean (°C)	Min (°C)	Max (°C)	Relative Humidity (%)	Precip-itation (mm)	Days w/ Precip. >0.2 mm	Sunshine (hours)
January	2019	-0.4	-6.0	4.5	97.0	88.7	22.0	33.0
	10-y	-0.6	-3.9	2.8	90.8	61.7	15.6	45.3
	50-y	-2.4	-5.1	1.0	85.7	51.7	13.7	44.5
February	2019	1.6	-4.6	8.3	89.0	40.0	8.0	132.0
	10-y	-0.3	-4.1	3.9	86.3	38.2	11.6	69.6
	50-y	-1.2	-5.1	2.9	82.8	48.4	12.8	68.7
March	2019	6.3	2.0	9.7	85.0	41.5	14.0	156.0
	10-y	4.4	-0.5	10.3	79.8	42.3	12.2	149.0
	50-y	2.7	-2.3	8.2	78.8	43.5	11.3	134.4
April	2019	10.2	4.6	17.2	71.0	19.5	6.0	240.0
	10-y	10.2	3.2	16.2	73.1	41.7	9.5	200.8
	50-y	7.4	1.8	13.3	75.9	55.9	12.4	165.0
May	2019	11.0	4.2	16.2	84.0	126.2	16.0	168.0
	10-y	13.6	7.8	19.6	75.3	105.3	15.9	206.9
	50-y	11.9	5.7	17.8	75.1	86.1	14.0	207.4
June	2019	19.8	15.8	25.6	79.0	70.1	8.0	305.0
	10-y	17.0	10.9	23.1	75.9	114.8	14.2	221.3
	50-y	15.3	8.9	21.2	75.6	106.1	14.2	220.0
July	2019	19.3	14.1	26.1	79.0	37.1	13.0	250.0
	10-y	18.9	12.3	25.8	75.6	102.3	12.7	247.9
	50-y	16.9	10.6	23.1	76.3	108.4	13.9	240.3
August	2019	18.7	14.8	22.9	88.0	99.2	15.0	225.0
	10-y	18.2	11.7	25.6	79.4	98.3	11.5	244.3
	50-y	16.0	10.2	22.5	79.4	94.9	13.3	218.4
September	2019	13.7	8.2	20.2	89.0	35.7	13.0	178.0
	10-y	13.8	8.3	20.5	84.7	60.4	10.7	170.0
	50-y	12.8	7.4	19.4	81.5	65.9	11.4	174.5
October	2019	10.2	3.3	13.9	96.0	53.9	13.0	111.0
	10-y	8.8	4.3	14.4	89.1	54.1	11.0	113.4
	50-y	7.5	2.8	13.0	84.8	60.0	10.4	112.9
November	2019	4.9	1.1	11.7	99.0	39.3	15.0	38.0
	10-y	4.5	1.2	8.4	92.5	54.6	11.3	60.0
	50-y	3.2	-0.2	6.4	87.5	58.8	12.6	42.8
December	2019	2.4	-3.5	8.3	98.0	40.3	15.0	55.0
	10-y	1.2	-1.9	4.4	92.5	63.9	15.9	39.7
	50-y	-0.9	-4.4	1.6	88.1	49.1	13.3	34.3
Ø-Year	2019	9.8	4.5	15.4	87.0	691.5	158.0	1891.0
	10-y	9.1	4.1	14.6	82.9	837.6	152.1	1768.0
	50-y	7.4	2.5	12.5	81.0	828.8	153.3	1663.2

* The 10-year mean covers the years 2010 – 2019

** The 50-year mean covers the years 1927 – 1976

3 Research

3.1 IPZ 5a – Hop growing, production technology

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

AG (working groups) Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5a J. Portner, J. Stampfl	Improving the nutrient efficiency of hops through fertilization systems with fertigation (5612)	2017-2020	Erzeugergemeinschaft HVG *(HVG Hop Producer Group)*	Prof. F. Wiesler, University Hohenheim Prof. T. Ebertseder, HSWT Hop farms IPZ 5c, IPZ 5d
IPZ 5a J. Portner, A. Schlagenhaufer	Nitrogen dynamics in hop soils in operating hop farms with different types of soil and fertilizer systems (6054)	2018-2021	Erzeugergemeinschaft HVG *(HVG Hop Producer Group)*	21 hop farms; IPZ 5b
IPZ 5a J. Portner, A. Schlagenhaufer	Attempts to compost and utilize chopped bines to optimize the nutrient efficiency of organically bound nitrogen (6141)	2018-2021	Erzeugergemeinschaft HVG *(HVG Hop Producer Group)*	Prof. E. Meinken, HSWT Dr. D. Lohr, HSWT Prof. T. Ebertseder, HSWT M. Stadler, FZ Agrarökologie, AELF PAF; IPZ 5c

Permanent tasks and product-technical trials

AG (working groups)	Project	Project Duration	Collaborators
5a	Training and continued education of hop growers	Permanent task	
5a	Production-technical and business management specialty consulting in hop production	Permanent task	
5a	Development and updating of documents for consulting services	Permanent task	
5a	Transfer of advisory strategies and exchange of information with group advisory services	Permanent task	Hopfenring e.V. *(Hop Circle)*
5a	Implementation of peronospora infestation forecasts and creation of warning messages	Permanent task	
5a	Generation of business data for profit margins and other business calculations	Permanent task	
5a	Optimization of PS applications and device technologies	Permanent task	
5a	Optimization of techniques and procedures to avoid soil erosion and to promote soil fertility in hops	Permanent task	IAB
5a	Development of strategies and measures to avoid nitrate movements in the soil and seepage in hop cultivation	Permanent task	IAB, water consultant, AELF PAF u. SR, ECOZEPT

AG (working groups)	Project	Project Duration	Collaborators
5a	HopfeNO$_3$ - practical optimization of the nitrogen cycle in hop cultivation	2016-2020 (2022)	Ecozept, LfU Leader-AG
5a	Influence of the number and timing of the N fertilizer applications on yield and quality	2017-2019	Hop growers
5a	Use of thermal imaging technology to optimize drying in hop kilns	2018-2019	Hop growers
5a	Optimization of settings for different drying processes of different hop varieties in multi-tier kilns	2018-2020	Hop growers
5a	Optimization of drying processes in belt dryers	2018-2020	Hop growers
5a	Investigation of root and nutrient distribution in soil profiles depending on irrigation and drip hose positioning (2 bachelor theses)	2019	TUM / HSWT Florian Weiß Isabella Riedl
5a	Investigation of the absorption rate and distribution of nitrogen (15-N) applied via fertigation (master thesis)	2019	TUM / HSWT Martin Waldinger
5a	Investigation of the yield evolution of hops depending on the amount and timing of N fertilization (2 bachelor theses)	2019	HSWT Anna Baum Simon Arnold

3.2 IPZ 5b - Crop protection in hop production

Current research projects of IPZ 5b (crop protection in hop production) funded by third-parties

AG (working groups) Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5b S. Euringer, K. Lutz	GfH project for verticillium research	2017-2023	Gesellschaft für Hopfenforschung e.V. (GfH) *(Society for Hop Research)*	IPZ 5c, Dr. E. Seigner, P. Hager, R. Enders, J. Kneidl, A. Lutz Dr. Radišek, Slovenian Institute of Hop Research and Brewing
IPZ 5b S. Euringer, K. Lutz	Biological soil decontamination	2018-2019	Erzeugergemeinschaft Hopfen HVG *(HVG Hop Producer Group)*	IPZ 5c, IPZ 5a
IPZ 5b S. Euringer, K. Lutz	Verticillium in selected hop gardens: Niederlauterbach (from 2015) Engelbrechtsmünster (from 2016) Gebrontshausen (from 2021)	2015-2024	Erzeugergemeinschaft Hopfen HVG *(HVG Hop Producer Group)*	IPZ 5c
IPZ 5b S. Euringer	GfH technician AMP G. Thalmeier K. Kaindl	2019-2020	Gesellschaft für Hopfenforschung e.V. (GfH) *(Society for Hop Research)*	

3.3 PZ 5c – Hop breeding research

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

AG (working groups) Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
<u>IPZ 5c</u> A. Lutz Dr. E. Seigner	Crossbreeding of the Tettnanger landrace	2011-2020	Tettnanger Hopfen-pflanzerverband *(Tettnanger Hop Growers Association)*; Erzeugergemeinschaft Hopfen HVG *(HVG Hop Producer Group);* Ministerium für Ländlichen Raum und Verbraucherschutz (MLR) *(Ministry for Rural Affairs and Consumer Protection),* Baden-Württemberg; GfH (up to 2014)	IPZ 5d, Dr. K. Kamm-huber & Team; Versuchsgut Straß, F. Wöllhaf; B. Bohner, G. Bader
<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	2016-2020	Thüringer Ministerium für Infrastruktur und Landwirtschaft *(Thuringian Ministry of Infrastructure and Agriculture);* Ministerium für Landwirtschaft und Umwelt Sachsen-Anhalt *(Ministry of Agriculture and the Environment in Saxony-Anhalt);* Staatsministerium für Umwelt und Landwirtschaft Sachsen *(State Ministry of the Environment and Agriculture in Saxony);* Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Producer Group)*	IPZ 5d: Dr. K. Kamm-huber & Team; Hopfenpflanzerverband Elbe-Saale e.V. *(Elbe-Saale Hop Growers' Association)*; Betrieb Berthold, Thüringen (*Hop Farm Berthold in Thuringia*); Hopfengut Lautitz, Sachsen (*Hop Farm Lautitz in Saxony*); Agrargenoss. Querfurt, Sachsen-Anhalt *(Agriculatural Cooperative Querfurt, Saxony-Anhalt)*

AG (working groups) Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5c Dr. E. Seigner A. Lutz	Genome-based precision breeding for future-oriented quality hops	2017-2020	Landwirtschaftliche Rentenbank *(Agricultural Pension Bank)*	IPZ 5d: Dr. K. Kamm-huber & Team; IPZ 1d: Prof. Dr. V. Mohler; IPZ 2c: Dr. Th. Albrecht; University Hohenheim: Prof. Dr. J. Wünsche, Dr. M.H. Hagemann; Pflanzenbiotechnologie und Molekularbiologie (PBM) *(Plant Technology and Molecular Biology)*: Prof. Dr. G. Weber; Gesellschaft für Hopfenforschung *(Society for Hop Research)*: W. König; Hopfenverwertungsgen. *(Hop Sales Cooperative)*; HVG: Dr. E. Lehmair
IPZ 5c Dr. E. Seigner A. Lutz	Subproject for precision breeding of hops: testing of powdery mildew resistance for genome-wide association mapping	2016-2020	Wissenschaftsförderung der Deutschen Brauwirtschaft (Wifö) *(Scientific Funding from the German Brewing Industry)*	EpiLogic, Freising; University Hohenheim: Prof. Dr. J. Wünsche, Dr. M.H. Hagemann; Max-Planck-Institut für Entwicklungsbiologie *(Max-Planck Institute for Developmental Biology)* Tübingen: Prof. Weigel
IPZ 5c Dr. E. Seigner	Research and work on verticillium wilt in hops - molecular proof of verticillium presence	2015-2021	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
IPZ 5c Dr. E. Seigner A. Lutz	Powdery mildew isolates and their use in breeding powdery mildew resistance in hops	2017-2020	Gesellschaft für Hopfenforschung *(Society for Hop Research)*	EpiLogic, Freising

Permanent tasks: Hop breeding research

AG (working groups)	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 Brautechnologie n, (*Chair for Beverage and Brewing Technology)*; Bitburger Versuchsbrauerei *(Bitburger Pilot Brewery)*; Versuchsbrauerei St. Johann *(Pilot Brewery St. Johann)*; Breweries worldwide; Hop growers
5c	Breeding of resistant quality hops with special suitability for the cultivation in low-trellis systems	Since 2012	IPZ 5d: Dr. K. Kammhuber & Team; EpiLogic, Freising
5c	Breeding of quality varieties with increased levels of health-promoting, antioxidative and microbial substances, also for alternative areas of application of hops outside the brewing industry	Permanent task	IPZ 5d; EpiLogic, Freising
5c	Aphid resistance testing	Permanent task	IPZ 5b: M. Felsl
5c	Leaf system for testing hops for peronospora tolerance for breeding 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

AG (working groups) Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
<u>IPZ 5d</u> Dr. K. Kammhuber	Isolation, identification and analysis of multifidols in hops	2919- 2020	Wissenschaftliche Station für Brauerei München e.V. *(Scientific station for Brewery Munich e.V.)*	TU Berlin Dr. Wittstock

Continuous tasks: Hop quality and analytics

AG (working groups)	Project	Duration	Collaborators
5d	All analytical investigations in support of the working groups of the hop division, in particular, hop breeding	Permanent task	IPZ 5a, IPZ 5b, IPZ 5c, IPZ 5e
5d	Development and optimization of a reliable aroma analysis with the help of gas chromatography mass spectroscopy	Permanent task	
5d	Establishment and optimization of NIRS methods for hop bitter substances and water content	Permanent task	
5d	Development of analytical methods for hop polyphenols	Permanent task	Arbeitsgruppe für Hopfenanalytik (AHA) *(Hop Analytics Working Group)*
5d	Organization and evaluation of analyses for hop contracts	Permanent task	Labore der Hopfen-wirtschaft (Laboratories in the hop industry)
5d	Analysis, evaluation and forwarding of follow-up and control examinations for hop contracts	Permanent task	Labore der Hopfen-wirtschaft (Laboratories in the hop industry)
5d	Analyses of hop varieties as administrative assistance for food safety authorities	Permanent task	Lebensmittelüber-wachung der Landratsämter *(Food safety monitoring by district offices)*
5d	Supervision of IT and Internet for the Hop Research Center in Hüll	Permanent task	AIW ITP

3.5 IPZ 5e – Ecological issues in hop production

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

AG (working groups) Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5e Dr. F. Weihrauch M. Obermaier	Reduction in the use of copper-containing crop protection agents in ecological and integrated hop cultivation	2014-2021	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Producer Group)*	Betrieb Ludwig Gmeiner *(Farm Ludwig Gmeiner)*, Uttenhofen; Agrolytix GmbH, Erlangen; Forschungsinstitut für Biologischen Landbau (FiBL) *(Research Institute for Organic Agriculture)*, Frick, Schweiz; Boku Wien, IFA-Tulln Institut für Umweltbiotechnologie, Österreich *(Boku Vienna, IFA-Tulln Institute for Environmental Bio-technology, Austria)*

AG (working groups) Project Management Project Operations	Project	Project Duration	Cost Allocation	Collaborators
IPZ 5e Dr. F. Weihrauch M. Obermaier	Micro-encapsulated hop extracts as a new type of organic fungicide to combat downy mildew in hop cultivation	2016-2019	Wissenschaftsförderung der Deutschen Brauwirtschaft e.V. (Wifö) *(Scientific Funding from the German Brewing Industry)*	Betrieb Ludwig Gmeiner *(Farm Ludwig Gmeiner)*, Uttenhofen; Lehrstuhl für Prozessmaschinen und Anlagentechnik *(Department of Process Technology and Machinery)* (iPAT), Friedrich-Alexander-University Erlangen-Nürnberg; Agrolytix GmbH, Erlangen; Hallertauer Hopfenveredelungsgesellschaft m.b.H. *(Hop Processing Society)*, Mainburg
IPZ 5e Dr. F. Weihrauch M. Obermaier	Further development of culture-specific strategies for ecological crop protection with the help of divisional networks - Hop Division	2017-2020	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: What is possible?	2018-2020	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Producer Group)*	TU München, *(HVG Hop Producer Group)* (Prof. W. Weisser)
IPZ 5e Dr. F. Weihrauch M. Obermaier	Establishment of predatory mites in hop cultivation practice via undersowing cover crops	2018-2021	Bundesanstalt für Landwirtschaft und Ernährung (BLE), BÖLN-Projekt 2815NA131 (*Federal Agency for Agriculture and Food (BLE)*; Gesellschaft für Hopfenforschung (GfH) e.V. *(Society for Hop Research)*	Companies practicing ecological and integrated hop cultivation

4 Hop Cultivation, Production Techniques

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

4.1 N_{min}-Investigation 2019

The nitrogen soil analysis required by DSN (N_{min}) (Düngeberatungssystem Stickstoff = fertilizer advisory system nitrogen) has by now become an integral part of the fertilizer planning on every hop farm. According to the new Fertilizer Ordinance, at least 3 separate analyses are now compulsory for farms that take advantage of certain exemptions from the Fertilizer Ordinance as they relate to reusing shredded bines as fertilizer in the field and to the cultivation of hops in designated "**red areas**."

In 2019, three quarters of hop farms in the Bavarian growing regions of the Hallertau and Spalt participated in a DSN survey. Within this program, 4,078 hop gardens were examined for N_{min} content. In 2018, the number of hop gardens was 4,010. The 2019 studies revealed an average N_{min} content in Bavarian hop soils of 66 kg N/ha, which was slightly higher than the value in the previous year (51 kg N/ha). The difference was the result of a much lower nitrogen absorption rate by the plants in the dry summer of 2018, when nitrogen probably remained mineralized even during the wet fall that followed. Therefore, the higher N_{min} values in the spring 2019 were no surprise. As is always the case, the N_{min} analyses revealed large fluctuations from one farm to the next and even among different hop gardens and hop varieties on the same farm.

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

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

Tab.4.1: Number of samples, preliminary and final N_{min} *values 2019 in the various districts and growing regions*

County/Region	Number of tests	Preliminary N_{min} value (as of March 25, 2019)	**Final N_{min} value**
Eichstätt (including Kinding)	276	83	**74**
Freising	406	62	**64**
Hersbruck	83	59	**56**
Kelheim	1,567	66	**65**
Landshut	242	75	**75**
Pfaffenhofen (including Neuburg-Schrobenhausen)	1,374	62	**61**
Spalt	130	90	**90**
Bayern	**4,078**	**66**	**66**

Hop growers who have calculated their nitrogen requirements using the preliminary N_{min} averages for their district or their growing region need to adjust their N_{min} values only if applicable final N_{min} values are more than 10 kg N/ha higher than the preliminary N_{min} values. In 2019, there were no districts or growing regions where this provision had to be invoked.

Farms that cultivate hops in **red areas** had to have at least 3 hop parcels examined for N_{min} in 2019. If these farms had additional hop parcels in red areas, the farm's average N_{min} value applied to those parcels as well!

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

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

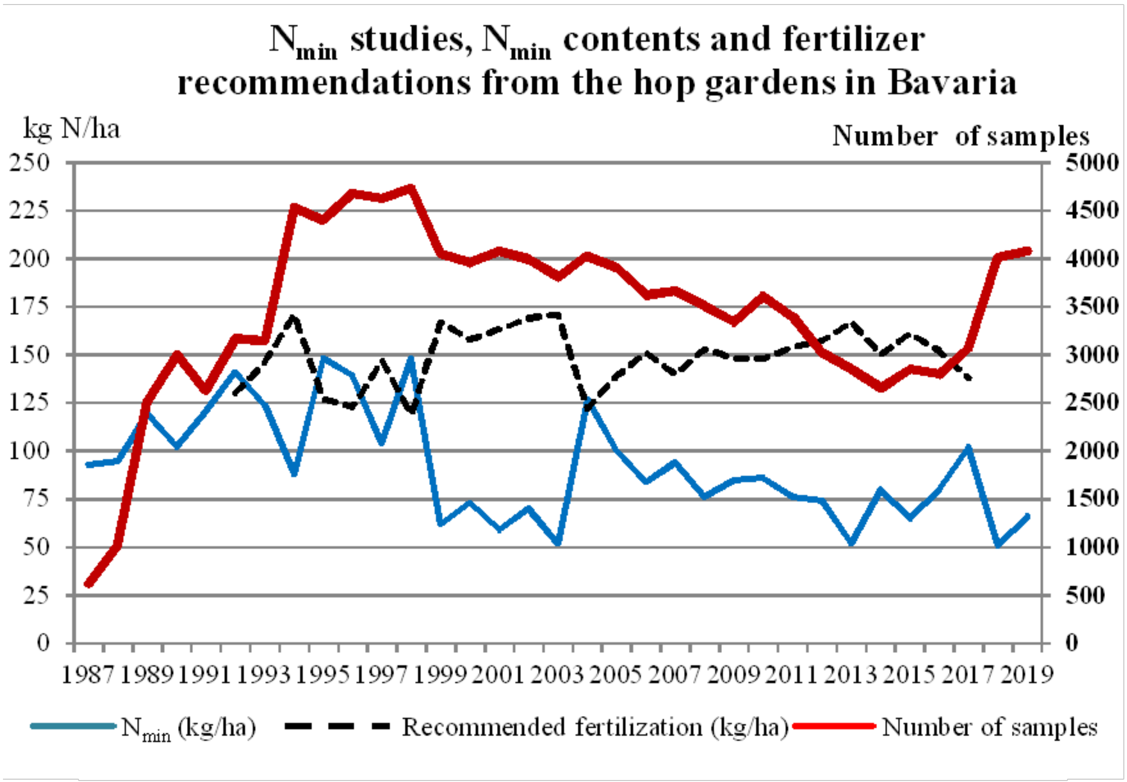

Fig. 4.1: N_{min}-*analyses,* N_{min}-*values and fertilizer recommendations (up to 2017) for the hop gardens in Bavaria over the years*

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

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

Hop is a specialty crop that is highly water use-intensive. Otherwise, it could not produce stable yields at a consistent quality. In this context, it is not only the absolute amount of water that is crucial, but also the distribution and timing of precipitation. Therefore, irrigation can be important in dry years, as well as in years when the rainfall distribution is uneven. Irrigation can both safeguard yields and minimize risks. In addition to ensuring the plant's water supply, irrigation systems can also be used to supply the plant with nutrients dissolved in water. This requires carefully controlled dosages administered at the right time. This type of fertilization is known as fertigation. It has an established track record in agriculture especially in very dry regions of the world, such as in the Yakima Valley in the USA. In addition to providing the plant with optimal, targeted nutrition throughout the vegetation period, it also allows the farm to minimize any environmental impact from nutrient seepage into other ecosystems, such as the groundwater. In the Hallertau, by contrast, much of the nutrients are dispersed in the form of surface-spread fertilizer granules. This poses the risk of nutrients not being taken up by the plant in time, in which case they remain unused in the soil, especially under dry conditions. As part of this research project, tests are being conducted by the LfL, between 2017 and 2020, to determine optimal irrigation and fertigation strategies with a view towards nitrogen efficiency in hop production.

Objectives

- Optimization of N fertilization by adjusting application times and quantities
- Development of N fertilizer systems with fertigation to adapt N applications to:
    - è The hop plant's absorption development
    - è N replenishment by the plant from the soil
- Establishment of measurement methods for determining the current N supply status of a hop plant
- Improvement of N efficiency and minimization of N seepage into other ecosystems

Fig. 4.2: Drip irrigation system for hops

Fig. 4.3: Fertilizer dispensing device for fertigation

Method

- Creation and implementation of precise fertilization and irrigation trials in the period from 2017 to 2019 at various locations and for different varieties
- Harvest hops from field trials to determine the amount of dry matter of cones and of the rest of the plants
- Analysis of nutrient levels in cones and the rest of the plants
- Calculation of N uptakes to assess N utilization
- Taking soil samples in spring and fall for N_{min} analyses
- Determination of the biomass development and nutrient uptake of current hop varieties during their vegetation periods
- Weekly application of defined amounts of nitrogen via irrigation water, timed for the highest absorption rates (Fig. 4.3)
- Conducting chlorophyll and optical reflection measurements to determine N supply levels
- Investigation of the influence of different water dispensing methods in different N fertilizer systems
- Use of climatic models in combination with soil moisture sensors for determining location-specific watering rates.

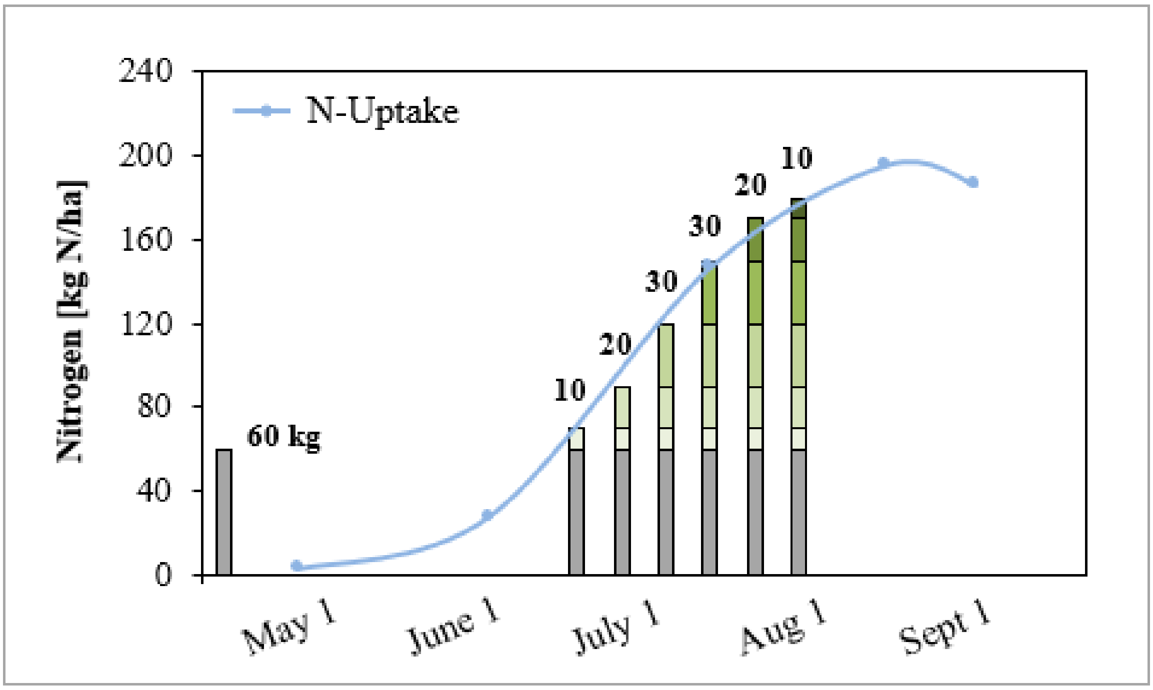

Fig. 4.4: N-fertilization system with fertigation (1/3 spread, 2/3 fertigation) and N-uptake by hops during the vegetation period

Results

The results of this project from 2017 to 2019 show that the yield and quality of hops can be optimized in a targeted way using N-fertilization systems with fertigation. It turned out that the timing of N-applications can also influence cone yields. Furthermore, in all 3 test years, it could be shown that alpha-acid formation is reduced when too much N-fertilization is applied or when it is applied too late. Basically, the project shows that fertigation should not be seen as a mere supplement to irrigation, but rather as a new, efficient fertilizer system that ensures the hop plant is being fed with nitrogen in a way that is appropriate and environmentally compatible, regardless of whether or not there are dry periods.

Compared to fertilization applied entirely in the form of granulated N, plants fertilized via fertigation not only produce higher cone yields but also more biomass overall. Considering the respective N-contents of the plant mass, identical amounts of N-fertilization cause increased N-uptakes when applied via fertigation.

This improvement in the utilization of nitrogen fertilizer is true regardless of farm location or hop variety. In addition, drip irrigation or fertigation not only optimize such agronomic indicators as hop yield and quality, but also reduce the risk of N-seepage into other ecosystems, including nitrates leaching into groundwater.

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

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

Background

In the Hallertau, hops are cultivated intensively as a high-density specialty crop, principally because it generates very high added-value gains. Therefore, the use of nitrogen fertilization has never been a limiting production factor in the past. The groundwater, too, has elevated high nitrate levels in many areas and the soils are often well supplied with nitrogen in the spring. Higher N-values may also be the result of shredded bines or other organic fertilizers being returned to the soil in the fall. After harvesting, any residual nitrogen that remains in the soil is no longer absorbed by the hops and can be absorbed only partially by intermediate crops. The nitrogen remaining in the soil, therefore, may shift from one soil stratum to another or leach out.

Objectives

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

Method

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

Fig. 4.5: N_{min}-soil-sampler

Results

After the first two trial years 2018 and 2019, the first findings on nitrogen dynamics in hops could be compiled. The first five samples show the distribution of N_{min}-values within the respective layers as a function of the sampling date (Fig. 4.6). One result that is already noticeable are the higher N_{min}-levels in the fall, in the top 30 centimeters.

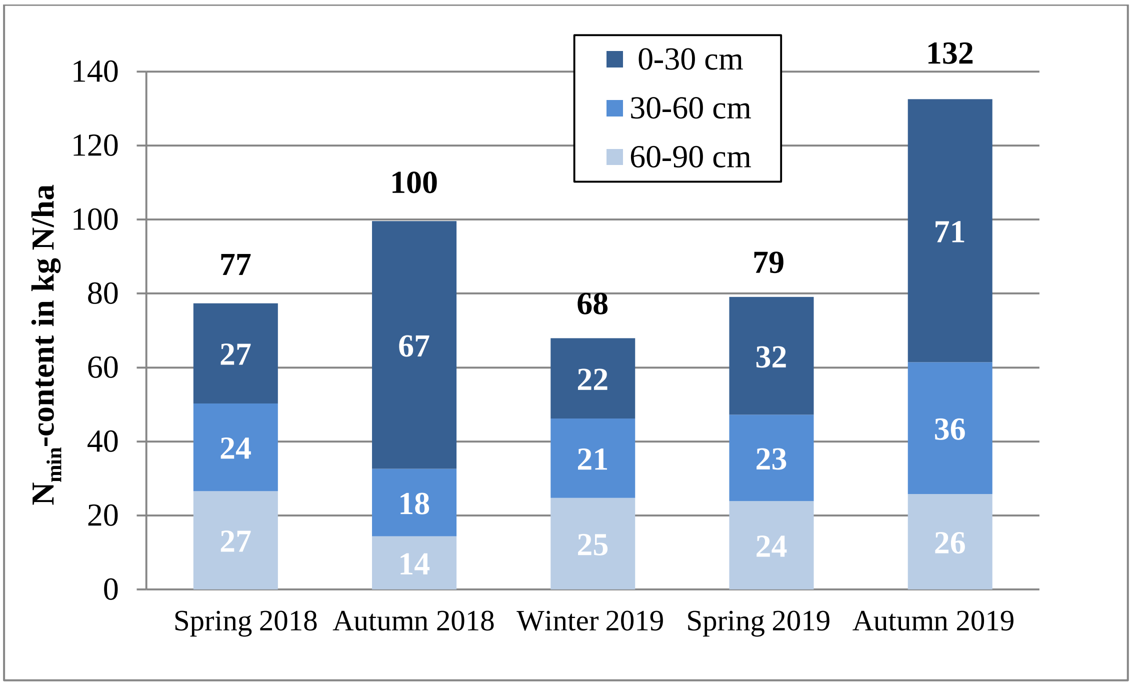

Fig. 4.6: N_{min}-values from 5 sampling dates by soil layers (n = 62)

When analyzed in terms of hop varieties, it is also noteworthy that aroma varieties, on average, have higher N_{min}-values for all sampling dates (Fig. 4.7).

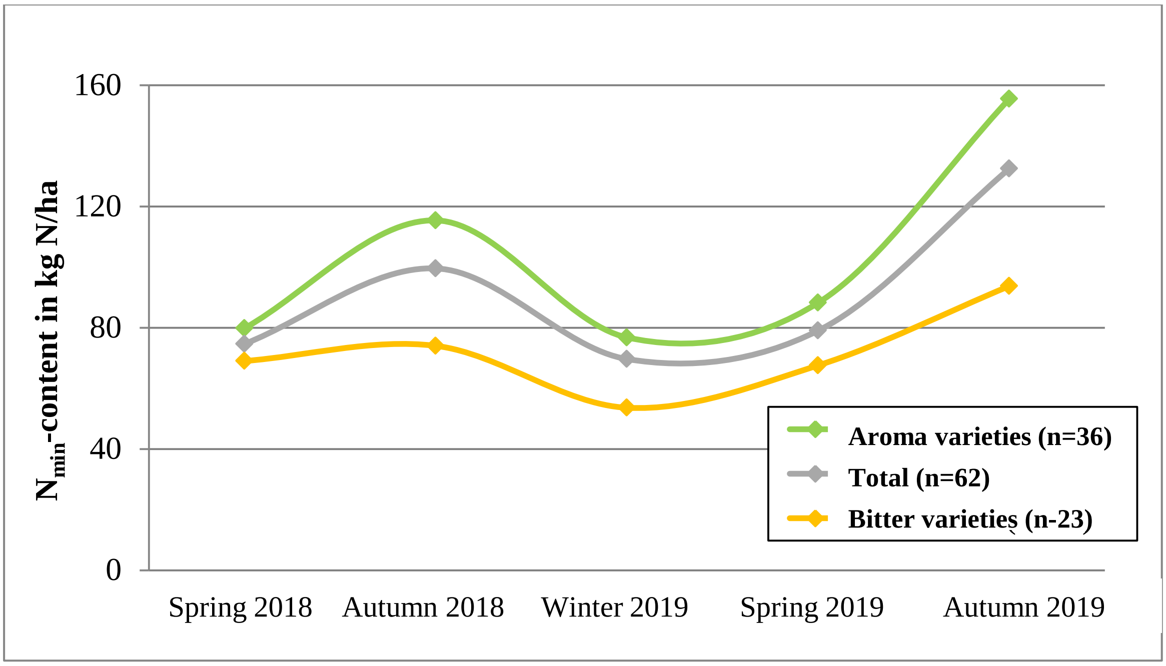

Fig. 4.7: N_{min} values for 5 sampling dates by types of varieties

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

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

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

Project Management: J. Portner

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

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

Duration: September 1, 2018 – December 31, 2021

In the Hallertau, 886 farms manage 16,995 ha of hops. After the harvest, these farms are left with roughly 230,000 MT of shredded bines per year. Around 80% of this plant matter is currently being returned to the fields as fertilizer. These bines, however, contain substantial amounts of nitrogen.

According to the new Fertilizer Ordinance, farmers are required to use the nitrogen contained in the shredded bines as efficiently as possible and to avoid N-dispersion into other ecosystems. To meet these requirements, extensive composting and field trials with shredded hop bines are to be conducted over three years.

Objectives

- Risk assessment of increased nitrate leaching as a result of the application of shredded hop bines in the fall in accordance with current practice
- Development of environmentally compatible and practicable composting processes with 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, 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 Witte method (MC composting). This composting trial under practical conditions has several objectives. On the one hand, the knowledge gained under small-scale conditions should be verified for its real-world practical applicability. Also, aerobic composting is to be compared to the three other variants with regard to the practicality and the conservation potential for nitrogen present in the shredded hop bines. Furthermore, these trials produce the material for plot tests to determine the N-efficiency of the four materials (stored shredded hop bines, aerobic and MC compost, silage), which form the third project part (AP 3). The material for the fourth part of the project, that is, practical experiments to determine N-dynamics in hop gardens (AP 4), comes from these tests, too. All four sub-projects were started at the same time after the hop harvest in the fall of 2018. In addition, in 2017, as part of a bachelor's thesis, vascular tests with shredded bines were conducted. These will be continued as part of this project.

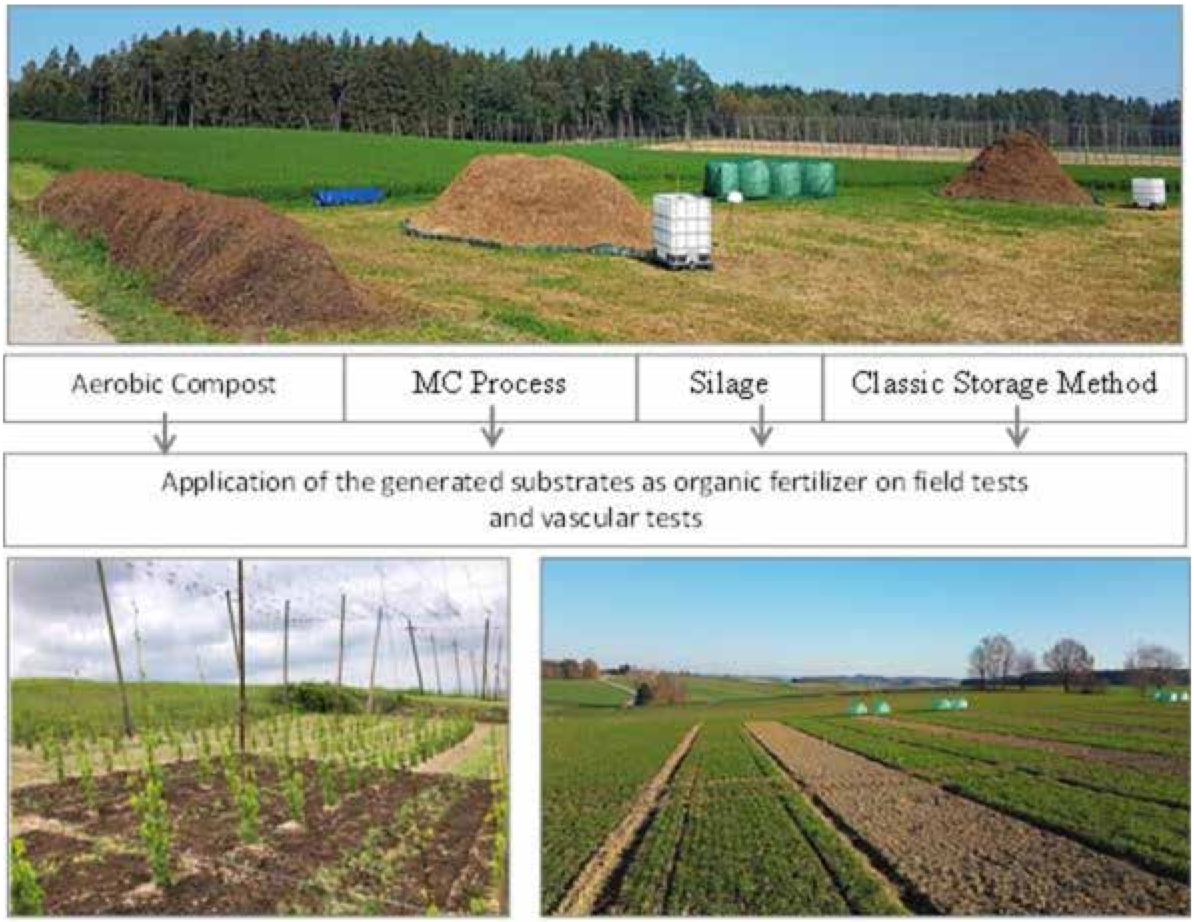

Fig. 4.8: Top: Different storage types for shredded bines
Bottom left: Field trial with shredded hop bines spread in May (AP 4)
Bottom right: Rye plot tests with shredded grape vines as fertilizer (AP 3)

Results

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

Field trials
In the first trial year 2018/19, there was no increase in nitrogen mineralization in shredded bines between the fall, when they were placed outside, and the beginning of the vegetation period. This suggests a low mineralization potential of this organic fertilizer. Similar findings could be obtained in vascular tests. This mineralization behavior suggests that the timing of placing shredded bines outside in the fall does not increase the risk of nitrate leaching into the groundwater.

4.5 Opportunities for using reflection measurements in hops

Team:	M. Waldinger (Bachelor thesis), J. Stampfl
Collaboration:	Dr. F.-X. Maidl Lehrstuhl für Ökologischen Landbau und Pflanzenbausysteme Wissenschaftszentrum, Weihenstephan, TU München *(Chair of Organic Agriculture and Crop Systems Science Center, Weihenstephan, Munich Technical University)*
Duration:	May 2018 - August 2019

Background and objectives

As is the case with many other crops, nitrogen (N) is the most yield-limiting nutrient in hops. With the new Fertilizer Ordinance of 2017 and the upcoming tightening of the Ordinance in 2020, the application of nitrogen is becoming increasingly strictly regulated. When fertilizing, therefore, there ought to be a balance between the expected nutrient requirement of a cultivar and the actual nutrient supply (N-supply in the soil and N-fertilization). In order to meet these requirements in practice, there are already various sensor systems available for determining the nutritional status of N and thus the optimization of N-fertilization in cereal cultivation. Such a technique does not exist in hops yet. As part of a bachelor's thesis, it was examined to which extent differentiated N-fertilization influences the growth and yield of hops. A further assignment was to determine whether N-supply differences can be measured with passive spectral images (Fig. 4.9) and which measuring points and vegetation indices in hops are best suited for this.

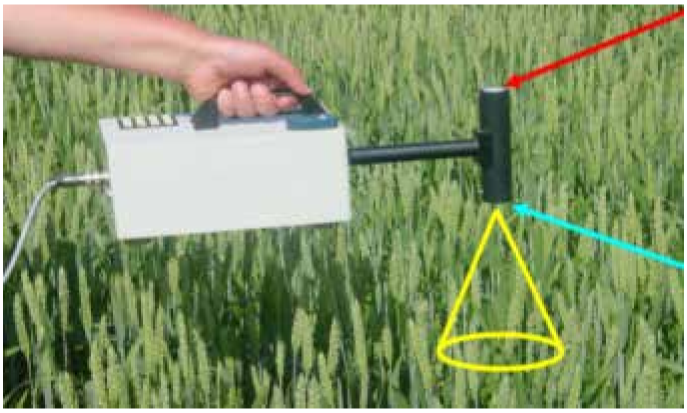

Fig. 4.9: Multispectrometer in grain (WZW, Technical University Munich)

Method

As part of the research project, "Improving nutrient efficiency in hops through fertilization systems with fertigation" (see chapter 4.2), nitrogen-increasing experiments were conducted to determine the effects of differentiated N-fertilization. The relevant measurements were taken in various plots. In one of the trial plots, Herkules, Germany’s most important hop variety, was cultivated. The N-fertilizer requirement was determined in accordance with the requirements of the Fertilizer Ordinance.

The four-fold repetition of the experimentation variants was structured as follows:

Tab. 4.1: N-fertilization varied by timing and quantity in kg N/ha

Variante		**1st Addition**	**2nd Addition**	**3rd Addition**	**Total N**
A	Control				**0**
B	Only 1st addition	60			**60**
C	Only 2nd addition		60		**60**
D	Only 3rd addition			60	**60**
E	1st + 2nd additions	60	60		**120**
F	1st + 2nd + 3rd additions	60	60	60	**180**

In order to test for a possible relationship between biomass growth and N-content or N-uptake, on the one hand, and reflection measurements, on the other, all plots were examined at 5 different times for the following parameters:

- Fresh mass in kg/ha
- Dry matter content in %
- Dry matter in kg/ha
- N-content in % of DM
- N-uptake in kg/ha
- Spectral measurements (325-940 nm)

Using a hand-held spectral measurement device from tec5 (Fig. 4.9), measurements were taken at three different heights (Fig. 4.10). At each examination time, 14 reflection-optical recordings were made in each plot for each measuring height. The reflection data for the plants was acquired using wavelengths ranging from 325 to 940 nm, whereby different vegetation indices were calculated based on the reflected wavelength spectrum. Linear regression models then allowed for the identification of indices to map the measured plant parameters of biomass, N-content and N-uptake.

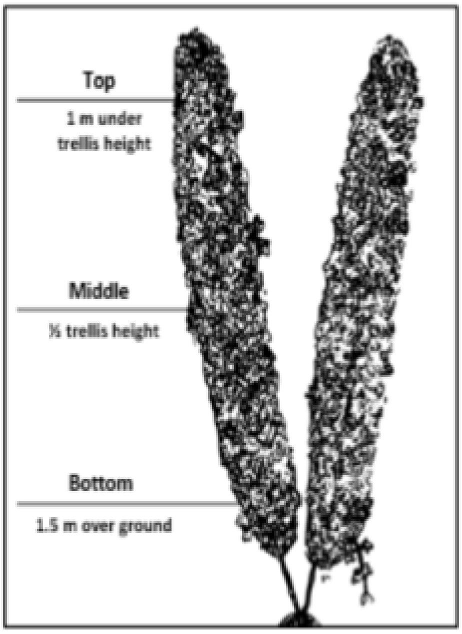

Fig. 4.10: Locations of the spectral measurements

Results

The statistical evaluation showed that the parameters dry matter, N-content and N-uptake can be represented by the vegetation indices generated by the experiments. The dry matter could be mapped to the vegetation index "IR G" with a confidence coefficient (R^2) of up to 0.80. The N-content in the dry matter was almost always closely related to the vegetation indices "IR G" and "REIP" with a confidence coefficient of up to 0.82. This demonstrates that the N-content can be determined relatively easily by using reflection measurements.

The most reliable determination made using spectral measurements was for the most important parameter, N-uptake. For an early measuring point (June) the "REIP" delivered the most precise results (R^2 to 0.81), for later points (July-August) the "IR G" achieved the highest determinants (R^2 to 0.91). In addition, it was possible to identify differences in the nitrogen supply of the different variants with the "REIP" and "IR G" indices, which suggests a possible suitability for practical use.

During this work, the middle measuring height turned out to be the best. At the top measuring point, by contrast, there was a lack of reflecting biomass early on; and at the bottom measuring point, at a later time, shade interfered with the measurements. The results, therefore, were the most consistent at the middle height.

Outlook

The results of this work show that the determination of the N-content and the N-uptake by way of reflection measurements in hops is indeed possible. In order to further adapt the system to the special characteristics of hops and to improve the correlations, it is conceivable to use the available measurement results to develop a vegetation index specifically for hops, which can then determine the examined parameters even more precisely.

4.6 Using thermal imaging technology to optimize hop kilning

Project Management:	J. Portner
Project Editor:	J. Münsterer
Duration:	2018 - 2019

Initial status and objectives

An even distribution of temperature and air is a key requirement for an even and optimal drying process of hops. The longer the drying period at a high air flow rate, at which hops lose most of their moisture, the better is the overall drying process. However, even when the heat and air distribution in the kiln is optimally adjusted — especially at high air flow rates — the hops may still start drying unevenly almost from the start. There are several reasons for this: The different flow resistance of the top layer of green hops; the different storage times of different portions of the hops in the silo before drying; the different lengths of time that different portions of the hops spend in the kiln during filling; and uneven layer heights and densities throughout the kiln. Different flow resistances result in different velocities of the air used for drying. Since the air follows a path of least resistance, there are inevitably zones with different degrees of drying. If unevenly dried hops are dropped from the drying tier to the next lower tier, so-called "nests" may form very quickly, as well as the dreaded "blow-out holes." Therefore, the air speed must be reduced. This in turn means that the blower capacity can no longer be used optimally, the drying performance drops sharply, and, in addition, the moisture content of finished hops will still be uneven.

With the help of thermal imaging technology, however, it is possible to use the surface temperature of the cones to determine temperature distribution across the entire hop layer in the kiln. This allows for monitoring of the uniformity of the drying process and, if necessary, for targeted corrective measures to be initiated.

Method

In various hop kilns, thermal imaging cameras were installed above the hop beds, whereby the camera distance and angle depended on the size of the drying area to be monitored. The camera was connected to a PC or laptop via a USB port. Data evaluation was by means of custom software, which displayed the temperature distribution during the drying process continuously in real time on the screen.

Fig. 4.11: Thermal imaging camera; measuring surface on top of the hop bed in the kiln; thermal measurement image

Results

Different colors in the thermal image revealed moisture nests or areas with uneven drying early on in the process. When needed, corrective measures could be taken, such as redistributing the hops by hand with a rake or by poking wet areas with a fork. This quickly restored uniformity in the drying process.

With automatic filling systems, the settings can be changed accordingly as the kiln is being refilled with green hops. Once again, any irregularities show up quickly and can be corrected. Thus, with the simple aid of thermal imaging, the uniformity of the hop drying process can be improved. This leads to a better overall drying performance of the kiln. In addition, thermal imaging technology confirms the saying by those who are old hands at hop drying: "Hops are always dried in the top layer!"

4.7 LfL-Projects as part of the production and quality initiative

After the completion of the 2nd project phase, which lasted from 2014 to 2018, the Bayerische Landesanstalt für Landwirtschaft (*Bavarian State Research Center for Agriculture*) has once again commissioned studies to generate representative yield and quality data for a selected number of agricultural crops, as part of a production and quality offensive in Bavaria, over the next 5 years, from 2019 to 2023. For the Institut für Pflanzenbau und Pflanzenzüchtung (IPZ) – Arbeitsbereich Hopfen (*Institute for Plant Cultivation and Plant Breeding - Hop Division*), these activities were managed by the Hopfenring e.V. *(Hop Circle)* as a program partner. The objectives of these hop projects, some of which are partially modified ones or entirely new ones, are briefly described below, and the results are summarized for 2019.

4.7.1 TS (*Trockensubstanz* = dry matter content) and alpha-acid monitoring

During the period from August 13 to September 24, 2019, sample bines were harvested and dried separately in weekly intervals in 10 commercial plots distributed throughout the Hallertau region. The samples were taken on 5 different dates for 4 aroma varieties. Likewise, samples were taken on 7 different dates for 2 bitter varieties. The initial analyses revealed the amount of moisture depletion, dry substance (TS) and alpha-acid content. A day later, an accredited laboratory analyzed each sample for the dry substance and alpha-acid content of the green hop at a moisture content of 10%. The data was passed on to the LfL hop consulting office for evaluation and data crunching. The results were averaged, tabulated, graphically prepared and posted with comments on the Internet. This information assisted hop farmers in determining the maturity and harvest readiness of the most important hop varieties.

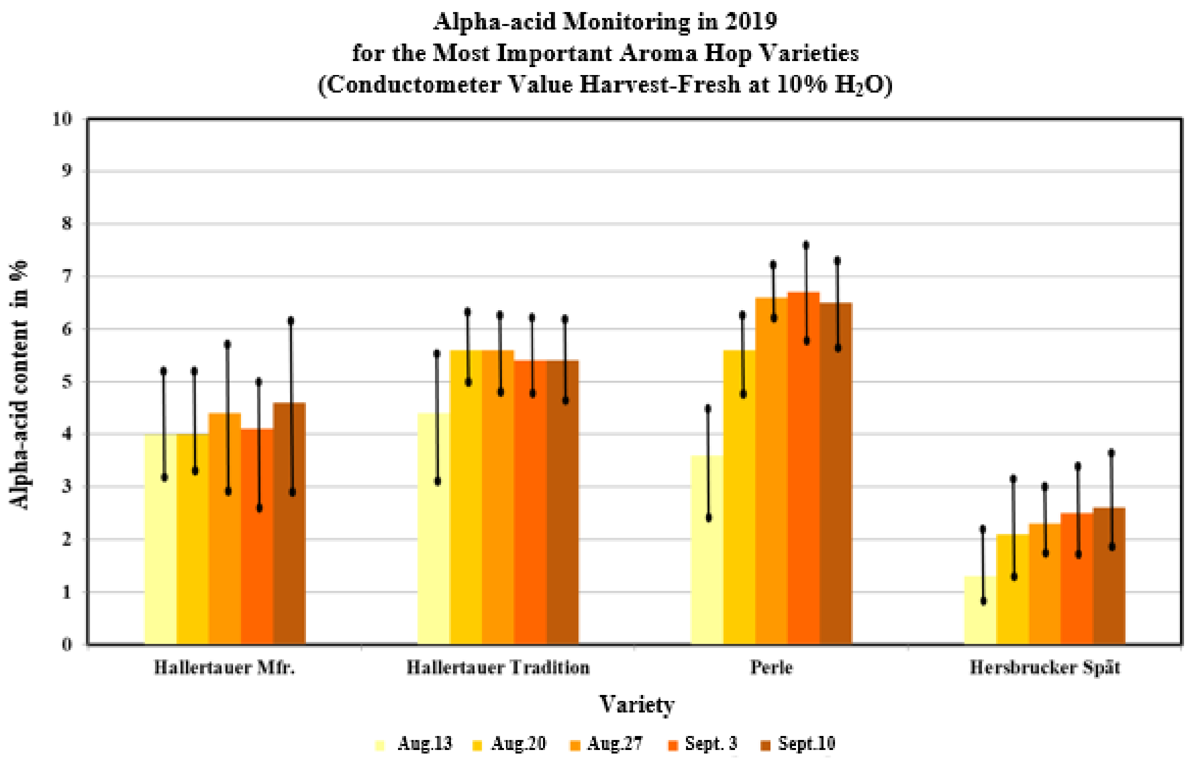

Fig. 4.12: Monitoring of the development of alpha-acid levels in 2019 in the most important aroma varieties

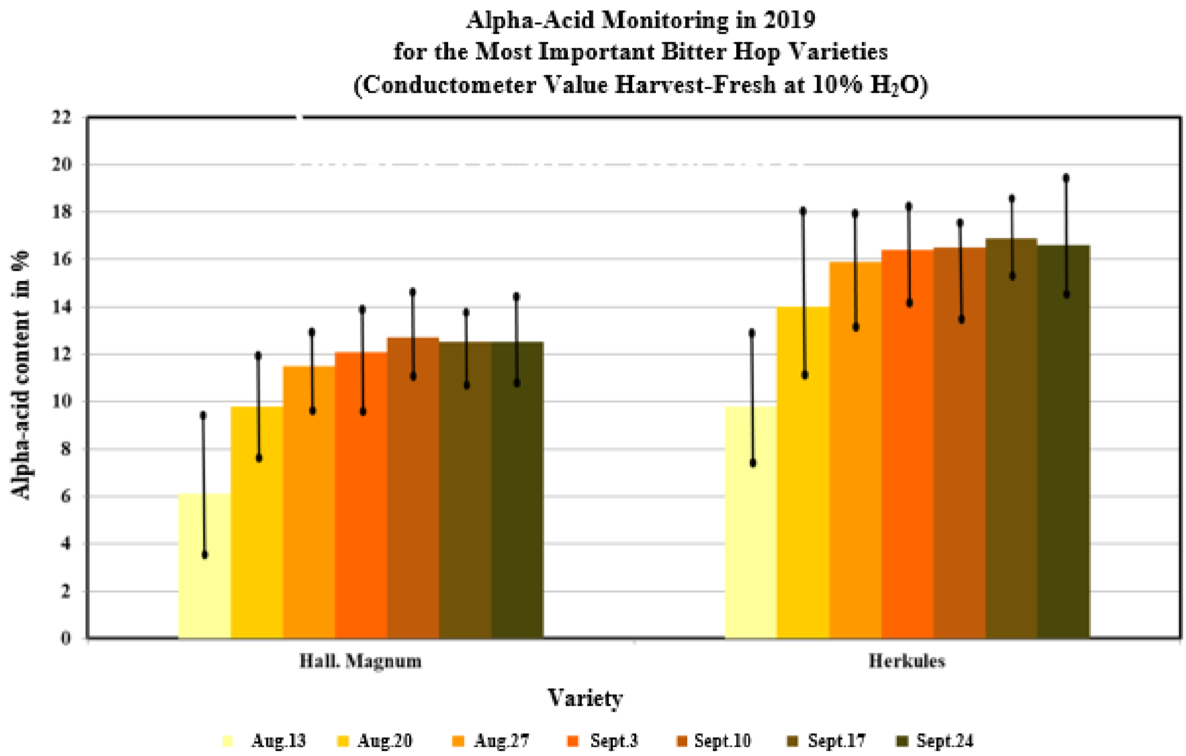

Fig. 4.13: Monitoring of the development of alpha-acid levels in 2019 in high-alpha varieties

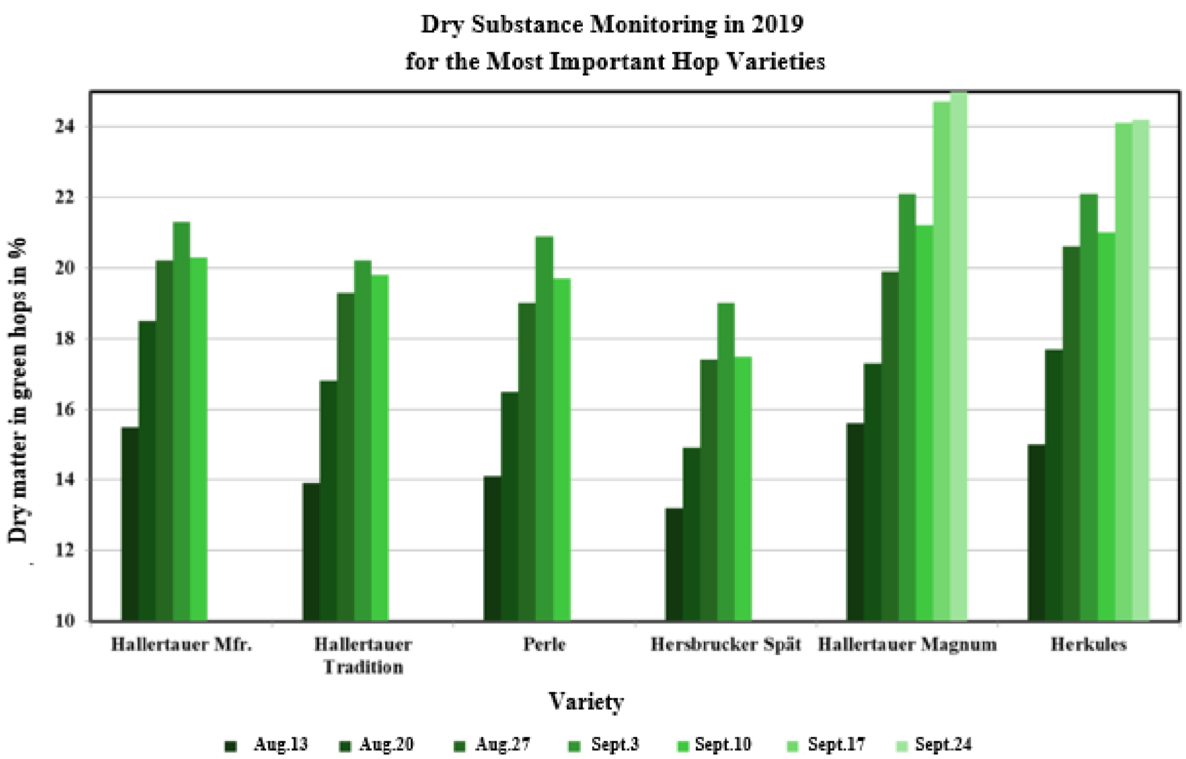

Fig. 4.14: Monitoring of the development of dry substance in 2019 in the most important hop varieties

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

Assessing aphid and spider mite infestations in any given year requires in-field surveys and precise assays in commercial hop gardens. This information can then be used to give farmers advice on pest control strategies.

To this end, 12 weekly visits of 33 representative hop gardens (including 3 organic hop gardens) were conducted between May 20 to August 5, 2019. The hop gardens in the Hallertau cultivate 23 varieties; in Spalt, 7; and in Hersbruck, 3. These gardens were analyzed in terms of their infestations with hop aphids and common spider mite. The data was then aggregated in terms of average numbers of aphids and an infestation index for spider mites.

This data tracking over time served as the basis for consultations and advice regarding control strategies.

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

Objectives

The requirements and restrictions contained in the new Fertilizer Ordinance pose major challenges for hop growers. On the one hand, it is important to maintain sufficient yield levels of hops and to achieve optimal quality; on the other hand, the goals of water protection must be pursued with vigor, too. In terms of nitrogen fertilization, this means that nitrogen must be administered in an even more targeted, nutrient-efficient way than ever. Since the main nitrogen uptake of hops occurs in June and July, it sometimes happens that nitrogen is not dissolved when the weather is too dry, or nitrogen mineralizes under moist soil conditions. This makes it difficult to estimate the nitrogen supply available in the soil, as well as the amount of fertilizer that is still needed. Regular leaf inspections at different growing locations and for different varieties, however, should provide information about the nutritional status of the hop plants and thus contribute to an assessment of fertilizer requirements tailored to the plants' needs.

Method

On 10 dates at weekly intervals between the beginning of June and mid-August 2019, chlorophyll measurements were taken on hop leaves from 2 hop varieties at 2 different locations in the Hallertau. The tool used was an SPAD-502 meter ("soil plant analysis development"). To generate representative results, 20 measurements were taken for each variety, on several plants, at 2 different heights. In order to obtain information about the current N-supply status, the 20 measured leaves were separated, collected, dried and examined together for total N-content (Dumas method). For each type and location, the SPAD values were tabulated individually per height and then aggregated into an average. The relationship between measured chlorophyll values and actual N-contents could then be calculated using linear regression models. In 2019, the measurements were conducted in actual fertilizer tests, followed by yield determinations. In addition, from a comparison between the SPAD values and the yield data, valuable insights could be gained for improving the chlorophyll measurement method with a view towards optimizing nitrogen fertilization.

Results

The graphic shows the averaged measured SPAD values over the course of the year for the Herkules variety in an easy location. The different curves represent the measurements at different fertilizer levels. While the control (0 kg N/ha) is noticeable for its low SPAD values throughout the vegetation period, the fertilization variants start to differentiate only after the main nitrogen uptake. In the reduced fertilization variant (120 kg N/ha), the values drop slightly starting in July and indicate a latent N-deficiency. With the optimally fertilized variant (180 kg N/ha), the SPAD values remained stable until the start of the ripening phase.

The results are promising in that the SPAD measurements on hop leaves provide a rough estimate of the nitrogen supply status of the hop plant. The influence of the hop variety, of the cultivation location and of the growing year on the results still needs to be investigated further.

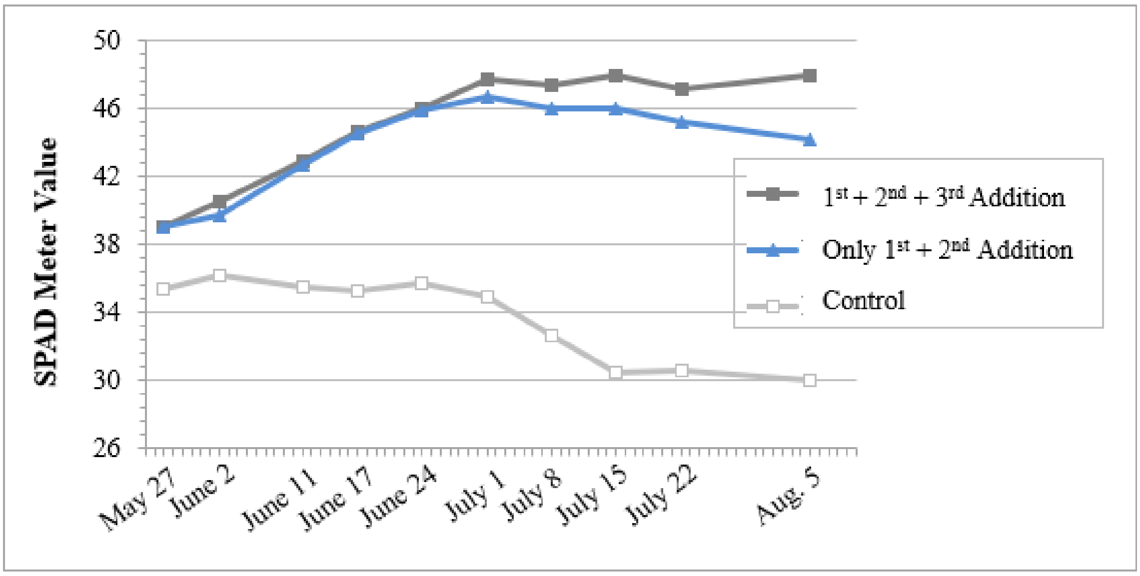

Fig. 4.15: SPAD values over the course of 2019 of the Hercules variety in an easy location with three fertilizer levels ("1st + 2nd + 3rd application" = 180 kg N/ha; "Only 1st + 2nd application" = 120 kg N/ha; "control" = 0 kg N/ha)

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

For years now, hop supply contracts contain clauses stipulating that the alpha-acid content of hop batches will be taken into account when calculating payment amounts. Depending on available testing capacities, alpha-acid contents are determined by state, corporate or private laboratories. The procedures (sample sizes, storage) are precisely regulated by specifications set by the Arbeitsgruppe für Hopfenanalytik (*Working Group for Hop Analytics*). These specifications include a list of laboratories that are permitted to conduct follow-up tests, as well as allowable tolerance ranges for results of the analyses. In order to ensure the quality of these alpha-acid determinations, the chain analyses are organized, conducted and evaluated by the Bayerischen Landesanstalt für Landwirtschaft (*Bavarian State Research Center for Agriculture)* as a neutral body. This protects the interests of hop growers.

As part of the project, the Hopfenring *(Hop Circle)* is tasked with sampling a total of 60 randomly selected hop lots for inspection, in the Hallertau, on 9 to 10 dates, and with making the results available to the LfL laboratory in Hüll.

4.8 Consulting and training activities

In addition to the task of conducting applied research in the field of production technology for hop cultivation, the Arbeitsgruppe Hopfenbau, Produktionstechnik (IPZ 5a) *[Working Group for Hop Cultivation and Production Technologies (IPZ 5a)]* also has the task of preparing test results for the group’s consulting and advisory activities. For this, it offers special assistance, training, working groups, courses, seminars, lectures, print media and Internet content. Also part of the working group’s assignment is organizing, continuously updating and implementing the peronospora warning service; as well as cooperating with hop organizations; and providing training and technical support to its partner Hopfenring *(Hop Circle).*

The working group’s training and consulting activities over the past year are summarized below:

4.8.1 Information disseminated in written form

- The so-called Grüne Heft *(Green Pamphlet)* “Hopfen 2019 – Anbau, Sorten, Düngung, Pflanzenschutz, Ernte” *(Hops 2019 - Cultivation, Varieties, Fertilization, Plant Protection, Harvest)* has been updated in cooperation with the Arbeitsgruppe Pflanzenschutz *(Plant Protection Working Group)* and in liaison with the consulting services of the federal states of Baden-Württemberg and Thuringia. The press run was 2,250 copies, distributed via the LfL to the ÄELF *(Center of Expertise for Agroecology)* and to various research institutions, as well as via the Hallertau office of the Hopfenring to hop growers.
- The creation of a 60-page brochure “Leitlinien zum integrierten Pflanzenschutz im Hopfenanbau” *(Guidelines for Integrated Crop Protection in Hop Cultivation)* is a comprehensive reference work covering the implementation of integrated crop protection measures in hop cultivation. It was made available to all hop growers via the Hopfenpflanzerverband *(Hop Growers Association).*
- Via the Ringfax list (fax list of the *Hop Circle*): In 2019, 960 subscribers received 50 faxes for the Hallertau and 2 additional ones for Spalt and Hersbruck. The latest hop growing instructions and warning messages from the LfL were sent to hop growers in 23 separate fax messages.
- Advice and specialist articles for the hop growers and the brewing industry were published in 2 circulars of the Hopfenring (*Hop Circle*), 8 monthly issues of the *Hopfenrundschau*, 2 articles in the *Hopfenrundschau International* and 1 article in *BRAUWELT*.

4.8.2 Internet and intranet

Warning messages, advice, specialist articles and lectures were made available to hop growers on the Internet.

4.8.3 Telephone advice, announcement and warning services

- The peronospora warning service was in operation from June 7 to August 30, 2019. The information was generated by the Arbeitsgruppe Hopfenbau, Produktionstechnik *[Working Group for Hop Cultivation and Production Technologies (IPZ 5a)]* in Wolnzach in cooperation with the Arbeitsgruppe Pflanzenschutz *(Working Group Hop Plant Protection)* in Hüll and updated 80 times for access on an automated answering machine (Phone +49-8442/9257-60 and -61) or on the Internet.
- Specialists at the Working Group for Hop Cultivation and Production Technologies answered about 1,400 requests for information on the phone or in one-on-one, on-site consultations regarding special issues relating to hop production.

4.8.4 Lectures, conferences, guided tours, training and meetings

- Weekly exchange of experiences during the growing season with advisors of the Hopfenring (*Hop Circle*).
- 9 meetings about hop cultivation in cooperation with the ÄELF (*Centre of Expertise for Agroecology*)
- 50 lectures
- 3 guided tours for hop growers and the hop industry
- 8 conferences, specialist events or seminars
- Open house day in the Haus des Hopfens (*House of Hops*), Wolnzach

4.8.5 Education and training

- Creation of 4 examinations and 4 work projects as part of the master certification
- 10 lessons at the Pfaffenhofen agricultural school for students in hop growing
- 1 school day as part of the summer semester at the Pfaffenhofen agricultural school
- 1 information event for vocational students from Pfaffenhofen
- 6 meetings of the Unternehmensführung Hopfen (*Working Group Hop Management*)
- Participation in the Soil Fertility Working Group of the Hopfenring *(Hop Circle)*

5 Plant Protection in Hops

Simon Euringer, M.Sc. Agricultural Management

5.1 Pests and diseases of hops

5.1.1 Soil pests

Because the spring of 2019 was warm and dry, hops developed early and rapidly in many parts of the country, and such pests as wire worms, alfalfa snout beetles and hop flea beetles were mostly just a minor problem. There were, however, several localized infestations that caused substantial damage. These hop gardens suffered from hop flea beetles and alfalfa snout beetles, especially if the work there started at a later date. This resulted in the plants showing little growth during the cool temperature period in late April to early May. In most conventional hop gardens, the last time the insecticide Actara was used was during the 2018 cultivation year.

The long development cycles of most soil pests (hop flea beetle, 1 year; alfalfa snout beetle, 2-3 years) resulted in a low reproductive potential. The damage potential, however, must be rated as high.

The application for emergency use of Actara, supported jointly by the German Hop Growers' Association and the product manufacturer, was rejected.

5.1.2 Powdery mildew

Starting with the crop year 2014, there has been an increase in infection pressure from powdery mildew. In regions with high infestation rates, infections were already noticeable on leaves in May.

Preventive measures such as the appropriate selection of varieties, hop culling, additional ploughing, hop cleaning, reducing the number of shoots at the training stage and practicing general sanitary field measures (control of random shoots and of wild hops, as well as of grasses and weeds) are becoming increasingly important. Furthermore, a high nitrogen level promotes the susceptibility of the hop plant to powdery mildew.

In order to ensure the best possible success against powdery mildew, treatment must be administered at the proper time. Because the range of countermeasures is made up of curative active ingredients, it is essential that the intervals for spraying against powdery mildew are not too long. Alternating active ingredients is also essential.

5.1.3 Peronospora primary infection

The 2019 hop season got off to a quick start in the spring because of the warm weather. Rapid early development reduced the risk of primary downy mildew infections. Therefore, all countermeasures against primary downy mildew infections could be carried out on schedule.

5.1.4 Peronospora secondary infection

The cool and rainy May led to an increase in the number of zoosporangia and thus to the first spraying recommendation for all varieties against secondary downy mildew infections on June 3, 2019. During the subsequent very dry and hot phase in June and July, no infection pressure could build up. Further spraying recommendations were not issued until July 31, 2019, and then on August 14, 2019 and finally on August 26, 2019 (Fig. 5.1).

Because of the weather, downy mildew turned out not to be much of a problem for hops in the 2019 growing season. The spectrum of approved active ingredients against downy mildew was sufficient. The peronospora warning service also confirms the low infection pressure in 2019.

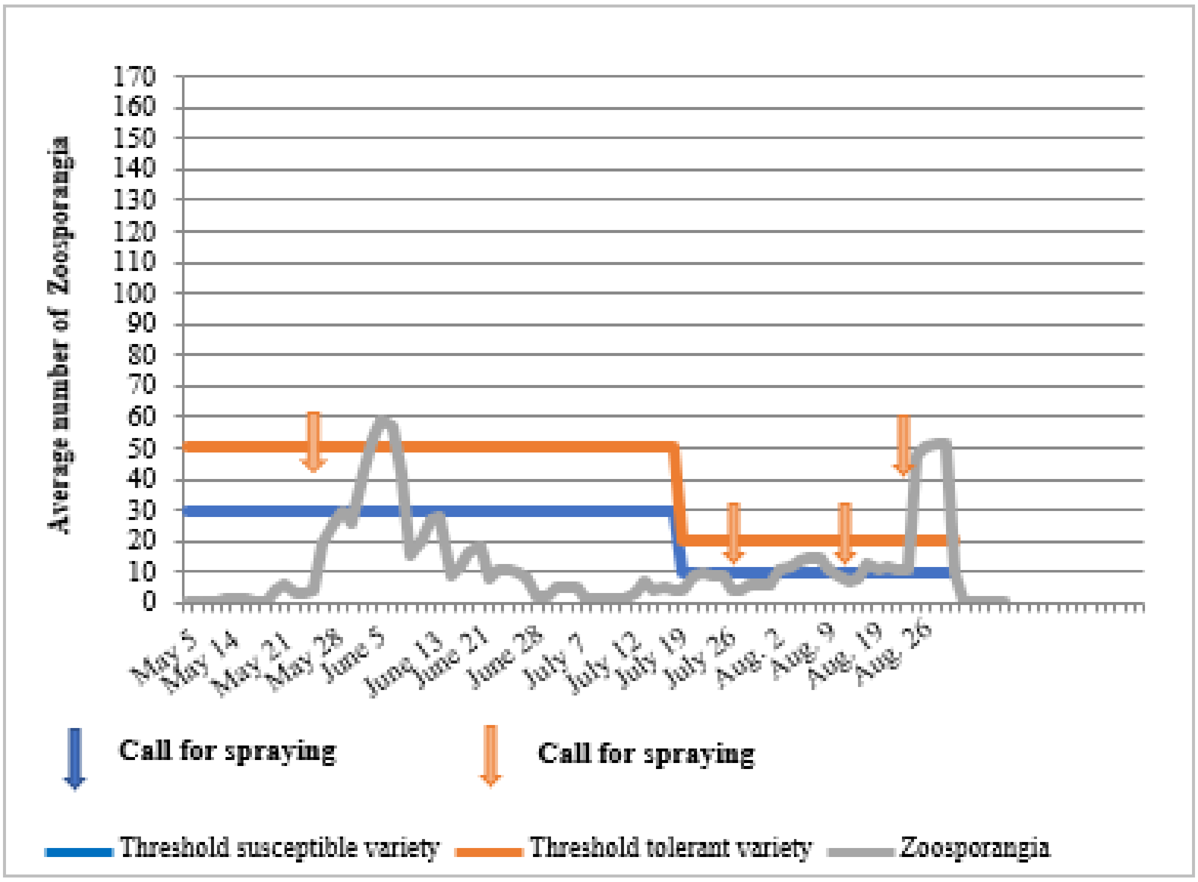

Fig. 5.1: Peronospora warning service 2019 (IPZ 5a)

5.1.5 Hop aphid (*Phordon humuli*)

In Hüll, for instance, because of the warm spring weather, aphis flies were already active in their winter hosts in April, but the cold snap from late April to early May delayed the influx and colonization of hop aphids in the hop gardens (Fig. 5.2).

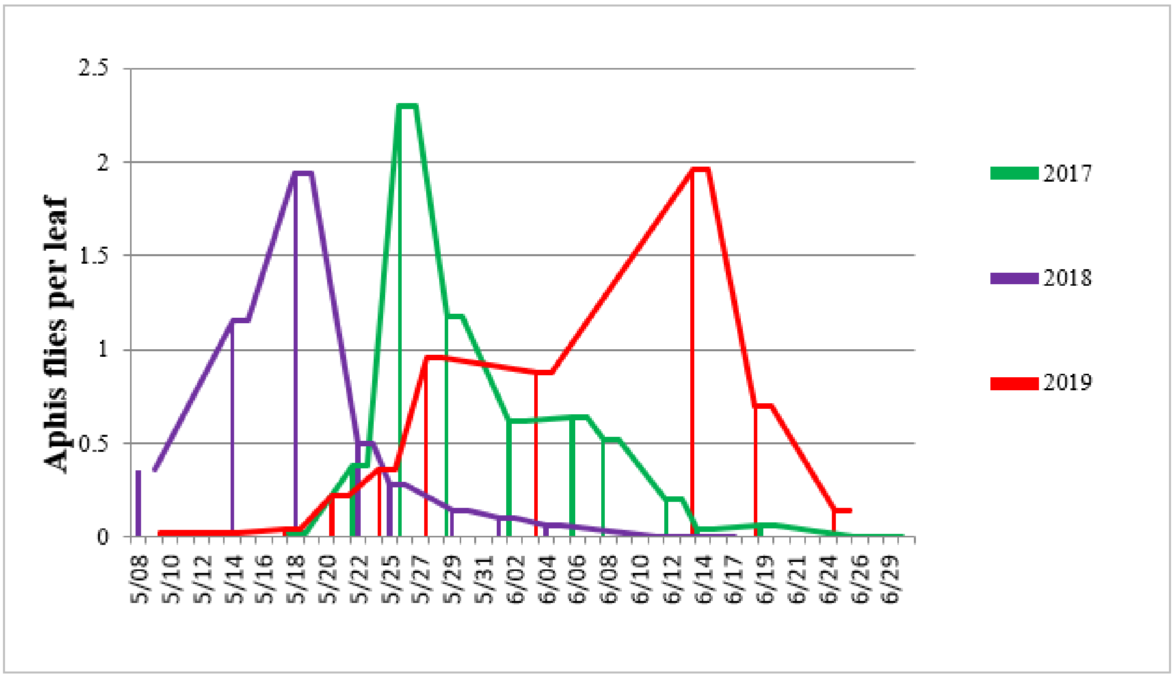

Fig. 5.2: Aphid influx in Hallertauer Magnum in a Hüll hop garden, where no Actara had been used since 2016

As expected, hop aphids multiplied until the end of June. Once the aphis fly migration was complete, a targeted application of the insecticide Movento SC 100 (Art. 53) was very successful in containing them, in most cases. Stocks that needed additional treatment at the flowering stage were given mostly Teppeki or Plenum 50 WG. Overall, the containment of hop aphids was good to very good in 2019 (Table 5.1.).

5.1.6 Common spider mite

The common spider mite benefited from the dry and warm to even hot weather from mid-May to late July. The effects of the insecticide Movento SC 100 came in handy at all commercial hop farms. Spider mites that survived this treatment were successfully kept in check by conventional means, including acaricide applications. Even in hop gardens with severe infestations, successful pest mitigation was still possible within the Integrated Crop Protection regulations, mostly because of the broad spectrum of available countermeasure products (Table 5.2).

Tab. 5.1: Hop aphid monitoring at 30 locations in the Bavarian hop growing regions (Hopfenring e.V.)

Date	Aphis fly colonization Ø	Aphids per leaf			
		Top	Middle	Bottom	Ø
May 20	0.1	0.9	0.4	0.0	0.6
May 27	0.4	2.8	0.7	0.1	1.6
June 3	0.7	7.5	1.3	0.5	4.2
June 11	1.9	13.4	3.7	1.3	8.0
June 17	1.3	25.5	3.7	1.7	14.1
June 24	0.2	38.5	4.8	2.4	21.1
July 1	0.0	6.0	1.3	0.1	3.4
Jul 8	0.0	1.0	0.5	0.2	0.7
July 15	0.0	0.3	0.8	0.1	0.4
July 22	0.0	0.1	0.0	0.0	0.0
July 29	0.0	0.0	0.0	0.0	0.0
August 5	0.0	0.0	0.0	0.0	0.0
Main Treatment Period June 24 to July 1					

Tab. 5.2: Common spider mite monitoring at 30 locations in the Bavarian hop growing regions (Hopfenring e.V.)

Date	Eggs	Spider Mites	Spider Mite Index Ø
May 20	0.21	0.20	0.05
May 27	0.76	0.35	0.10
June 3	1.17	0.43	0.15
June 11	1.35	0.86	0.22
June 17	0.96	0.85	0.22
June 24	1.34	1.42	0.25
July 1	0.26	0.62	0.15
Jul 8	0.34	0.26	0.12
July 15	0.56	0.40	0.13
July 22	0.19	0.14	0.07
July 29	0.08	0.17	0.06
August 5	0.15	0.14	0.04
Main Treatment Period June 24 to July 15			

5.2 Official examination of media

Project Management: S. Euringer

Team: A. Baumgartner, M. Felsl, K. Kaindl (GfH), S. Laupheimer, K. Lutz, M. Mühlbauer, M. Obermaier (IPZ 5e), G. Thalmaier (GfH), J. Weiher

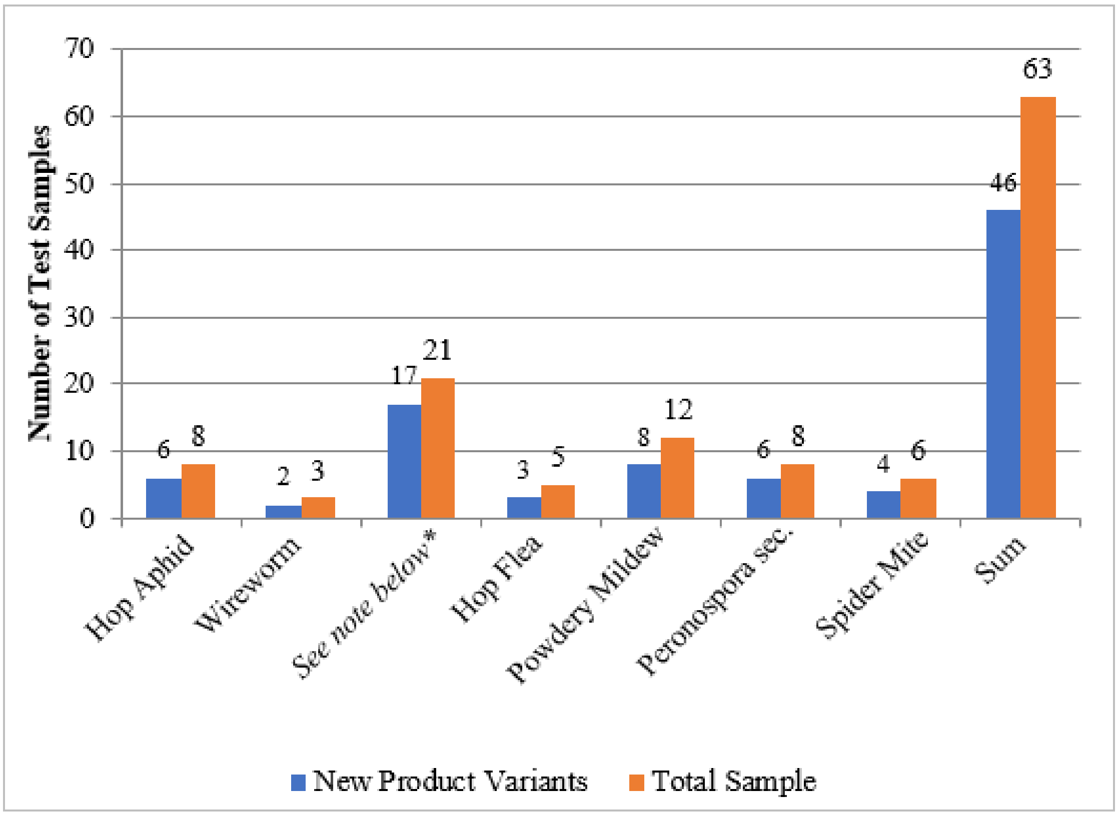

Fig. 5.3: Official examination of media 2019

*Method of “cleaning” hop gardens with grazing sheep (“*Hopfenputzen*”)

As part of the 2019 official media testing [Amtlichen Mittelprüfung (AMP)], 9 tests were conducted in accordance with the standards of good experimental practice [Grundsätze der Guten Experimentellen Praxis (GEP)]. These covered 7 media. This means that a total of 46 new products or combinations of products were tested in 63 test samples on approx. 8.5 ha (Fig. 5.3).

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

Project Management: S. Euringer

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

Hop aphids affect all hop varieties every year. The disappearance from the market of important insecticides makes it significantly more difficult to alternate among active ingredients to avoid resistance against them. Repeated use of the same active ingredient or of active ingredients that rely on the same mechanism to be effective eventually lead to a selection of harmful organisms that are immune to treatment. As a result, they will develop resistances that make control of the harmful organisms with available active ingredients impossible. Therefore, current and new active ingredients are tested in spray towers to determine if hop aphids become resistant to them. Depending on the type of active ingredient, the results achieved in the tests may differ greatly from those experienced in practice. This is why the test results are not being published. In 2019, 10 active substances (8 new, 2 already approved) were tested in 7 concentrations each.

5.4 Enzyme-linked immunosorbent assay (ELISA) for the identification of hop mosaic virus (HPMV) and apple mosaic virus (ApMV) infections in hops

Project Management: S. Euringer

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

Viral diseases are widespread in all hop growing regions. In order to identify and remove plants infected with viruses, the ELISA test (enzyme-linked immunosorbent assay) was reintroduced at the Hop Research Center in Hüll. For each virus tested, at least one duplicate determination is carried out.

Tab. 5.3: *Result of the ELISA tests in 2019*

	Number of Plants	
	negative	positive
ApMV	1,459	62
HpMV	1,390	88

	Number
Plants tested	1,481
Plants discarded	135
Plants virus free	1,346

Of 1,481 plants tested, 135 had to be discarded. The healthy plants were used as breeding material and as mother plants for hop propagations (Table 5.3).

5.5 GfH-Project for verticillium research

5.5.1 Research and other work on the verticillium problem in hops

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Collaboration:	AG Züchtungsforschung *(WG Breeding Research):* Dr. E. Seigner, P. Hager, R. Enders, J. Kneidl, A. Lutz Dr. S. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia
Financing:	Gesellschaft für Hopfenforschung, *(Society for Hop Research)* Erzeugergemeinschaft HVG *(Hop Producer Group)*

Combatting verticillium wilt in German hop growing regions is a long-term task. LfL research and advice are of central importance in supporting hop growers in their fight against verticillium.

Selection of verticillium-tolerant breeding material and remediation of verticillium-infected soils

Objectives

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

Method

Surveys of practices at hop farms with and without wilting problems in the Hallertau are intended to generate data that can lead to effective cultivation-technical measures that can be implemented in practice to prevent and reduce attacks of this fungus. The recovery of infested plots needs to be supervised scientifically in order to develop innovative approaches for optimizing soil remediation. In addition, there is a further need to develop and optimize existing detection and analysis methods for verticillium. One approach is to use a sensitive indicator plant system.

Collaboration with commercial hop farms

In 2019, 500 hop samples were analyzed for verticillium using real-time PCR, in addition to visual assays in the field. These samples came from the breeding garden in Hüll and from gardens used for selections in Niederlauterbach and Engelbrechtsmünster, as well as from 43 commercially cultivated plots. These analyses are carried out by AG Züchtungsforschung (*AG Breeding Research*) (Dr. E. Seigner, P. Hager, R. Enders).

The results confirmed the visual assays conducted in the respective areas. They also revealed the distribution of verticillium and the aggressiveness of the respective verticillium races. A mixture of mild and lethal strains was detected in 40 of the 43 plots under commercial cultivation. This high proportion of aggressive verticillium strains is not representative of the Hallertau in general but is the result of selection bias for sampling areas known to be prone to have such infections. Nevertheless, the study confirmed that there is an increasing occurrence of lethal races of verticillium.

5.5.2 Thermal hygienization of bine shreds — a bio-test using eggplants as indicator plants

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

In the pot system, the plants are kept under observation for signs of wilting. This includes, among other indicators, the plants' height, vitality and occurrence of typical wilting symptoms. The development of the eggplants in the midst of different hop plants can be used indirectly to determine whether there is infectious verticillium in the plant pots and thus whether the sanitary measures were successful. In addition, the qPCR validation method is used for the reliable detection of the fungus in the plants.

This experiment also tested the efficacy of the thermal hygienization of shredded hop bines stored in a heap for four weeks. It was found that turning the bine shreds regularly during the four-week storage time reduced the infection potential of the verticillium fungus. To achieve this result, however, it is essential that the crop residues are turned regularly. This promotes the hygienic cleaning of all layers, as high temperatures develop in the interior of the heap of shredded bines. The heat breaks down the fungus sufficiently well to significantly lessen the infection potential of the bine shreds.

Description of Experiment

The first step was to collect and shred hop bines infected with verticillium. The infected material was then separated into fine material (leaves, stems, smaller bine pieces) and coarse material (bine sections) so that the difference in the infection potential of the various portions of the bine shreds could be assessed. Next, portions of both types of material was mixed to simulate bine shreds generated by real-life hop harvesters. Depending on the chipper/shredder model installed on the harvester, the material varies in coarseness. Every grower should adjust hygiene measures based on the characteristics of the bine material.

Part of the material was handed over to Weihenstephan University for thermal hygienization. There, part of the material was stored for four weeks in a heap and turned over regularly (similar to aerobic composting), while the remaining, unhygienized material was kept in cold storage for the same length of time to minimize any degradation by microorganisms or other factors.

Tab. 5.4: Experimental data on "Thermal hygienization of shredded bines"

Planting date	July 2019
Start of experiment	November 27, 2019
Evaluation dates	January 7, 2020 January 15, 2020 January 22, 2020 January 28, 2020 February 5, 2020
Fertilizer application	January 9, 2020 (200 g pure N)
Pot volume	3 liters

The eggplants were planted in July 2019. Their slow early development up to the end of November was the result of decreasing day lengths and a lack of greenhouse lighting (Table 5.4).

After four weeks of storage, the bine shreds were mixed into the potting soil of the eggplants. In addition to a control variant without bine shreds, six variants with 15 plants each were set up, each differing in terms of their infection potential and their material properties:

1) Control (without bine shreds)
2) Not hygienized, fine
3) Not hygienized, coarse
4) Not hygienized, real-life (fine + coarse mix)
5) Thermally hygienized, fine
6) Thermally hygienized, coarse
7) Thermally hygienized, real-life

Results

The first symptoms of wilt appeared after one month in the variant "fine, not hygienized." Five weeks after these first symptoms, the experiment was stopped because it was not likely that further differences between the variants would develop afterwards.

During these five weeks, however, there were significant differences in the height of the eggplants among the infection variants. The growth rate of the variants with untreated, fine bine shreds lagged significantly behind those of the other variants, with the growth rate of the hygienized variants differing from one another. This suggests that there is a relationship between growth and the nature of the bine shred material that is used as fertilizer (Fig. 5.4).

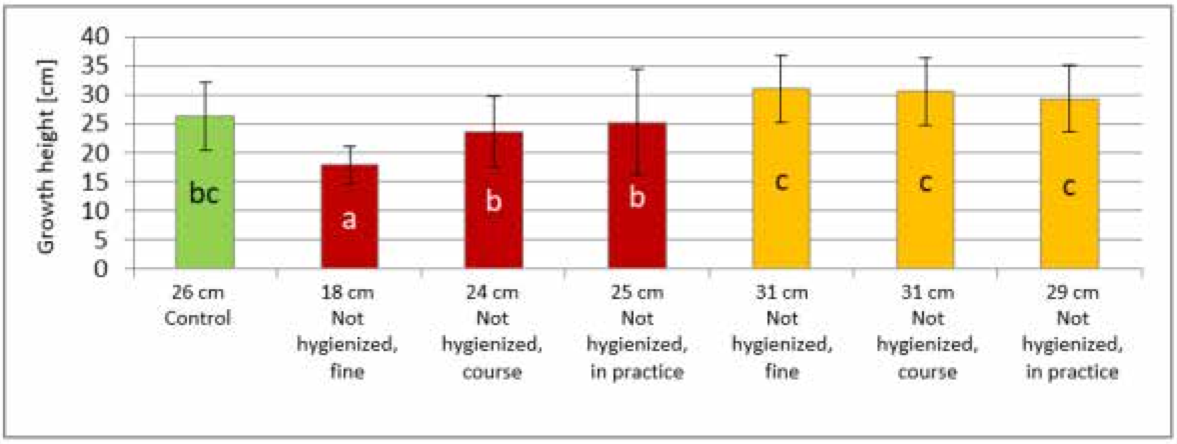

Fig. 5.4: Height of eggplants [cm] on February 5, 2020, that is, 71 days after the infection; different letters represent significant differences between the variants

There are significant differences with regard to vitality, which involves a subjective assessment of the plant's fitness. As expected, the control plant performed best since it grew in pure potting soil without any potential for infection. The variants that were fertilized with untreated bine shreds performed the worst. The highest infection potential was observed in plants fertilized with finely shredded, unhygienized material. This suggests that the fine structure of the material exposed the fungal mycelium, which provide the fungus with ideal conditions to infect the eggplants. A somewhat lower infection rate was found for the coarsely shredded, thermally untreated bine material. The vitality of the variant representing real-life conditions ("in practice") was in between these two (Fig. 5.5).

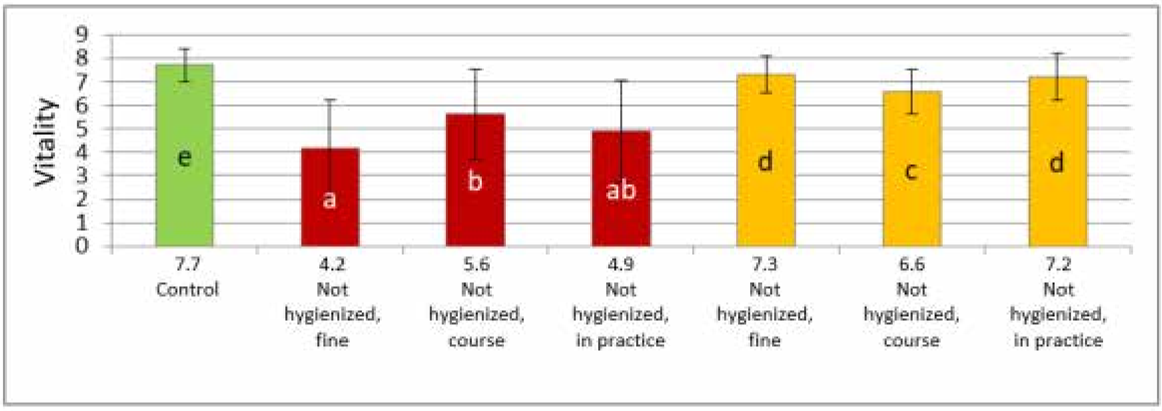

Fig. 5.5: Vitality of eggplants averaged over the entire experiment; 1 = dead, 9 = very good fitness; different letters represent significant differences between the variants

The thermal treatment of bine shreds also reduced the symptoms of wilt. In contrast to vitality, verticillium symptoms relate only to the progress of the disease itself. These symptoms include the wilting, curling and yellowing of leaves, as well as leaf necrosis. In the study, the value "0" represents healthy plants, while "9" represents plants that have died from an excess of wilt. The thermally treated bine shreds performed worse than the non-infected control, but significantly better than the non-hygienized variants. The lowest infection reduction was in plants fertilized with treated, finely shredded material and in the real-life ("in practice") variant.

The plants were also healthier than with the coarse hygienized bine shreds. This is because the coarse nature of the shreds, which results in a small surface area of the material and poor accessibility inside the bine, protects the fungus. The thermal treatment of this material cannot achieve the same effect as that of the finer material with a significantly larger surface area. In addition, the coarse bine pieces degrade very slowly. They remain in their original condition for a relatively long time and thus prevent the fungal mycelium from being damaged by the heat developed inside the heap (Fig. 5.6).

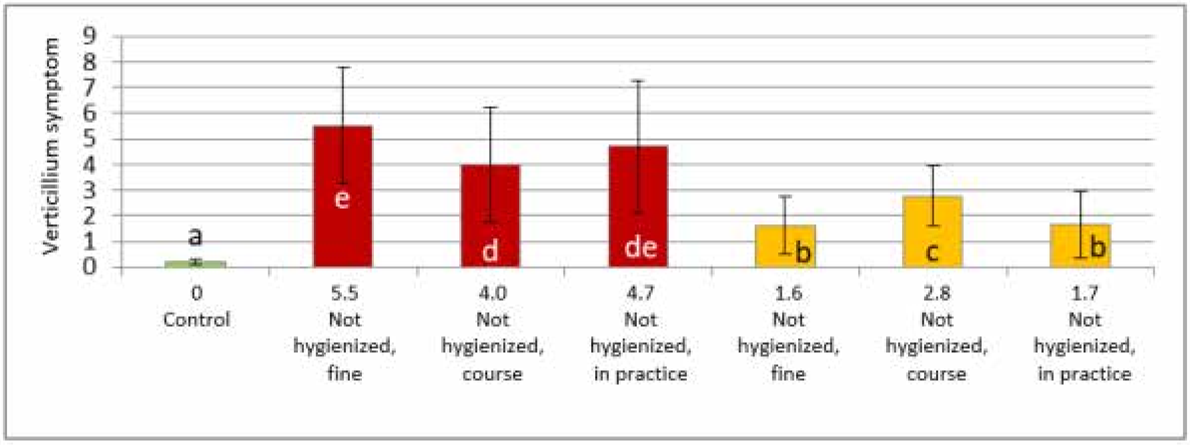

Fig. 5.6: Verticillium symptoms of eggplants averaged over the entire experiment; 0 = no symptoms, 9 = dead; different letters represent significant differences between the variants

If the infection potential is to be reduced by increasing the storage time of the heap, it is important that it contains as little coarse material as possible. Conversely, the coarser the material in the heap, the longer the storage time has to be. However, if extended storage periods are not possible, bine pieces are significantly less infectious than leaves, stems or shreds. The finer the material, the more likely the presence of fungal mycelium on the surface will infect new host plants. The structure of the material makes it easier for the fungus to migrate from an already infected host plant to another as-yet uninfected one.

When evaluating verticillium symptoms, the drought stress of the eggplants is also assessed. Thermal hygienization can significantly improve the plants’ water supply. The fungal mycelium seems to have a lesser effect on the conduction pathways of the plants. This suggests that the infection potential could be significantly reduced. The hygienized variants performed identically or similarly as the non-infected control plants and thus differed significantly from the non-hygienized plants (Fig. 5.7).

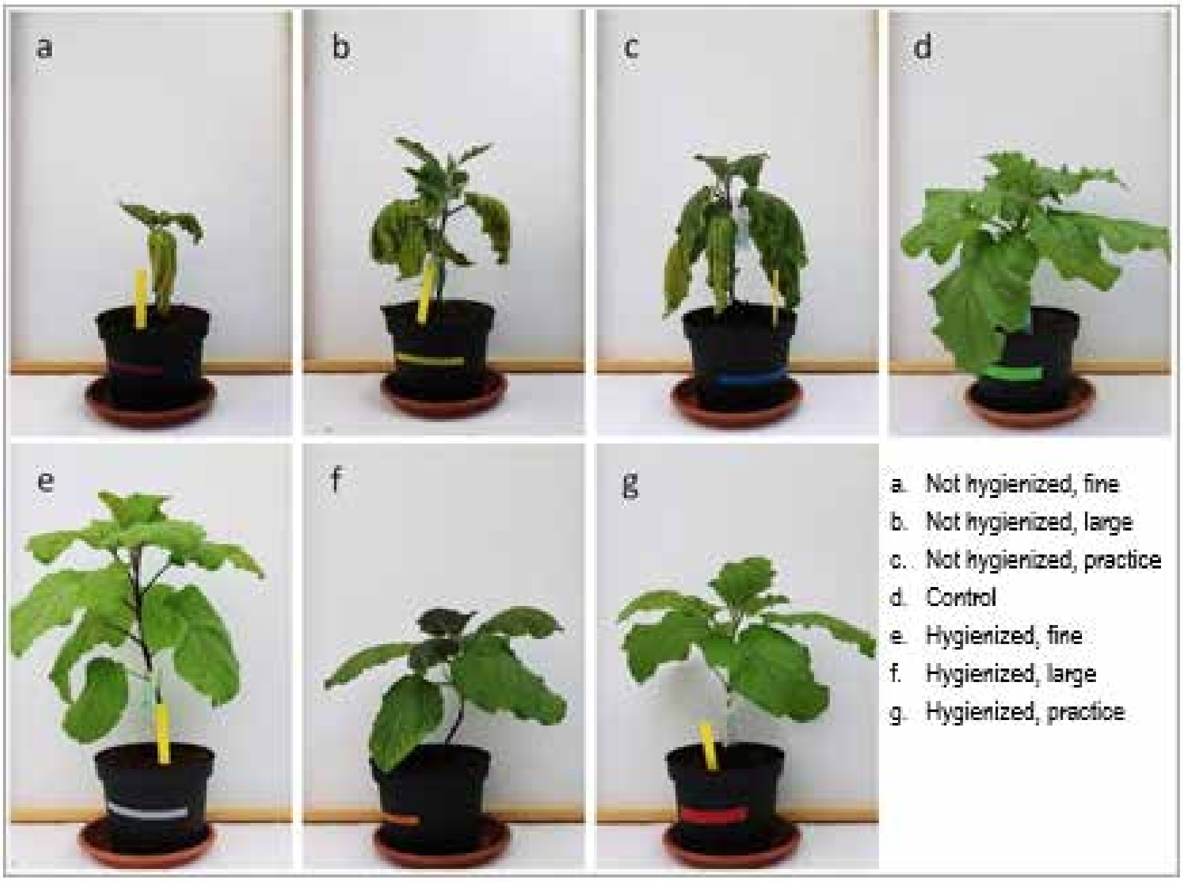

Fig. 5.7: *Comparison of the bine shred variants after infection with verticillium-infected bine shreds (not stored compared to stored for 4 weeks with regular turning of the bine shred layers); selection of representative plants from each variant. Photos on January 22, 2020, that is, 58 days after infection*

Summary

Overall, the infection potential could be significantly reduced by storing the heap for four weeks with regular turning of the shreds. The thermally treated variants performed better than the untreated variants. None of the plants performed as well as the control plants. Nevertheless, there was a clear improvement in the plants' vitality. This supports the notion that longer storage periods or an overlay of the material is advantageous, because it does not increase infection pressures when the bine shreds are spread in the hop garden. As a general rule, however, it is advisable not to return bine shreds from infected stocks to the hop gardens, because there remains a certain residual infection potential. It is not clear yet, to which extent this potential can be decreased by even longer storage periods.

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

Assessing the efficacy of measures against verticillium wilt requires objective observations over a period of several years. Because testing individual plants is very time consuming, remote sensing is a potentially useful alternative. Drones offer the possibility of specifically monitoring individual plots. In order to assess the spread of verticillium across the Hallertau, a verticillium infestation map of the entire growing region was created with the help of aerial imaging by BayernAtlasPlus, an online application of the Bavarian Surveying Administration.

The images recorded in July 2018 proved particularly suitable because the verticillium damage was already clearly visible at that time. Because *Verticillium nonalfalfae* is a soil fungus, it is locally anchored and can thus be mapped. If the map is updated once every 2 years, it can prove useful for monitoring the spread of verticillium in the Hallertau.

5.5.4 Biological soil disinfestation as a possible alternative remedial measure

Biological soil disinfestation might be a possible remedial measure. This involves depriving the fungus of oxygen, next to an addition of protein-containing preparations to the soil. These two measures in conjunction with anaerobic microorganisms already in the soil gradually degrade the fungus. To disinfect a hop garden quickly, a granulate is first worked into the soil. Then, the surface is flooded and covered with a special foil in order to promote the break-down of fungi by anaerobic microorganisms in about four to six weeks. In addition, the fungus itself is harmed by the anaerobic conditions, as well as by the high temperatures that develop under the foil. The objective is to reduce the oxygen content in the soil underneath the foil as much as possible to obtain promising results.

Outlook

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

5.6 The arrival of the *Citrus bark cracking viroid* (CBCVd) in the Hallertau

Project Management: S. Euringer

Team: M. Obermaier (IPZ 5e), K. Lutz

Cooperation: Dr. D. Kaemmerer (IPS 4b), Dr. L. Seigner (IPS 2c) and team, Dr. S. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia
Dr. E. Seigner, A. Lutz (IPZ 5c) and Team, S. Fuß (IPZ 5a)

Monitoring: E. Fischer (IPZ 5a), K. Kaindl, M. Ludwig (IPZ 6a), M. Felsl

5.6.1 Known spread of CBCVd

Arrival in the Hallertau

On July 17, 2019, the LfL received information of a hop plot with unknown disease symptoms. On July 18 and 23, 2019, after inspecting the plot, leaf samples were collected from symptomatic plants. Subsequently, the Working Group IPS 2c used real-time reverse transcriptase PCR (RT-PCR) to examine the samples suspected of harboring CBCVd; and the sequencing confirmed the infestation with CBCVd on July 26, 2019. This was the first confirmed case of CBCVd in hops in Germany. The scientific name for CBCVd is *Citrus bark cracking viroid*, formerly also known as *Citrus viroid IV*.

Known spread of CBCVd in Europe

In Europe, CBCVd is especially widespread on citrus plants in Italy and Greece (Fig. 5.8). In these plants, CBCVd usually causes no or only minor symptoms. Therefore, CBCVd is not regulated in citrus plants and citrus fruit. In hops, CBCVd was first confirmed in 2014 in Slovenia, even though the first symptoms had already been observed in 2007.

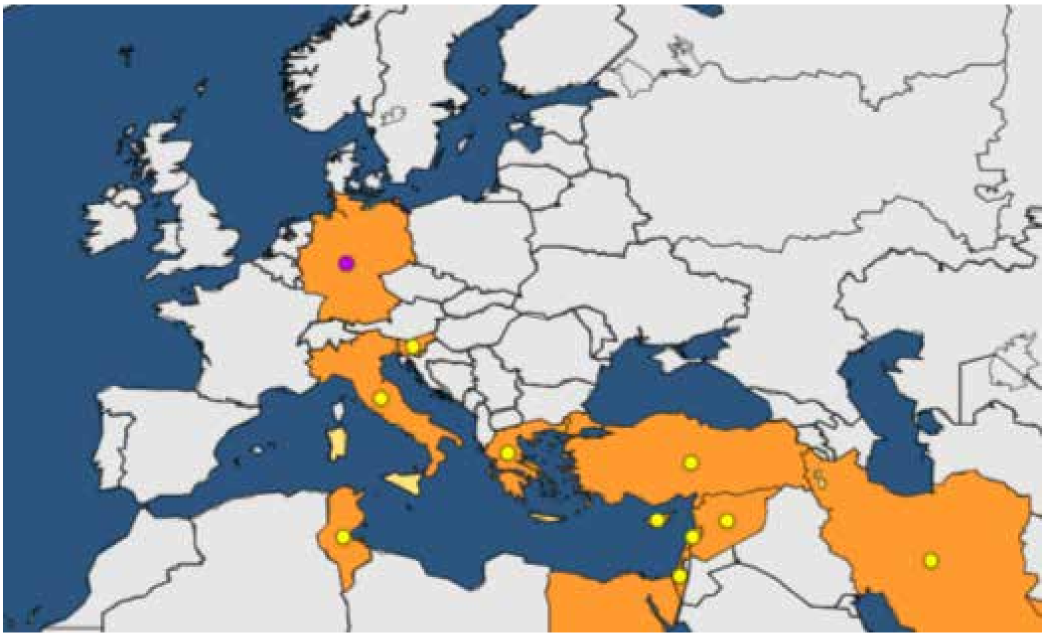

Fig. 5.8: Distribution of the CBCVd - Europe © EPPO 2020

Although citrus viroids are highly contagious, they are used in some countries [Israel, Australia, United States (California)] as a dwarfing agent in the commercial cultivation of citrus fruit. This allows crops to be planted more densely (Bar-Joseph, 1993) without effecting their yields. However, it also leads to calls that agronomic processes relying on pathogens as cultivation aids should be reviewed (J. Jakse et al., 2014).

5.6.2 CBCVd in Slovenian hops

An unknown, highly contagious disease-causing stunting has been reported in Slovenian hop gardens since 2007. The symptoms were immediately attributed to the well-known hop stunt viroid (HSVd), whose damage had been described as early as 1940 in Japan and later in hop gardens in Korea (Sano, 2013). In addition, HSVd infections in hops were reported in the USA in 2004 (Eastwell and Nelson) and in China in 2007 (Sano, 2013). Then in 2013, using molecular techniques (Pokorn et al., 2013; Radišek et al., 2013), a mixed infection of hop stunt viroid and citrus bark cracking viroid was detected for the first time in Slovenian hops. Ultimately, it turned out that the dramatic damage in growth pattern in Slovenian hops was caused primarily by CBCVd as the more aggressive pathogen. By the end of 2013, infections were found on 13 farms covering an area of 44.82 ha (J. Jakse et al., 2014). In 2019, in Slovenia, 238.5 ha were affected (Fig.5.9) (Radišek S., 2019).

Infestation origin in Slovenia

It is believed that the CBCVd transmission in Slovenia comes most likely from citrus waste underneath a hop plot. This hypothesis is borne out by the fact that the parts of the hop garden with the primary outbreak were located on top of an illegal landfill for household waste and waste from a fruit sales center. Experimental infection trials have since confirmed that CBCVd-infected citrus fruit can indeed infect hops (Radišek S., 2016).

Combating CBCVd in Slovenia

Starting in 2011, clearings became the preferred method of fighting CBCVd in Slovenia. The procedure was modified in 2015 and remained the principal strategy for curbing the spread of CBCVd until 2018. In 2019, stricter measures were put into effect; and the current eradication program has been approved by the Slovenian government to stay in effect until 2021. Whenever an infected plant is discovered in Slovenia, the entire furrow plus additional rows, two each on the left and on the right, are being cleared. This clearing represents the minimum a grower is legally mandated to plow under, but the individual farmer is free to clear more rows or even the entire hop garden (Radišek S., 2019).

Up until and including the 2018 growing season, Slovenian hop growers received compensation payments for individual infected plants only. Since the beginning of the new eradication program in 2019, compensation payments extend to the entire area that needs to be cleared because of a CBCVd infection. Depending on the age of the plant and the variety, affected growers receive compensation payments of up to 20,000 €/ha. Currently, 29 Slovenian growers are affected. Since 2011, a total of 293.6 ha has been cleared in Slovenia because of CBCVd infections (Fig. 5.9) (Radišek S., 2019).

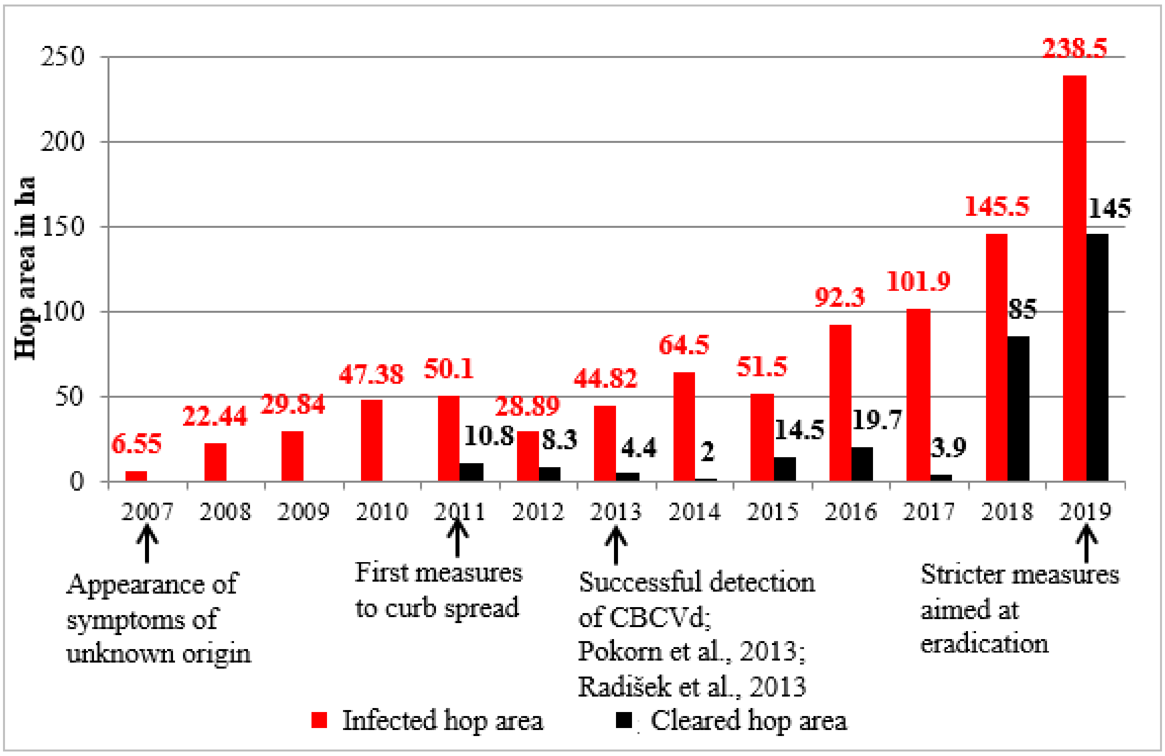

Fig. 5.9: Data on combating CBCVd in Slovenia (Radišek S., 2019)

Tab. 5.5: Hop growing area in Slovenia 2011-2019 (Radišek S., 2019; Simon H. Steiner, Hopfen, GmbH, 2013 and 2016 and 2019)

	Hop acreage in hectares				
Year	**Slovenia**	**Change**	**Infected hop gardens**	**Cleared area**	
2011	1,376	15	50.1	10.8	
2012	1,160	-216	28.9	8.3	
2013	1,166	6	44.8	4.4	
2014	1,528	362	64.5	2.0	
2015	1,403	-125	51.5	14.5	
2016	1,484	81	92.3	19.7	
2017	1,590	106	101.9	3.9	
2018	1,667	77	145.5	85.0	
2019	1,637	-30	238.5	145.0	
				293.6	**Sum**

5.6.3 Express-PRA (Pest Risk Analysis) for *Citrus bark cracking viroid*

The Express PRA (Tab. 5.6) was created by the Julius Kühn-Institut für nationale und internationale Angelegenheiten der Pflanzengesundheit [*Central Institution for Decision Support Systems in Crop Protection and Crop Production* (ZEPP)] on July 31, 2019 (Wilstermann A. et al., 2019).

Tab. 5.6: Excerpts of Express-PRA for CBCVd from July 31, 2019

Express Risk Analysis (PRA)	**Citrus Bark Cracking Viroid**		
Phytosanitary risk for DE	**high** ☒	**medium**	**low**
Phytosanitary risk for EU	**high** ☒	**medium**	**low**
Confidence of assessment	**high** ☒	**medium**	**low**
Conclusion	The *Citrus Bark Cracking Viroid* (CBCVd) was first detected in 1988 in California (USA), but so far it has not been found in Germany. CBCVd is known to occur in Greece, Italy and Slovenia. It has not yet been listed in the Annexes to Directive 2000/29/EC but has been on the EPPO A2 list since 2017. Slovenia has taken emergency measures against the introduction and spread of the viroid after it appeared in hops. CBCVd is mainly known as a viroid with low damage potential for citrus plants. In 2007 symptoms of CBCVd on hops in Slovenia were observed for the first time, infected plants die after 3 - 5 years. It can be assumed that because of suitable climatic conditions, CBCVd can settle outdoors in warm regions of Germany. It is already established in southern European EU member states in Citrus and similar species. Because of its high harm potential for hops, CBCVd poses a high phytosanitary risk for Germany and other EU member states with hop cultivation. Based on this risk analysis, there is reason to believe that the harmful organism will settle in Germany and another member state and can cause considerable damage. Measures should, therefore, be taken to avert the danger of introducing this potential quarantine pest organism in accordance with Section 4a of the PBVO (Pflanzenbeschauverordnung = plant inspection regulation). An infestation must therefore be reported and eliminated in accordance with Section 4a of the PBVO.		
Taxonomy[2)]	Kingdom: Viruses and viroids; Class: Viroids; Family: Pospiviroidae; Genus: Cocadviroid; Species: *Citrus bark cracking viroid* (CBCVd).		

The complete German Express PRA can be found under the following link: https://pflanzengesundheit.julius-kuehn.de/index.php?menuid=57&downloadid=2571&reporeid=76

5.6.4 CBCVd symptoms on hops and the progression of the disease

Once hops are infected with CBCVd, the first visual symptoms appear one to two years later. The infected hops will continue to grow normally until May. A reduction in the distance between new internodes starts in June. The plants' development pattern appears to be stymied (Radišek S., 2019). If the disease is severe, the plant cannot reach the trellis height and the formation of side shoots is drastically reduced. Accordingly, only a few and partially underdeveloped flowers evolve. There is unfortunately no data about the alpha-acid content of infected varieties in Germany. However, there is no doubt that yields are significantly reduced. The plants remain infected until they die. Reports form Slovenia suggest that the plant death is induced by dry rot. So far, this symptom has not been observed in Germany.

Given the lack of data, it has previously been assumed that all varieties cultivated in Germany are susceptible to the CBCVd. During monitoring, some stocks of Hallertauer Magnum tested positive for CBCVd, even though these plants showed no symptoms. Because these stocks were located at the center of an infestation, they are considered “false stocks," which is why Hallertauer Magnum is currently suspected to be tolerant.

The eponymous bursting of the bine (Fig. 5.10) (bark cracking) can also be observed on hops. However, because hop bines can also burst as a result of mechanical injuries or motions caused by wind, the cause of the symptom cannot be clearly attributed. It was striking, however, that bursting was also observed at a height of up to five meters, at a point where the bines had not yet become woody.

Some varieties also show strong symptoms of leaf chlorosis/yellowing, which, however, can be caused by a variety of other causes (Fig. 5.11). The matter is therefore still confusing.

Fig. 5.10: Bark cracking

Fig. 5.11: Leaf chlorosis/yellowing of the leaves

The most typical symptom of infection with CBCVd is the development pattern of the hop plant itself. From June onwards, infected plants show a clearly compressed or "pointed" growth (Fig. 5.12, Fig. 5.13). The current assumption is that the onset of visible symptoms in June depends on the plant’s stress level and could therefore be dependent on the weather.

Another important indication for a CBCVd infection is the distribution of symptom-bearing plants in a plot. Because the CBCVd can be spread easily mechanically (Radišek S., 2019), the spread follows the direction in which cultivation work is performed in the hop garden. During monitoring in 2019, it was observed that the spread of the infection often begins with the furrows that are worked first because of their easy accessibility by tractor.

Fig. 5.12: Mandarina Bavaria, healthy bines on the left and bines infected with CBCVd on the right, July 2019

Fig. 5.13: Hops infected with CBCVd shortly before harvest, variety unknown, August 2019

5.6.5 CBCVd in German hop cultivation

CBCVd monitoring 2019

The examination focused on furrows in a total of 64 plot portions that showed signs of an initial infection. These plots were assayed systematically by physical inspections and by drone flights. In addition, aerial photos from 2018 (Bayernatlas) were used. The monitoring teams took targeted samples of plants that looked conspicuously sick. These samples were examined by the Working Group IPS 2c using real-time RT-PCR.

Conclusions from CBCVd monitoring in 2019

Of 215 samples that were taken, 63 tested positive. A total of 12 plot portions belonging to three farms were affected. These amounted to a combined area of 44.53 ha (calculated according to multiple applications). Apart from these known symptom-bearing plants, there is no information about the actual area of latent infections. All monitoring ceased with the start of the hop harvest. The affected farms were given appropriate advice for dealing with the affected areas.

The infestation map, created on the basis of CBCVd monitoring, will not be published in the 2019 annual hop crop report. Given currently available knowledge, the infestation appears to be limited locally.

Actions taken

The measures ordered here were drawn up based on the JKI PRA (Julius Kühn-Institut pest risk analysis), which, in turn, was based on measures taken in Slovenia in 2015:

- Destruction of all above-ground growth, as well as of the excavated rhizomes of infected plants
- Cleaning and disinfecting of machines and devices
- Destruction of new shoots from cleared plants
- Ban on replanting cleared areas with host plants for two years
- Ban on the production of hop propagation material for up to two years after the last confirmed infection
- Ban on the transport of shredded hop bines from farms to biogas production facilities

Compensation or subsidies for affected farms are currently not planned.

In 2013, the LfL created a "catalog of measures for the prevention and control of viroid infections in hops" (compare "Green Pamphlet") and advised hop farms accordingly. These guidelines will continue to be used:

- Use of healthy propagation material
- No spreading of compost in hop plots
- Regular monitoring of stocks for symptoms of HSVd and CBCVd

Starting in 2008, the LfL has offered voluntary viroid monitoring (HSVd) to farmers. In 2013, based on the first reports of CBCVd detected in Slovenia (Pokorn et al., 2013; Radišek et al., 2013), a molecular detection regimen for CBCVd was established at IPS 2c. This amounted to an expansion of voluntary monitoring so that CBCVd could be included. Thus far, this monitoring between 2013 and 2018 has not unearthed any positive carriers of the disease.

The origins of infestations in Germany

There has been some research regarding possible sources of infection.

- Two farms used compost made from shredded green material (not likely to contain citrus material, but not excluded either)
- All three farms produced hop propagation material that comes from purchased, cultivated substrates of different origins (also unlikely to contain citrus material)
- All three companies purchased propagation material (it is no longer possible to determine whether the recommendation to use only tested material was followed)
- One farm used plant growth preparations based on citrus oil (risk unknown)

Result: the cause of the infestation in Germany is still unknown.

5.6.6 Disease management

No direct chemical or biological control of CBCVd is known. Plants that are infected remain infected until they die. The conventional method used by the LfL (IPZ 5c) of “virus clearance” by way of a meristem culture with heat therapy to produce **virus or verticillum**-free plant material has thus far not been successful with **viroids**.

The only way to contain and eradicate an infestation with CBCVd, therefore, is to remove and destroy all infected plant material.

If CBCVd is allowed to spread uncontrolled on a farm, it can cause a total failure of the entire enterprise within just a few years (Radišek S., 2019). Because an increasing spread within a farm’s holdings is very likely without adequate disease management, CBCVd can be an existential threat.

Until a disease management protocol for CBCVd is developed, the sanitary measures that apply to verticillium wilt apply similarly also to CBCVd.

In contrast to CBCVd, however, verticillium is a soil-based fungus. *Verticillium nonalfalfae* is an organism that can survive independently in the soil for up to five years, whereas such viroids as CBCVd rely on a living host (such as hops) for reproduction. Therefore, it is important to recognize that even after clearing all hop bines, root material remains in the soil, which can be infectious.

Here are a few general rules for combatting CBCVd:

- Destruction of all infected or suspect plant material
- As far as possible, avoid using machinery from outside the farm
- Practice extreme hygiene in the gardens
- Use only healthy planting material

For effective disease management, in-depth knowledge of the CBCVd pathogen itself and its epidemiology is essential (Jakse J. et al. 2014, Radišek S., 2019).

5.6.7 Previous research activities by the Slovenian Institute for Hop Research and Brewing

Insect pests as vectors

Initial tests in Slovenia demonstrated that hop aphids, European corn borers and hop flea beetles do not absorb CBCVd during their sucking or biting activities. In common spider mites that had suckled on infected plants, however, the presence of CBCVd could be determined, but when these CBCVd-positive mites were placed on healthy hop plants, no transfer of CBCVd to the hops could be demonstrated (Radišek S., 2019).

Associated flora in hop cultivation

In principle, it is possible that the associated flora in hop gardens (intermediate crops, grasses, weeds) can be an interim host for CBCVd. Previous test in Slovenia have eliminated grasses as vectors. Data about other intermediate crops, however, is still lacking (Radišek S., 2019).

Mechanical transmission

According to the current state of knowledge, the greatest danger of infection comes from already infected plant material and sap. Because of the large number of processing steps in hop production (including cutting, training, mechanical defoliation and harvesting), CBCVd spreads through the stocks primarily along the same path as the processing (Radišek S., 2019).

Using RT-PCR, CBCVd infections could be detected on tools and devices after 14 days (Radišek S., 2019). Thus, all surfaces in direct contact with plants are likely to be a potential source of transmission long after their last direct contact with infected hops.

Sap on tractor tires and on implements appears to pose a particular danger during and immediately after the harvest. Any injuries caused to the plants by repositioning bines during the growth phase can become entry points for an infection. At the same time, ripening bines with infectious sap are likely to be a source of transmission even after they have dried (Radišek S., 2019).

Hygienization of shredded bines

Over a period of 63 days, CBCVd-positive samples of shredded bines were placed in heaps and checked regularly for CBCVd. Care was taken to ensure that the critical areas that heat up less (edge and bottom areas) were included. The storage time currently recommended in Slovenia for heaps of shredded bines is three to four months without a cover or two to three months with a cover (Radišek S., 2019).

The same applies to the hygienization of shredded bines infected with verticillium. There is no guarantee of absolute success when using this method with CBCVd, because definitive findings apply only to the material actually examined. It is simply not possible to examine the entire mass in a heap of shredded bines.

In the interest of plant health, therefore, returning freshly shredded bines to the field should always be avoided. Hygienization of shredded bines can reduce the likelihood of infection with CBCVd or verticillium to a minimum. As much as possible, contaminated or suspect material should not be reused in hop gardens.

In Germany, therefore, there is now a clear conflict in hop cultivation between the objectives of fertilizer regulations and those of crop protection.

5.6.8 The next steps

In order to gain a sound decision-making basis for dealing with CBCVd in German hop gardens, intensified monitoring is a top priority in the 2020 growing season. Monitoring is planned from the end of June to the end of July. According to the current state of knowledge, this monitoring is divided into three areas:

- Bavarian growing regions (the Hallertau including Hersbruck and Spalt)
- Infested areas and their surroundings
- Hop plots of the farms already affected

The growing regions of Tettnang and Elbe-Saale will also have to participate in CBCVd monitoring. The authorities of the respective federal states are responsible for conducting such monitoring outside of Bavaria.

Based on CBCVd monitoring in Germany in 2020 and on the experience in Slovenia, strategies for combatting CBCVd will be drawn up after the 2020 season. These strategies will be discussed at the state, federal and EU levels. The Association of German Hop Growers e.V. and the German Hop Industry Association e.V. will be involved in the decision-making process.

Acknowledgements

A hearty thank-you goes out to the colleagues at the LfL, especially to the Hop Division, for the hard work and excellent collaboration.

The temporary staff, too, deserves special recognition. Without their valuable work, it would not have been possible to include monitoring on this scale into this report: F. Weiß, J. Röger, L. Weihrauch, L. Blass, L. Eiba, S. Theis and S. Kaindl.

The urgency of the new CBCVd problem and of the upcoming hop harvest presented the Hop Research Center in Hüll *(Hop Research Center Hüll)* with a Herculean challenge. The routine work, which included the official examination of media, for instance, could not have been conducted without the support of all key hop organizations, which made available their staff, vehicles and equipment. A warm “God bless you” to the following, in alphabetical order:

- Deutsche Hopfenwirtschaftsverband e.V. *(German Hop Trade Association)*
- Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Producer Group)*
- Gesellschaft für Hopfenforschung e.V. *(Society of Hop Research)*
- Hopfenring e.V. *(Hop Circle)*
- Verband deutscher Hopfenpflanzer e.V. *(Association of German Hop Growers)*

Special thanks go also to the colleagues from the Biotechnical Faculty of the University of Ljubljana and to the Slovenian Institute for Hop Research and Brewing, especially to Dr. Sebastjan Radišek, for making available, cheerfully and without delay, all their expertise and scientific results relating to CBCVd.

A final thank-you goes to the farmers who were affected by the monitoring for their patience and trust. May we all master the new challenges facing hop growing in German, in collaboration with hop growers, organizations and public authorities.

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6 Hop Breeding Research

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

The Hüll hop research center develops modern, high-performance varieties that meet the requirements of the brewing and hop industries. Our work is characterized by the following objectives:

- The development of classic aroma varieties with fine hop-typical aroma characteristics.
- Since 2006, the breeding of special aroma varieties with extremely broad brewing potential that can be used in both the hot and cold area, depending on the needs of individual breweries. These varieties contribute uniquely fruity-floral aroma profiles or hoppy-spicy notes to finished beers.
- The creation of robust, high-performance, high-alpha varieties.
- The long-standing development of bio-technological and genome analysis techniques in parallel to the classic breeding program.

6.1 2019 crosses

A total of 89 crosses were produced in 2019.

6.2 Diamant (Diamond) — a new, extremely fine aroma daughter of Spalter

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
	National and international brewing partners
	Partners in hop processing and the hop trade
	Verband Deutscher Hopfenpflanzer *(Association of German Hop Growers)*
	Hop growers

Terroir landraces of the Saazer family, such as Spalter and Tettnanger, have delicately spicy hop aromas. This is why they are in great demand in breweries around the world. However, it has become increasingly more difficult for hop growers to raise these old varieties economically.

The new variety Diamant is a direct daughter of Spalter. It was first crossed more than 20 years ago by Herbert Ehrmaier who was then a hop breeder at Hüll. Diamant combines the Spalter's extremely fine flavor profile with competitive agronomic properties.

In long-term cultivation trials, Diamant has demonstrated both improved plant health and higher agronomic performance compared to its mother Spalter. These represent key breeding steps going forward.

Tab. 6.1: Agronomic characteristics and key brewing compounds

Yield potential	1,900 kg/ha, which is significantly higher than that of Spalter and only slightly less than that of Hallertauer Tradition
Resistance/tolerances	Medium resistance or tolerance to diseases and pests
Stress and climate tolerance	Medium
Maturity	Mid to late
Alpha acids (%)	7 (5 – 9)
Beta acids (%)	6 (5 – 7)
Cohumulone (as % of alpha acids)	18 (16 – 20)
Xanthohumol (%)	0.5 (0.4 – 0.6)
Total oil (ml/100g)	1.7 (1.4 – 2.0)
Farnesene (mg/100g)	150 - 200
Linalool (mg/100g)	18

Fig. 6.1: Diamant – cones and cross section of cone

With its fine, classic hoppiness, Diamant belongs to the group of noble hops (see Fig. 6.2). This new variety from Hüll is particularly suited for lager beers. Depending on the timing of additions and their amounts, the large aroma potential of Diamant contributes slight floral-citrus notes or a subtle, mild and pleasant, typical “hoppy” aroma to beer (Fig.6.3).

Fig. 6.2: Aroma profile of Diamant hop

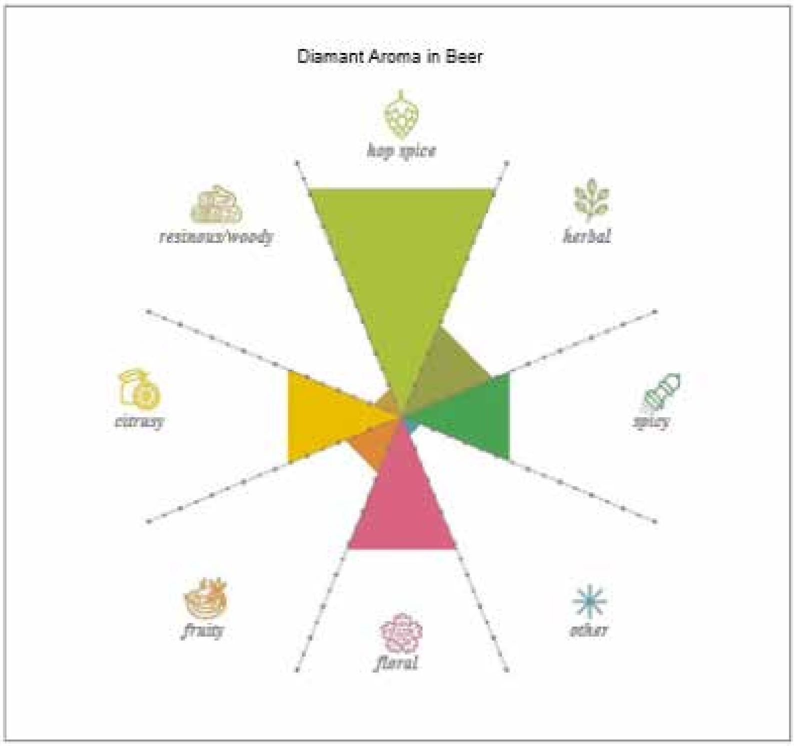

Fig. 6.3: Aroma profile of Diamant in beer

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6.3 Crossbreeding with Tettnanger

Objectives

Develop a new variety by cross breeding the traditional terroir landrace Tettnanger, whereby the classic, fine aromas of Tettnanger are preserved, but the yield potential and resistance to fungal infections are significantly improved. In addition, the problem of premature flowering of the old landrace as a result of higher prevailing temperatures nowadays is to be resolved. Finally, the new, climate-adapted offspring of Tettnanger must have optimal nutrient efficiency so that it complies with the new Fertilizer Ordinance.

Key words: Tettnanger replacement, aroma quality, resistance, climate adaptation, competitive production

Result

- Classic crossings with Tettnanger and preselected Hüll aroma lines
- Mildew resistance testing in the greenhouse and laboratory (see 6.5)
- Seedling testing (single plants) in the greenhouse
- Cultivation trials with reduced use of pesticides and fertilizers
- 3-year cultivation test in Hüll
- 4-year repetitive confirmation trials at two locations in the Hallertau and in Tettnang
- Cultivation trials on commercial farms in the Hallertau and in Tettnang
- **Chemical analyses of cone compounds (IPZ 5d)**
- **Organoleptic assessment of flavors**
- **Virus testing using DASELISA (Double Antibody Sandwich Enzyme Linked Immunosorbent Assay) technology (IPZ 5b)**
- Tests for verticillium infestation using real-time PCR technique (Maurer et al., 2013; Seigner et al., 2017)
- **Pathogen elimination via meristem culture (Seigner et al., 2017)**

Result

Seeding testing

Since 2010, a total of 37 targeted crosses have been produced. More than 1,400 seedings raised in a greenhouse were pre-selected for disease resistance and then planted in the breeding garden in Hüll, where they were tested over a three-year period. Thanks to the minimal use of pesticides and the reduced use of nitrogen in the cultivation tests with seedlings and plants in the breeding gardens, the most robust, resistant and nutrient-efficient candidates were selected.

A total of eight Tettnanger offspring were harvested for the first time in 2019 as part of the seedling examination. Five promising seedlings were selected as candidates for the 2020 plant test. After confirmation that they were virus- and verticillium-free, the seedlings were ready for reproduction and subsequent repetitive planting at the trial sites in the Hallertau at Hüll and Stadelhof. Only the most promising of these candidates will be admitted to further plant evaluations in Straß/Tettnang, in 2021.

Two seedlings showed verticillium infestations but were cured via meristem culture in 2019, after which they were confirmed as verticillium-free. After propagation, they are now available for further plant evaluations in 2020, but initially only in the Hallertau.

Plant evaluations

The breeding lines from the trials 2015, 2016 and 2017 were not satisfactory, neither in the Hallertau nor in Straß. There are several reasons for this. Among these are the plants' early flowering, unacceptably low or variable alpha levels, and susceptibility to peronospora and/or verticillium. Therefore, these plants were cleared.

In 2020, as part of this four-year trial, the plant evaluation phase will resume with ten new samples. The new samples will be tested under varied soil and weather conditions. Reliable conclusions about their growth performance, yield, resistance, composition and aromas will not be available until two or three years from now.

Outlook

After the examination phase of individuals plant, more tests will follow. The new plants will have to prove their performance in plot trials, as well as in rows and large-scale plot tests on commercial farms. To date, no promising candidates have emerged for these next steps. We do not expect cultivation tests in rows to start before 2021/2022 at the earliest, until which time the first new varieties from this crossbreeding program should be available.

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

Initial Situation

The Elbe-Saale hop growing region covers 1,550 ha, which amounts to 7.6% of the total German hop growing area. The region thus makes a significant contribution to Germany's role in the world hop markets. Bitter and high-alpha varieties dominate in the region. For the past 25 years, the main variety there has been the robust, high-alpha Hallertauer Magnum. Yet, in more recent times, the share of the cultivation area devoted to Magnum has decreased from 65% to 40.6%, while the range of other varieties has expanded noticeably. Part of the reason for the decline of Magnum is that its alpha-acid yield of 280 kg/ha is no longer competitive with that of the Hüll-bred high-alpha variety Herkules, which can produce more than 500 kg/ha of alpha acid. However, simply switching from Magnum to Herkules has not been successful in the Elbe-Saale region, because, in that region, Herkules is highly susceptible to crown rot.

Objectives

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

Implementation and method

Crossings

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

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

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

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

Results

Crossings

The selection of candidates began in the spring of 2019 in the greenhouse with more than 3,000 seedlings pre-selected for fungal resistance. Promising seedlings are currently undergoing the three-year seedling test in the breeding garden in Hüll. More than 40 breeding lines must prove their characteristics during the four-year trial in Hüll and Stadelhof. Reliable assessments about yield, composition and disease resistance, especially against crown rot pathogens, are only possible after the completion of this four-year cultivation test in the Hallertau.

Altogether 40 crossings were produced in 2019, all meeting the above-described objectives.

Cultivation trials

A hop grower in the Elbe-Saale region is currently testing three high-alpha breeding strains from the Hüll breeding program. The tests involve comparisons of these breeding strains with Hallertauer Magnum, Herkules, Polaris and Ariana to determine their location-specific suitability for cultivation in the Elbe-Saale region (see Tab. 6.2). The LfL in conjunction with the Thuringian State Institute for Agriculture participate in these cultivation experiments with scientific and technical assistance. For these trials, only high-alpha strains with good bine health, as well as demonstrated positive agronomic properties and resistances were selected from the breeding garden in Hüll.

Outlook

The new breeds show promising characteristics. In the spring of 2019, two additional promising high-alpha breeding lines from Hüll with demonstrated characteristics were planted. However, these candidates must first prove themselves in test plantings in rows and in entire plots in commercial hop farms in the Elbe-Saale region.

Test plantings in rows are currently conducted in trial cultivations on one farm each in Thuringia, Saxony and Saxony-Anhalt. In some plots, five strains are being tested; in others, two. In order to reach reliable conclusions about the suitability of each of the breeding lines, especially about their resistance to crown rot, these cultivaton tests must continue for five years.

Tab. 6.2 (next page.): Test results from an Elbe-Saale farm for Hüll high-alpha breeding lines, planted in rows of 102 plants per breeding line. The results were compared to Hallertauer Magnum, Herkules and Polaris as reference varieties; [1]alpha acids in % by weight according to EB 7

Properties	Hallertauer Magnum	Herkules	Polaris	Ariana	Breeding Line 2010/75/764	Breeding Line 2010/80/728	Breeding Line 2011/71/19
Planting year	1998	2001	2012	2016	March 2014	June 2015	June 2015
Aroma assessment	pleasant	pleasant	pleasant, special aroma	pleasant, fruity, special aroma	pleasant	medium	pleasant
Alpha acids (%)[1]	**12.4** (10.6 – 14.5)	**13.9** (13.5 – 14.5)	**16.4** (13.7 – 18.2)	**9.0** (8.2 – 9.9)	**12.8** (11.5 - 13.7)	**18.7** (17.1 – 20.2)	**16.3** (15.6 - 17.2)
Yield (kg/ha)							
Harvest year 2014	2,210	3,230	2,850		2,615 (Jungh.)		
Harvest year 2015	1,640	1,640	1,900		3,030		
Harvest year 2016	2,830	2,500	2,435	1,651 (Jungh.)	3,010	2,210	2,230
Harvest year 2017	2,925	1,950	2,785	4,488	2,750	3,375	2,930
Harvest year 2018	2,420	No longer planted due to crown rot	2,255	3,092	No longer planted due to crown rot	2,100	2,395
Harvest year 2019	2,740		2,555	3,177		2,145	2,335
kg α-/ha	**311** (174 – 410)	**325** (221 – 453)	**402** (309 – 507)	**324** (272 – 376)	**372** (348 – 392)	**464** (359 – 637)	**406** (376 – 466)
Plant health	very good	low	very good	very good	medium	good	good
Agronomic assessment	robust, strong growth	yield reduced because of crown rot	robust, medium – weak winding ability	broad, good resistances	head-heavy, fast-growing, variable alpha acids	complete powdery mildew resistance, limited cone density	good overall growth characteristics, high yield potential

6.5 Powdery mildew isolates and their use in mildew resistance breeding in hops

Sponsor:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenbau, Produktionstechnik (IPZ 5a) *[Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Production, Production Technology (IPZ 5a)]* AG Züchtungsforschung Hopfen *(WG Hop Breeding Research)*
Financing:	Gesellschaft für Hopfenforschung e.V. (GfH) (2013 -2014; 2017 – 2020) *(Society of Hop Research)* Erzeugergemeinschaft HVG e. G. (2015 - 2016) *(HVG Hop Producer Group)*
Project Management:	Dr. E. Seigner, A. Lutz
Team:	AG Züchtungforschung Hopfen *(WG Hop Breeding Research)*: A. Lutz, J. Kneidl EpiLogic: S. Hasyn
Collaboration:	Dr. F. Felsenstein, EpiLogic GmbH, Agarbiologische Forshung u. Beratung, *(Agri-biological Research and Consulting)*, Freising
Duration:	January 1, 2013 to December 31, 2020

Objectives

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

Starting in 2000, powdery mildew isolates with virulence properties have been used for powdery mildew resistance tests in the greenhouse and the laboratory (Seigner et al., 2002). In conjunction with constantly improving test systems in the greenhouse and laboratory, these resistance tests form the backbone of effective resistance breeding (Seigner et al., 2005; Seigner et al., 2006; Seigner et al., 2009). The source of between 10 and 12 powdery mildew isolates with all currently known virulence genes is EpiLogic, Agrarbiologische Forschung und Beratung (*Agri-biological Research and Consulting)*, in Freising. These isolates are made available for the various efforts related to mildew resistance breeding.

Description of work

Powdery mildew isolates – preservation and characterization of their virulence properties

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

Testing for powdery mildew resistance in the greenhouse in Hüll

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

Fig. 6.4: Resistance test in the greenhouse with seedling trays amidst inoculator plants

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

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

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

- The virulence genes of current powdery mildew populations in German hop gardens are identified every year. The reaction of 11 cultivated and several wild varieties that carry all the resistance genes known to date worldwide (= so-called hop differential assortment), is tested against all currently available mildew isolates. This makes it possible to assess whether existing resistances are still fully effective in current varieties (such as the fully mildew-resistant Hallertauer Blanc aroma variety). Last year, the powdery mildew strain, which is starting to affect Herkules in more and more regions of the Hallertau, was examined by EpiLogic for its virulence properties. The presence of well-known virulences that break the R1 and R3 resistance gene could be confirmed. The virulence was also identified on mildew-infected leaves of Callista in commercial plots. According to our current understanding, the R18 resistance in Callista in these commercial plots appears to have been broken by regionally specific mildew strains with complementary v18 virulence.

These virulence tests provide crucial insights into the mildew strains that are found in commercial plots or greenhouses. These insights are necessary for assessing if the resistance of our varieties is still or no longer effective.

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

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

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

Tab. 6.3: Overview of mildew resistance tests in 2019 with mildew isolates of defined virulence

2019	Tests in greenhouse		Leaf tests in laboratory	
	Plants	**Assay data**	**Plants**	**Assay data**
Seedlings from 88 crossings	approx. 100,000 mass-selected		-	-
Breeding lines*	224	570	224	1,737
Varieties*	26	52	8	54
Wild hops*	1	2	0	0
Virulence powdery mildew isolates	-	-	10	486
Total (Individual tests)	**251**	**624**	**242**	**2,277**

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

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

Testing the effectiveness of active ingredients in combating powdery mildew

As the fight against powdery mildew in hop gardens is becoming increasing challenging, a first attempt was set up by EpiLogic to clarify whether the powdery mildew populations that occur in the Hallertau region have already developed resistance to frequently used active ingredient groups in plant protection products.

For this purpose, the effectiveness of the three approved active substances, pyraclostrobin (Bellis), myclobutanil (Systhane 20 EW) and metrafenone (Vivando), was tested with a mixed isolate from 5 stocks collected from commercial hop farms. However, no significant changes in resistance levels could be found. In other words, powdery mildew strains gathered in the field could still be fought under laboratory conditions with the above-mentioned active ingredients in conventional concentrations. Based on these results, other causes, such as the timing of the spraying or perhaps other application issues, had to be considered as explanations for the inadequate effect of some powdery mildew sprays in hop gardens. For a reliable assessment of the effectiveness of various plant protection products that are used to combat powdery mildew in the Hallertau region, further tests are certainly needed.

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

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

Team: B. Forster

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

Infection of hops with the downy mildew fungus (*Pseudoperonospora humuli*) always poses great challenges for growers. In addition to the peronospora warning service that has been in operation for two decades, hop breeding efforts can make a significant contribution to solving the peronospora problem. The goal is to develop hops with significantly improved tolerances for this fungus. Every year, thousands of young seedlings in the greenhouse are sprayed with a fungal spore suspension; and their reaction to the fungus is subsequently assessed. However, with this mass selection, the tolerance of individual hop plants cannot be determined precisely.

Objectives

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

Method

The first step is to spray the underside of the hop leaves with a peronospora sporangia suspension. Five to 14 days later, the reactions of the leaves are assessed visually, sometimes under a stereoscopic microscope. The reactions may range from no visible symptoms to chlorosis, necrosis or sporulation.

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

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

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

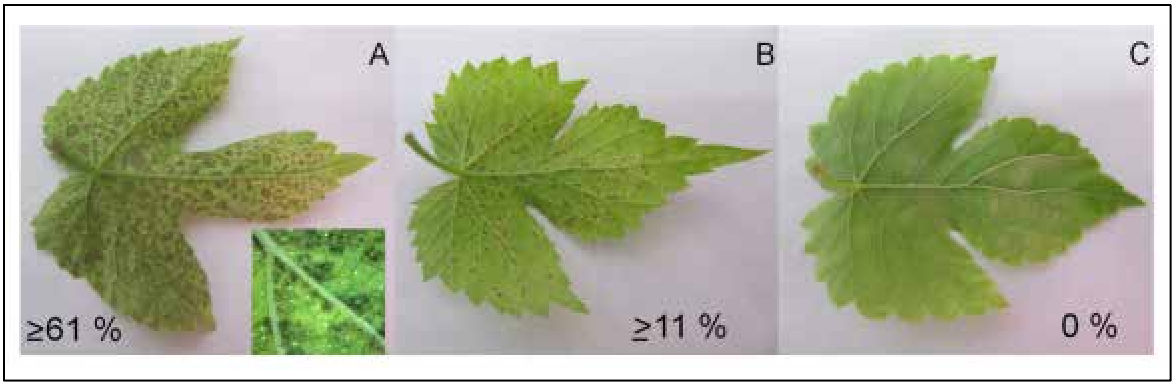

Fig. 6.5: *Different reactions of hop leaves 6 days after inoculation with peronospora: susceptible (A), medium tolerant (B) and highly tolerant (C) to the fungus; % of infected leaf area = sporulation; Photo A also shows a close-up of peronospora infestation with black spore areas*

Results

This leaf test system has been optimized over several years now with improvements in inoculation conditions, vitality of the zoospores, temperature control during leaf incubation in an incubator and the cultivation of test plants. Furthermore, since 2018, the conditions for freezing zoosporangia have been investigated with an eye towards extending the leaf test season by using frozen inoculation material.

In 2019 the test season started in April. By the end of September, 16 test series had been completed, each with two varieties and three breeding lines. Leaves of Hallertauer Tradition (high resistance), Polaris and Hallertauer Mittelfrüh (both with low tolerance) were included in every experiment as references for different peronospora tolerances. Seven additional experiments were conducted but not included in the statistical evaluation because they were carried out with frozen inoculation material.

Next, indices ranking the disease severity were compiled according to a statistical method developed by Townsend and Heuberger. This method uses peronospora evaluation results collected on examined varieties and breeding lines from 2017, 2018 and 2019 with a total of 17 standardized infection attempts. The following picture emerged:

The statistical evaluation confirmed the high peronospora tolerance of the Hüll varieties Hallertauer Tradition and Hallertau Blanc, while Polaris and Hallertauer Mittelfrüh were confirmed to be highly susceptible (Fig. 6.6). All other varieties and breeding lines have a medium tolerance level. Fig. 6.7 shows two tendencies: Mandarina Bavaria, Diamant, Hüll Melon and the high-alpha strain 2010/75/764 have a medium tolerance; all other varieties and breeding lines that were examined have a medium susceptibility. There are no statistically significant differences in the assay results of these hops over the three years (Fig. 6.6).

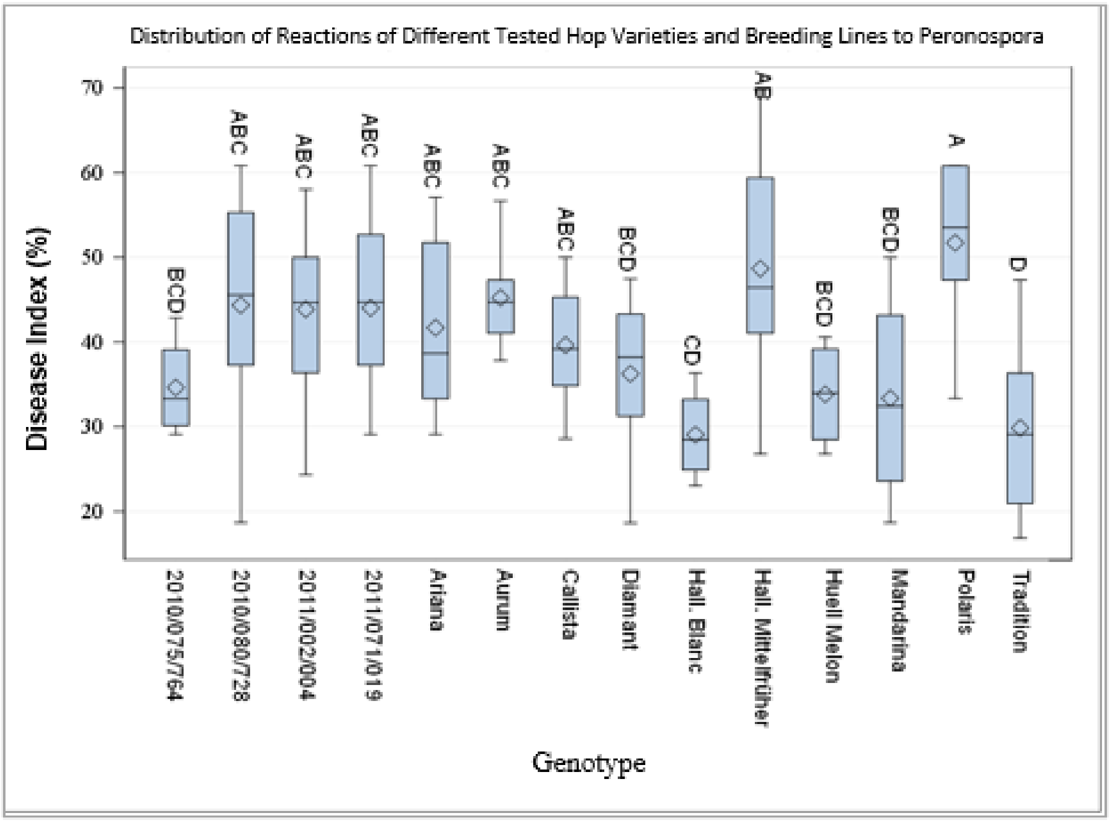

Fig. 6.6: Distribution of the reaction of the tested hop varieties/strains to peronospora from 2017 to 2019. Only hops indicated by different capital letters showed statistically significant differences in their peronospora infestation (Tukey-Kramer minimum significant difference (MSD) test with p <0.05).

Overall, the field ratings for the varieties and breeding lines that have been examined thus far confirmed the tolerance assessments generated by the leaf test system.

Outlook

A decisive advantage of the leaf test system is its ability to generate assessments of the disease tolerance of different hop varieties or strains under standardized conditions, regardless of weather and location influences. The key point for the practical suitability of the leaf test system for use in the breeding process is the correlation between tolerances or sensitivities of hops to peronospora secondary infections assessed in the laboratory, on the one hand, and field ratings, on the other. In the next season, breeding strains will once again be examined using the peronospora leaf test system.

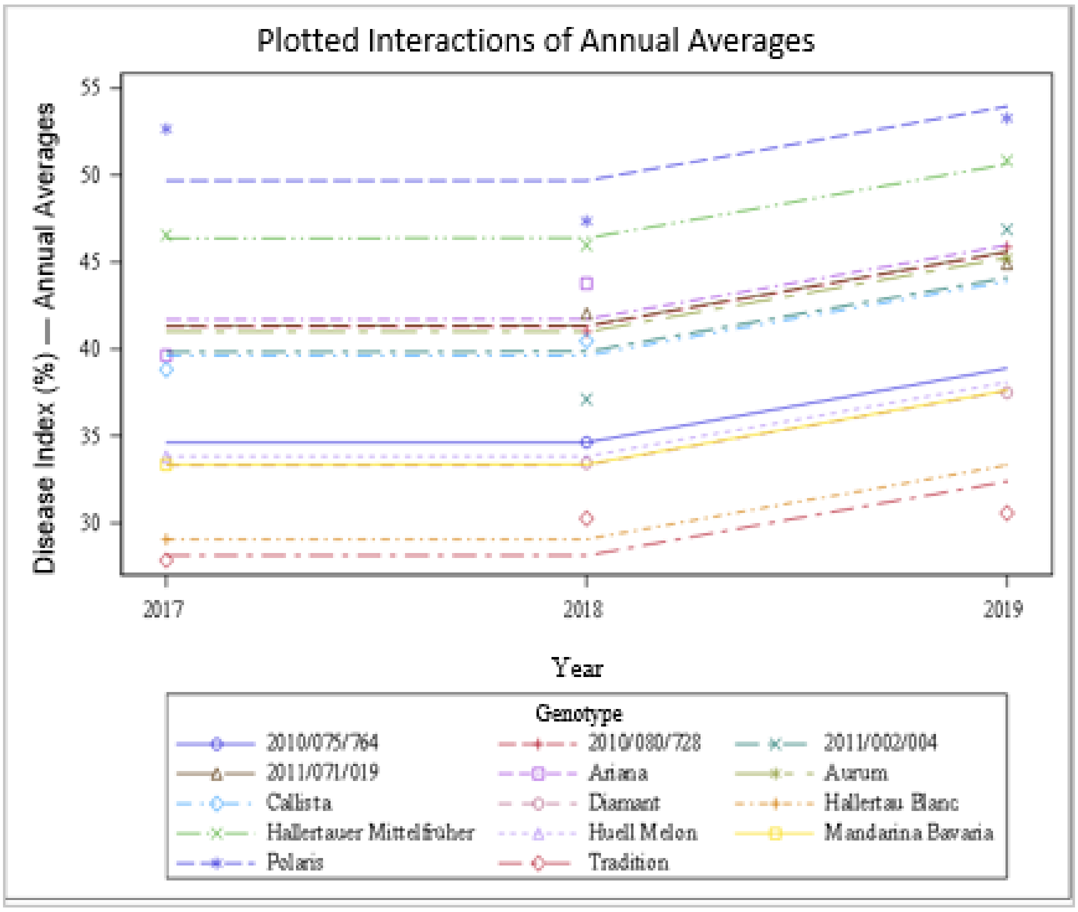

Fig. 6.7: Average values from 2017 to 2019 of the reactions of hop varieties/strains during peronospora test

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

Sponsor:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung *(Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)* AG Züchtungsforschung Hopfen *(WG Hop Breeding Research)*
Financing:	Erzeugergemeinschaft HVG e. G. *(HVG Hop Producer Group)*
Project Management:	Dr. E. Seigner
Team:	AG Züchtungsforschung Hopfen *(WG Hop Breeding Research)*: P. Hager, R. Enders, A. Lutz, J. Kneidl
Collaboration:	AG Pflanzenschutz im Hopfenbau *(WG Hop Plant Protection)*: S. Euringer, K. Lutz Dr. S. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia
Duration:	Starting in 2008 to December 31, 2021

Combating verticillium wilt in German hop growing regions is a long-term task. Research and advice from the LfL as well as the implementation of preventive measures by hop growers are of central importance in the common fight against verticillium in hop growing.

Objectives

In addition to conventional phytosanitary or horticultural measures, planting verticillium-free material is a key building block in the prevention of verticillium wilt spreading in a hop growing region. Since 2013, hop seedlings have been tested for verticillium using a highly sensitive PCR-based detection method. This is to ensure that only wilt-free hops are included in the LfL's own tests and passed on to the contract multiplier at the Gesellschaft für Hopfenforschung (*Society for Hop Research*) (GfH) and thus to hop growers.

Method

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

A sample of the interior of the bine (marrow), which contains the water-conducting vessels and thus possibly also verticillium spores or mycelium, is collected and prepared for examination. The sample material is macerated in a homogenizer and used for the isolation of DNA. In this process, hop DNA and DNA from fungal contaminations, if present in the vascular elements, are isolated.

With real-time PCR using the primers and probes specific for *Verticillium nonalfalfae*, the fungal attack ultimately reveals itself by way of an increase in fluorescence between propagation cycle 18 to approximately 35 (blue curve - see Fig. 6.8). This technique allows for the simultaneous detection of lethal strains of *Verticillium nonalfalfae* (primer pair and probe from Seefeld and Oberhollenzer, not published; violet curve). Furthermore, the functioning of the PCR is confirmed in each multiplex real-time test through the detection of the hop's own DNA (modified as an internal control for COX = cytochrome oxidase according to Weller et al., 2000), whereby "false negative" results can be excluded.

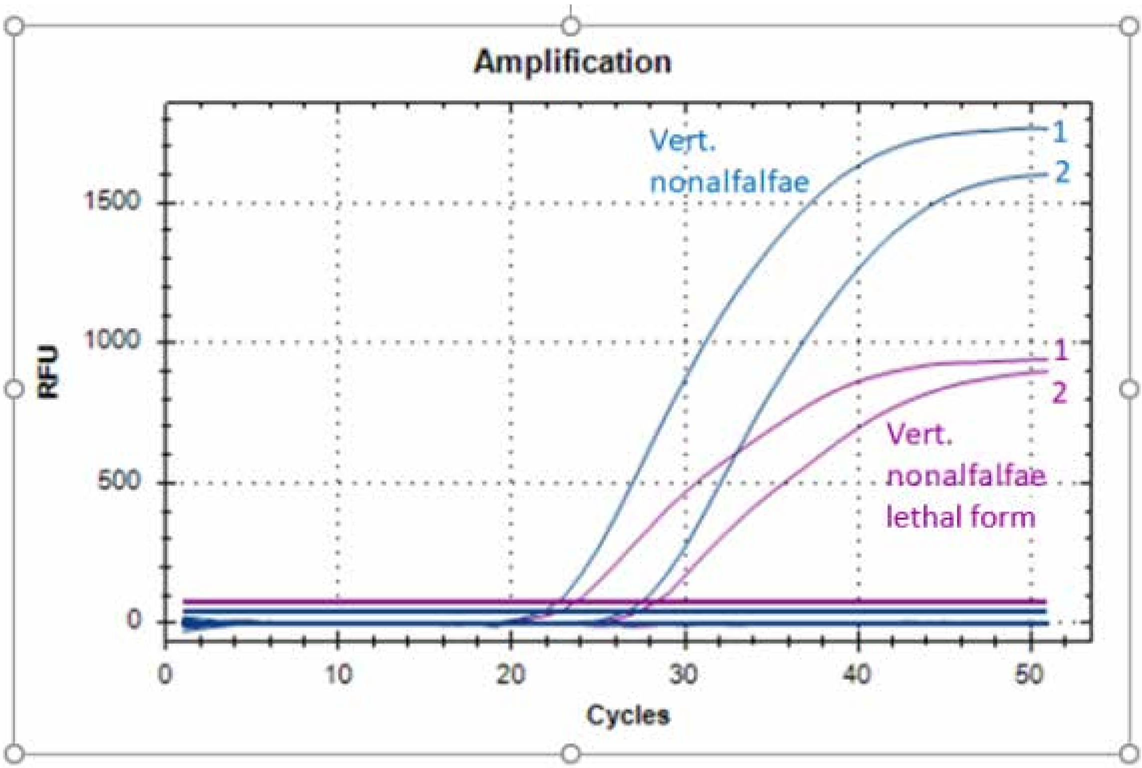

Fig. 6.8: Multiplex real-time PCR of 2 bine samples: The increasing slope of the blue curves means that the sequences specific for V. nonalfalfae were increased with the release of the fluorescent dye "FAM" coupled to the probe. The two examined bines 1 and 2 are infected with V. nonalfalfae *(primer pair does not differentiate between mild and lethal strains). At the same time, the infection with a lethal strain of* V. nonalfalfae *is detected in both hop samples (increase in the fluorescence signal "Cy5" = violet curve). The amplification curves of the hop-specific COX gene for the detection of a trouble-free course of the PCR reactions (green curves) and other samples have been hidden in this figure to facilitate the overview.*

Results

· **Hop Analysis**

Hop bines, roots/rhizomes, leaves and cones, as well as shoot tips and in vitro plants were examined with the real-time PCR for verticillium. The following objectives were pursued:

- Examination of the Hüll breeding material for *Verticillium nonalfalfae* and differentiation of the infections in mild or lethal races of *V. nonalfalfae*

- Examination of the mother plants of a GfH propagation plant for verticillium infestation to ensure the delivery of wilt-free rhizome material to growers
- Molecular verification of wilt symptoms in the Hüll breeding garden, in the wilt selection gardens and in commercial plots, in collaboration with S. Euringer and K. Lutz, both IPZ 5b
- Examination of regenerated meristem plants after "targeted" elimination of verticillium via meristem culture in combination with heat therapy
- Studies of verticillium infection patterns in hops in the field
- Artificial verticillium infection experiments with hops (K. Lutz, IPZ 5b) accompanied by molecular analyzes

· **Optimization of technique**

Various parameters were examined to improve the reliability and information value of the real-time PCR results: Comparison of results for single, duplex, triplex approaches.

· **Detection assistance using eggplants**

In studies of IPZ 5b with eggplants as indicator plants for verticillium-contaminated soils, IPZ 5c (as a collaboration partner) examined wilt symptom-bearing and symptom-free eggplants with real-time PCR and thus verified the ratings.

· **Provision of verticillium inoculation material**

Ten mild and ten lethal verticillium reference strains were made available as infection material from the IPZ 5c-owned reference collection for artificial inoculation experiments with hops and eggplants. For this purpose, the fungal strains from the glycerol stock solutions were refreshed on solid medium and multiplied. To confirm the virulence properties, the newly propagated fungal strains were analyzed using real-time PCR. Only then were the fungal strains propagated in liquid cultures and supplied to Hüll as the starting material for the artificial infection experiments.

Outlook

Real-time PCR is constantly being optimized. The primers used in the PCR reaction for the detection of *Verticillium nonalfalfae* are continuously checked to verify that they still detect all mild and aggressive races that occur in the Hallertau.

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6.8 Meristem culture for the production of healthy seedlings

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

Objectives

Verticillium and virus infestations of hops can lead to dramatic losses in yield and quality. However, there are no pesticides available to combat these diseases. Infected hop plants can only be returned to health via the so-called meristem culture, a bio-technological method.

Method

To produce verticillium-free and virus-free hop plants, the top growth zone (= meristem) located at the end of the shoot tip, is heat-treated and then prepared on a culture medium to induce growth. In about three weeks, special nutrients in the tissue of the culture medium cause leaf structures to develop from the meristem, which eventually develop into a complete plant.

In 2019, all new plants were already virus-free, making it unnecessary to conduct any final virus tests.

In order to confirm the elimination of the verticillium fungus by means of the meristem procedure, the plantlets that had formed in vitro were examined for verticillium using real-time PCR with specific TaqMan probes and primers (Seigner et al., 2017).

Results

In 2019, seven culture strains previously infected with verticillium were “cured” using the culture technique that had been optimized in recent years.

Because of constant improvements of the different cultivation steps, all breeding lines could be returned to Hüll as small, rooted plants within one year (received in March – delivered in March the following year). The regeneration process, which used to be heavily dependent on the genotype, was successfully completed for all genotypes “treated” thus far. However, weaker tissue culture suitability was still evident in a few plants, as well as in plants with a slightly longer regeneration time. In mid-January, the plantlets were moved from the tissue culture into soil. They were then delivered to Hüll, where they were acclimatized in a greenhouse and finally planted outdoors.

After pathogen elimination, promising breeding material from the aroma breeding program (one line) and from the Tettnang crossbreeding program (two lines; see 6.3), as well as from the high-alpha breeding program (four lines; see 6.4) could quickly be incorporated into the cultivation tests on wilt-free plots in spite of their initial verticillium infestations.

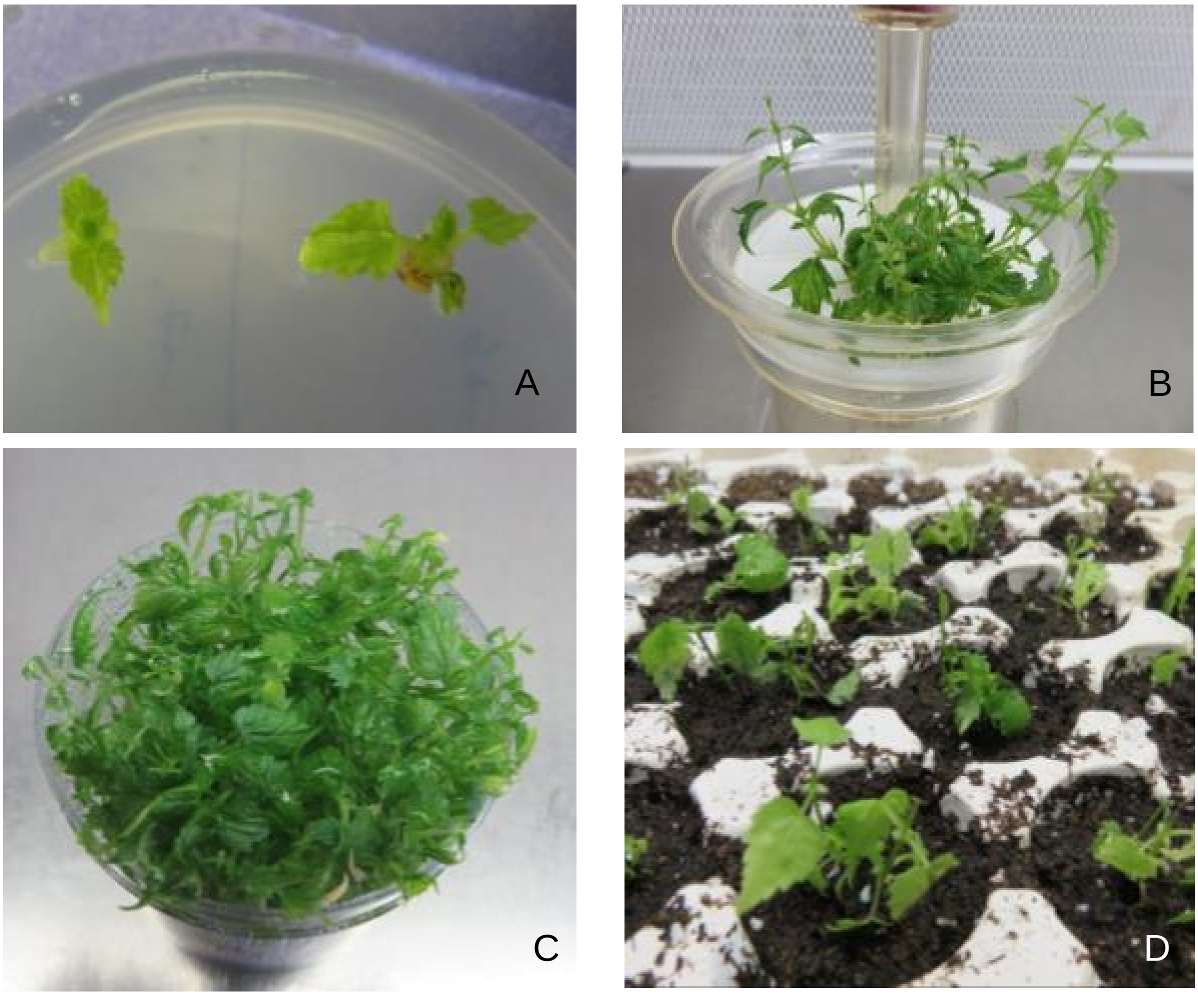

Fig. 6.9: Regeneration of the plantlets created from meristems A) 3 weeks after preparation on a solid medium in a petri dish, B) 10 weeks after preparation in a RITA® liquid culture system, C) after an in vitro cloning step five months after preparation of the meristems in a culture on a solid medium and D) 9-10 months after the start of the meristem culture in soil.

Outlook

Work to optimize the regeneration of meristems is continuing. Especially the elimination of viroids is now a serious challenge, and new approaches need to be pursued.

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Seigner, E., Haugg, B., Hager, P., Enders, R., Kneidl, J., Lutz A. and Seigner, L., Einberger, K., Absmeier, C., Keckel, L., Liebrecht, M. (2019): Realtime PCR based diagnostics and meristem culture -essential tools for healthy hops. Proceeding of the Scientific-Technical Commission of the International Hop Growers´

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

Sponsor:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung *(Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding)*
Financing:	Förderung aus Mitteln des Zweckvermögens des Bundes bei der Landwirtschaftlichen Rentenbank *(Funding provided out of the German Federal Government's earmarked deposits at the Landwirtschaftliche Rentenbank)*
Funding Indicator	Landwirtschaftlichen Rentenbank: 837 150; BLE File Number: 28RZ4IP025
Project Management:	Dr. M. H. Hagemann, Universität Hohenheim (*University of Hohenheim*) (overall project) Dr. E. Seigner (LfL)
Team:	AG Züchtungsforschung Hopfen *(WG Hop Breeding Research)* (IPZ 5c): A. Lutz, J. Kneidl, E. Seigner and the breeding team AG Hopfenqualität/Hopfenanalytik *(WG Hop Quality/ Hop Analytics* (IPZ 5d): Dr. K. Kammhuber, C. Petzina, B. Wyschkon, M. Hainzlmaier und S. Weihrauch AG Genomorientierte Züchtung *(WG Genome-Oriented Breeding)* (IPZ 1d), Prof. Dr. V. Mohler AG Züchtungsforschung Hafer und Gerste (*WG Breeding Research Oats and Barley)* (IPZ 2c), Dr. T. Albrecht
Network Partners:	Universität Hohenheim, Institut für Nutzpflanzenwissenschaften, FG Ertragsphysiologie der Sonderkulturen *(University of Hohenheim, Institute for Crop Science, FG Yield Physiology of Speciality Crops)*: Dr. M. H. Hagemann, Prof. Dr. J. Wünsche Institut für Pflanzenzüchtung, Saatgutforschung und Populationsgenetik *(Institute for Plant Breeding, Seed Research and Population Genetics)*: Prof. Dr. G. Weber *emeritus* Gesellschaft für Hopfenforschung e.V. *(Society of Hop Research)*: W. König Hopfenverwertungsgenossenschaft HVG e.G. *(Hop Sales Cooperative)*: Dr. E. Lehmair
Duration:	August 1, 2017 to December 31, 2020

Objectives

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

Method

Within a reference assortment, phenotypical data such as resistance, agronomic performance characteristics and cone compounds are generated. In addition, all hops are genotyped, that is, their genetic material is sequenced.

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

Phase 2: August 2017 - December 2020

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

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

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

rentenbank

6.10 Precision breeding for hops: Sub-project powdery mildew resistance for genome-wide association mapping

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 (IPZ 5c)
(WG Hop Breeding Research)

Funding: Wissenschaftsförderung der Deutschen Brauwirtschaft e.V. (Wifö)
(Scientific Funding from the German Brewing Industry)

Funding ID: R444

Project Management: Dr. E. Seigner (LfL), A. Lutz

Project Processing:

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

Dr. E. Seigner, A. Lutz, J. Kneidl - Züchtungsforschung Hopfen (*Hop Breeding Research)*

Dr. T. Albrecht - AG Züchtungsforschung Weizen und Hafer (*WG Breeding Research Wheat and Oats)*

Prof. Dr. V. Mohler - AG Genom-orientierte Züchtungsmethodik *(WG Genome-oriented Breeding Methodology)*

Collaboration: EpiLogic GmbH Agarbiologische Forshung u. Beratung
(EpiLogic GmbH Agribiological Research and Consulting)

Dr. F.G. Felsenstein, S. Hasyn, Freising

Research Center II: **Universität Hohenheim (UHOH)**
(University of Hohenheim)

Prof. Dr. J. N. Wünsche, Dr. M.H. Hagemann,
FG Ertragsphysiologie der Sonderkulturen,
(*Yield Physiology of Specialty Crops)*

Research Center III: **Max-Planck-Institut für Entwicklungsbiologie (MPI)**
(Max-Planck Institute for Developmental Biology)

Prof. Dr. D. Weigel, R. Schwab, C. Lanz, Dr. J. Hildebrandt, S. Kersten, Dr. F. Bemm, Dr. I. Bezrukov, Dr. G. Shirsekar

Duration: January 1, 2016 to December 31, 2017 (sponsorship), delivery: December 31, 2019

Objectives

Providing German hop breeding with an innovative precision tool using genome-based selection criteria derived from genetic sequencing (= molecular markers) has become a major goal. The tool is intended to supplement and accelerate traditional, highly labor-intensive and time-consuming selection processes, in which the parent candidates for crossing and their offspring are assessed on the basis of their external (phenotypical) appearances and characteristics — a process that has become more complicated of late because of environmental influences and seasonal factors. The new methods should make the breeding of market-conform new hop varieties faster and more efficient. The new varieties should withstand the challenges of climate change and of constantly changing pathogens, as well as meet changing demands of the hop and brewing industries.

Within the sub-project funded by Wifö, the focus was on improving mildew resistance breeding. Resistance to powdery mildew (*Sphaerotheca macularis*) is essential for new hop varieties. Quality hops can be produced only with varieties that have been improved in this area, because mildew infestations can cause dramatic qualitative and quantitative yield reductions under certain weather conditions; or they require cost-intensive plant protection measures. Therefore, this fungal disease is an extremely important economic factor in hop cultivation worldwide. This explains the urgency behind the need to breed new varieties more quickly and efficiently using genome-based selection criteria.

Results

Based on "genotyping-by-sequencing," more than 1,000 hops of a reference assortment of both aroma and bitter varieties were sequenced. The selection included female and male plants; resistant and susceptible strains and varieties; and individuals from a group of powdery mildew resistant offspring. Furthermore, phenotypical data relevant to breeding (cone compounds and agronomic performance characteristics, as well as resistances) were collected for this representative hop collection. Characteristic relationships are recorded to serve as the basis for marker selections of breeding-relevant traits.

In the sub-project funded by Wifö, the focus was on the phenotyping of the offspring (F1 population) that split off with regard to powdery mildew resistance. Using a standardized powdery mildew test system with defined virulence in the greenhouse, 290 F1 individuals of this special mapping population were examined in a first step in the greenhouse for their susceptibility or resistance. 144 hops were identified as susceptible based on their leaf infestations. They either had no powdery mildew resistance at all or their resistance had become ineffective (R1, R3, R4, R6, RB). The leaves of 126 seedlings, which showed no symptoms of mildew infection in the greenhouse were classified as resistant and were subsequently examined using two differentiating mildew strains in a standardized leaf test system in the EpiLogic laboratory. An attempt was made to attribute the resistance of these hops to the action of the resistance genes introduced into the mapping population: R18 alone or R18 in combination with the already ineffective gene R1 gene are candidates in this context. In order to verify the evaluations from the first test season in 2017, the F1 hops, which had been assessed in the greenhouse test in the previous year as mildew-resistant, were again subjected to mildew resistance screening in the greenhouse and at EpiLogic. However, this test season was severely hampered by the appearance of a super-virulent mildew strain from mid- to late-March 2017. Therefore, the following statements about the resistance reactions of the mapped F1 individuals are based largely on the findings from 2016.

A total of 144 mildew-prone genotypes contrast with 126 resistant F1 individuals. In addition, as a result of the lack of rating data, no clear statements could be made about 20 hops as to whether they were susceptible or resistant individuals.

Based on the reactions to the differentiating mildew isolates in the leaf test at EpiLogic, an assessment of the R genes behind the resistances was possible. Of the F1 individuals, 43 were identified as R18 carriers and in 74 individuals their resistance reaction could be attributed to a combination of R18 and R1. Because of unclear or too little rating data, no clear statements could be made about the underlying R genes in nine powdery mildew-resistant F1 offspring.

Subsequently, marker-trait relationships should be recognizable by means of quantitative trait locus (QTL) analysis and, within the framework of the overall project, by means of genome-wide association mapping. This should identify selection markers for powdery mildew resistance or susceptibility that can be used in resistance breeding. While in previous marker development projects only simple trait-to-marker relationships could be identified, the next step should be to record complex links between powdery mildew resistance and the entire genetic background.

The initial bio-information calculations and quality filtering of all available sequence data, which was much more time- and labor-intensive than initially anticipated, yielded 15,599 high-quality SNPs (single-nucleotide polymorphisms). Markers for R18 and R1 resistance genes have been identified, but it is expected that, as in Padgitt-Cobb et al. (2020) the number and quality of resistance markers can still be significantly improved. For this purpose, the GBS (genotyping-by-sequencing) raw data and powdery mildew data will again be compiled in conjunction with the recently published reference genome data based on Cascade (Padgitt-Cobb et al., 2019) instead of the Teamaker reference of genome assemblies and annotations.

A further validation of the discovered markers is available in an independent association study with various hop materials as part of the overall project for the development of precision breeding in hops.

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Padgitt-Cobb, L.K., Kingan, S.B., Henning, J.A. (2020): Genomic analysis of powdery mildew resistance in a hop (*Humulus lupulus* L.) bi-parental population segregating for "R6-locus. Euphytica 216 (10), https://doi.org/10.1007/s10681-019-2543-x

7 Hop Quality and Analytics

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

7.1 General

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

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

Fig. 7.1: Valuable compounds in hops

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

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

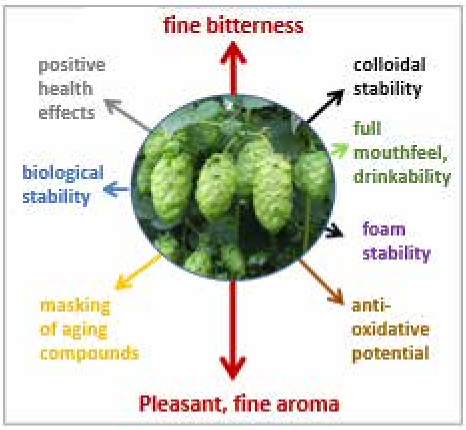


Fig. 7.2: The many functions of hops in beer

7.2 Demand for hop compounds

Hops are grown almost exclusively for brewing beer. Some 95% of the world's entire hop harvest is used in breweries and only 5% for alternative applications. There are now efforts underway to find additional uses for hops (Fig. 7.3).

Fig. 7.3: Uses for hops

7.2.1 Demand from the brewing industry

The demands for hop compounds by the hop and brewing industries are constantly changing. There is a consensus, however, that hop varieties with the largest amount of alpha acids and the most consistent alpha-acid values from one harvest year to the next are the most desirable. A low cohumulone value relative to the overall alpha-acid content is no longer considered important. For so-called downstream products and applications outside of beer making, high-alpha varieties with large portions of cohumulone are even desirable. In beer, however, a low proportion of cohumulone is beneficial for foam stability.

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

7.2.1.1 The craft brew movement is revolutionizing hop philosophy

The craft brew movement has changed the way we look at hops. Initially, this movement arose in the United States in opposition to industrial beer. This trend has since spilled over into many regions of the world, including Belgium, Scandinavia and Italy. However, the craft brew scene in the traditional beer country of Germany is not as important as it has become in other countries. Craft brewers tend to make flavorful, artisanally-brewed beers. As this movement is gaining momentum, it has a positive side effect on the image of beer and especially of hops. Craft brewers want hops with special, sometimes even non-hop-like aromas.

These varieties are now often called "special flavor hops." They have led to a much more differentiated perception of different hops and their terroirs.

The renaissance of dry-hopping

Craft brewers rediscovered the classic technique of adding hops to cold beer, called dry-hopping. This process was already well known in the nineteenth century and is now experiencing a revival. In principle, this method 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 their amounts of alpha acids. Beer is a polar solvent that consists of roughly 92% water and 5% ethanol. This means that primarily polar compounds are released by the hops (Fig. 7.4).

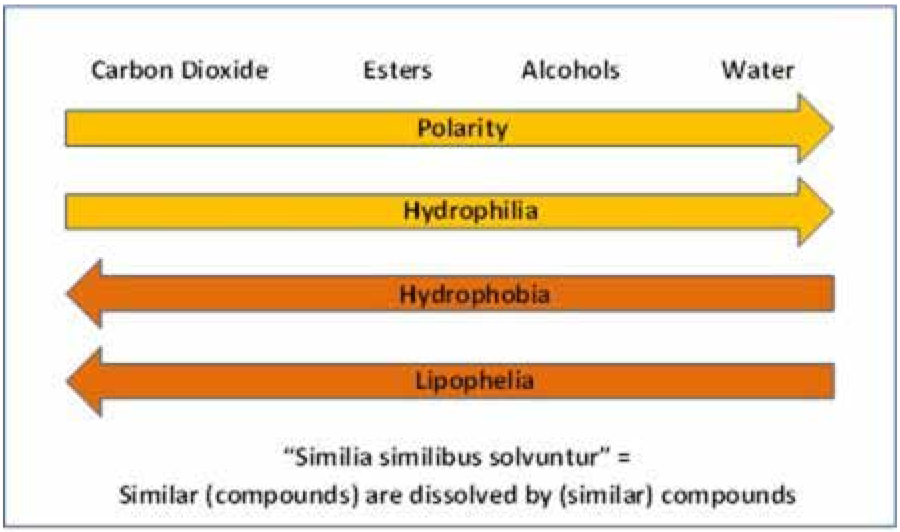


Fig. 7.4: The solubility behavior of hop compounds is based on polarity

Alpha acids dissolve only minimally in wort or beer as long as they remain non-isomerized. Especially low molecular esters and terpene alcohols, on the other hand, are easily transferred. This is why dry-hopped beers have fruity and floral aromas. Traces of non-polar substances such as myrcene are dissolved, too. The group of polyphenols is also soluble because of their polarity, as are, unfortunately, some undesirable substances, such as nitrate, which is completely absorbed by beer. The average nitrate content of hops is about 0.9%. However, the legal nitrate limit of 50 mg/l in drinking water does not apply to beer (in Germany). Plant protection products are generally non-polar and therefore not very soluble in water, which means that dry-hopped beers do not have higher residue levels of such products than do conventional beers.

Overall, the craft brew movement represents an enormous opportunity for hop growing and will change the hop economy fundamentally, because currently some 20% of the world's hop production is used for 2% of the world's beer production. In the United States, the hop area increases steadily year after year. In 2010 the total area was 12,670 ha, while in 2019 it had virtually doubled to roughly 24,000 ha. In Germany, the area for hop cultivation is 20,417 ha. Therefore, the development of hop cultivation around the world remains exciting.

7.2.1.2 Hop aromas are gaining in importance

Of all hop compounds, craft brewers are most interested in the hops’ essential oils, of which there are about 300 to 400 different types.

Aroma perception is the result of a wide range of complex interactions between a large number of aroma substances (Fig. 7.5), but a reductionist analytical approach can still be useful. It is important to define the key compounds that can serve as marker substances for fine hop aromas. Likewise, it is important to understand which substances pass into the beer and which don’t. When taking this approach, however, we must not forget the forest for the trees.

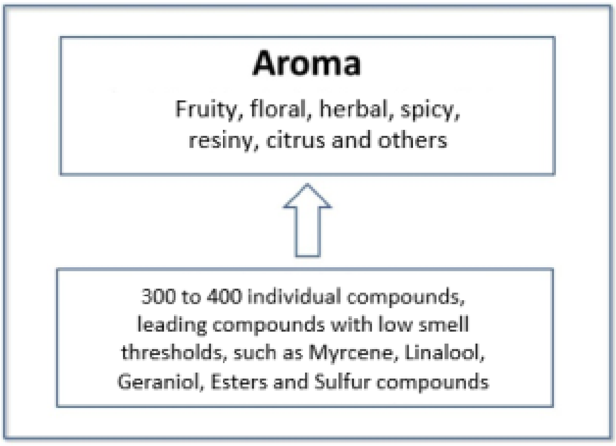


Fig. 7.5: Aroma perception is the result of many complex interactions between a large number of aroma substances

Craft brewers prefer hop varieties with "exotic flavors" such as tangerine, melon, mango or black currant.

7.2.1.3 The structure of essential oils

To date, 143 aroma substances in hops have been identified using gas chromatography mass spectrometer. This research was conducted in the laboratory in Hüll with two goals in mind. On the one hand, some substances are valued because they assist in variety identification. This is significant, because the Hüll laboratory is responsible for the analytics that verify the true-to-type purity of a variety for (German) food safety authorities. The other goal is to identify aroma compounds that can pass into beer.

Fig. 7.6 shows the most important monoterpenes and alcohols, as well as the esters and aldehydes that are derived from them. Monoterpenes are terpenoid hydrocarbons with 10 carbon atoms. The smell of raw hops is mainly determined by myrcene, while (E)-ß-Ocimene is a valuable substance for variety identification.

Linalool and geraniol can be found in larger concentrations in beer. The esters geranyl acetate and geranyl isobutyrate hydrolyze into geraniol during the brewing process.

Fig. 7.7 shows the structures of the most important sesquiterpenes. All compounds in this group consist of 15 carbon atoms and provide important information about the differentiation of varieties.

For instance, the ratio of humulenes to beta caryophyllene is very variety-specific, whereas beta farnesene is the key characteristic of hops in the Saazer family. Likewise, selinenes and cadinenes are very variety-differentiated.

Caryophyllene oxide and humulene oxides are indicators of the degree of oxidation of oils.

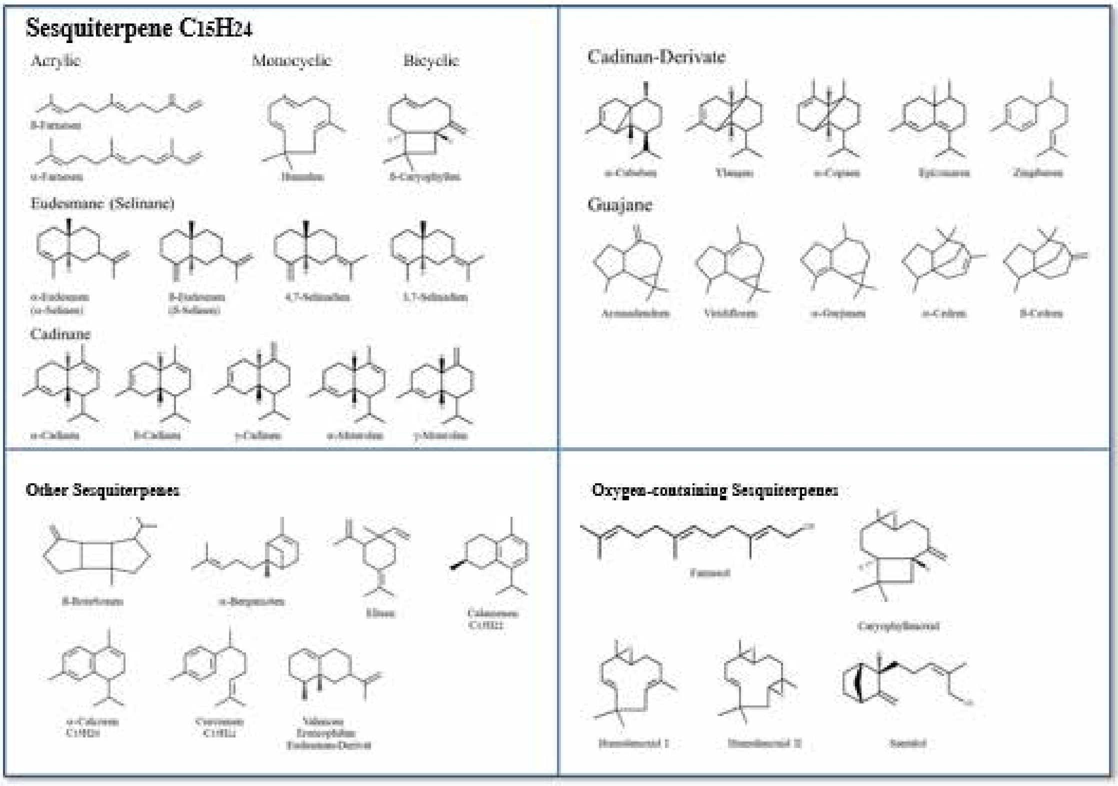


Fig. 7.6: Monoterpenes, monoterpene alcohols, esters and aldehydes

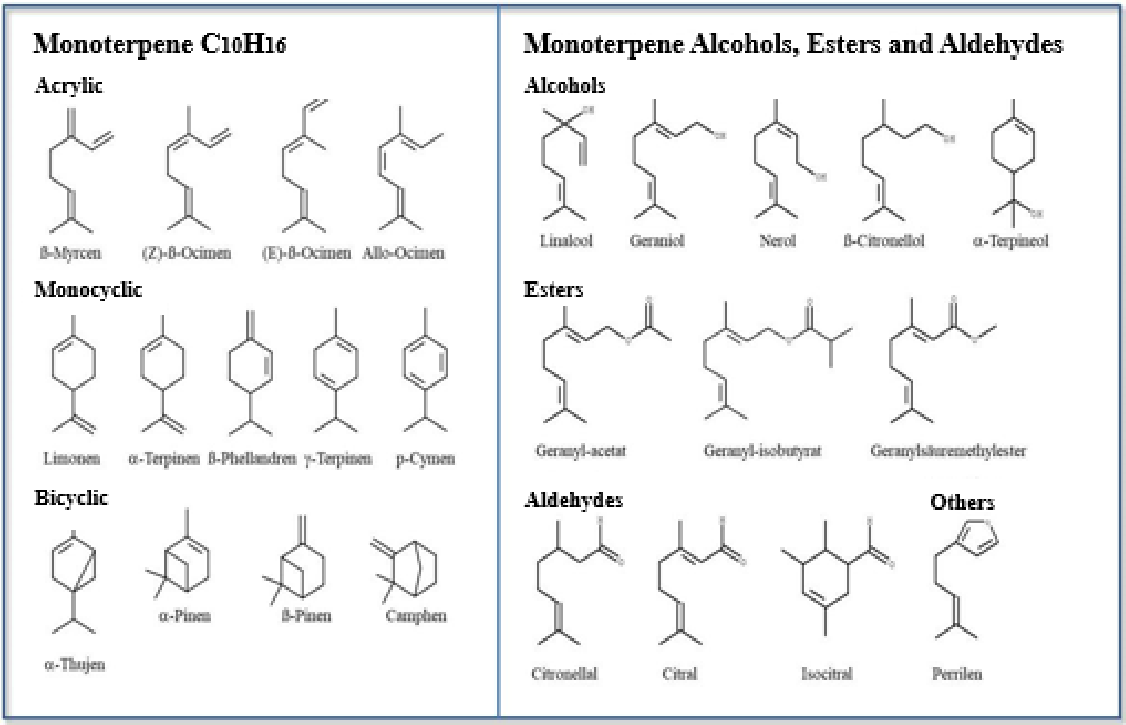


Fig. 7.7: Sesquiterpenes and compounds derived from them

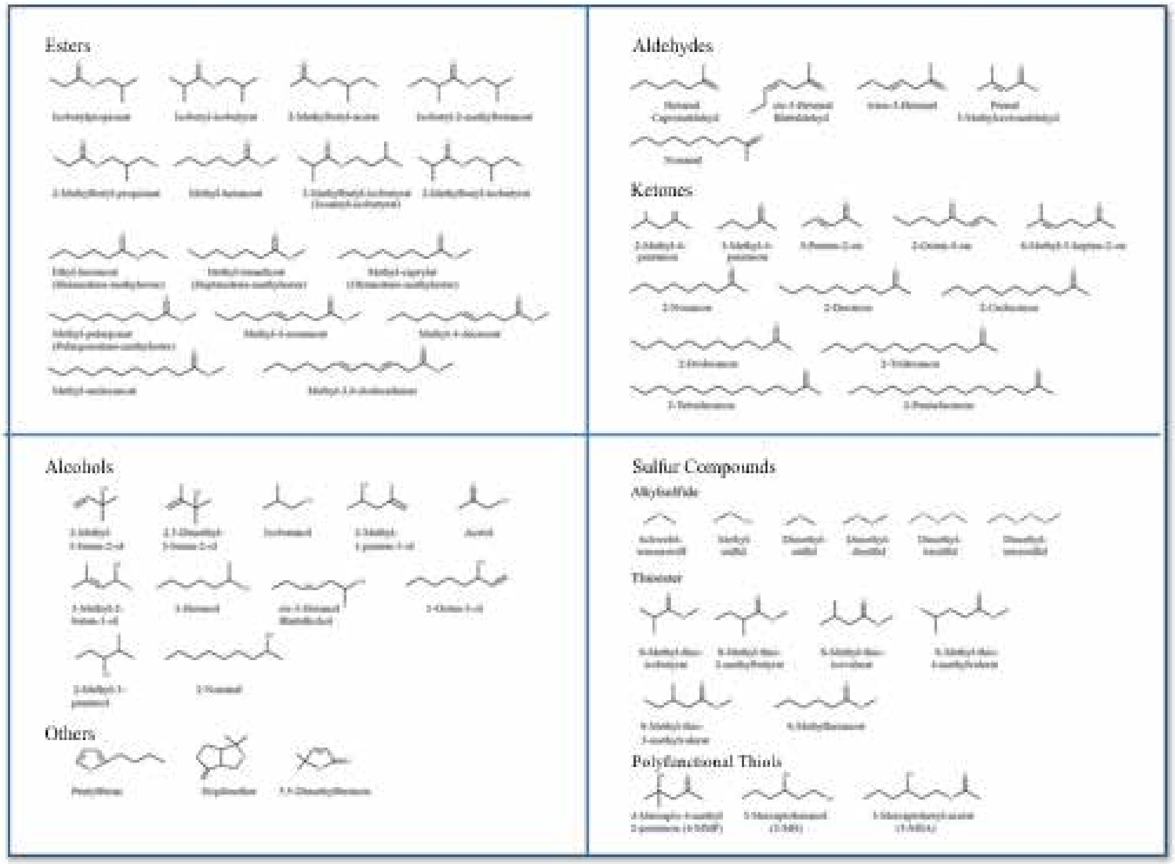


Fig. 7.8: Non-terpenoid esters, aldehydes, alcohols and sulfur compounds

Fig. 7.8 shows non-terpenoid esters, aldehydes, alcohols and sulfur compounds. Especially low-molecular esters are highly soluble in beer and are responsible for fruity aromas. Sulfur compounds have very low odor thresholds. Polyfunctional thiols such as 4-mercapto-4-methyl-2-pentanone (4-MMP), 3-mercaptohexanol (3-MH) and 3-mercaptohexyl acetate (3-MHA) contribute to the aroma of “special flavor hops,” whereby 4-MMP is a key aroma component typically associated with black currants. This substance has an odor threshold of only 0.0001 µg in 1 liter of water, which makes it one of the most odor-intensive compounds in hops.

Some hop aroma substances are not free but bound. For instance, 5% to 10% of linalool and geraniol are glycosidically bound to glucose, but yeast enzymes release these compounds during fermentation. Polyfunctional thiols such as 4-MMP and 3-MH are bound to cysteine or glutathione. Such conjugates can occur in relatively large concentrations in hops. Cysteine conjugates are present in hops in amounts up to 2 mg/kg; and glutathione conjugates, even up to 20 mg/kg.

Fig. 7.9 shows bound aroma compounds.

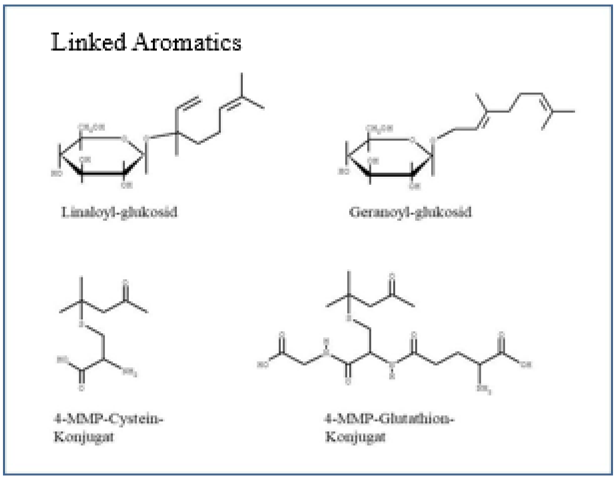


Fig. 7.9: Bound aroma compounds

7.2.2 Alternative uses of hops

For alternative applications, not only the cones but also the rest of the hop plant can be used. The inner, wooden parts of the hop bine, for instance, are known as shives or shoves. They have excellent insulation properties and mechanical strength which makes them well suited as material for bulk insulation or insulation sheets. 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.

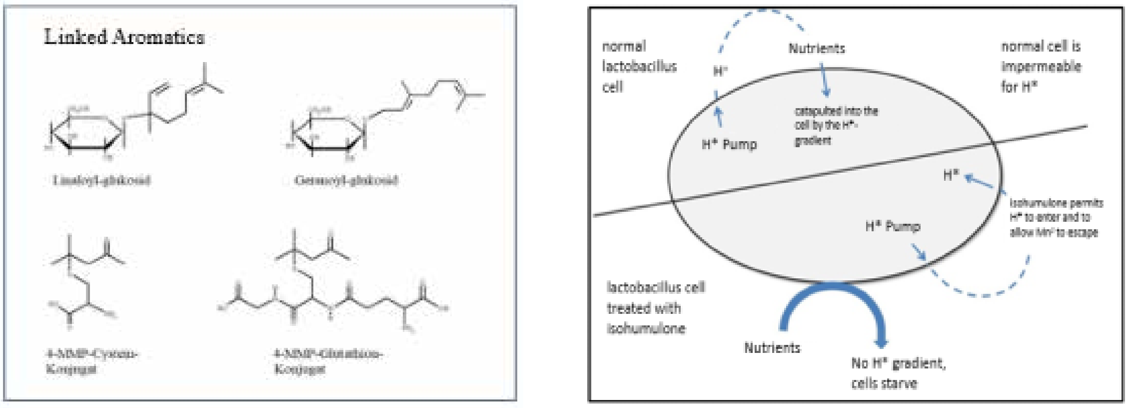


Fig. 7.10: Sequence of antimicrobial activity of iso-alpha acids, alpha acids and beta acids, as well as their effectiveness

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

Iso-alpha acids inhibit inflammatory processes and have positive effects on fat and sugar metabolisms. In beer, they even protect against *Helicobacter pylori*, a type of bacterium that can trigger stomach cancer. Beta acids are effective against the growth of gram-positive bacteria such as listeria and clostridia; and they can inhibit the tuberculosis-causing pathogen *Mycobacterium tuberculosis*. Because of these properties, hop bitter substances can be used as natural biocides wherever bacteria must be kept in check. In the sugar and ethanol industries, beta acids have already become a successful substitute for formalin. Other possible uses of hops' antimicrobial functions are as preservatives in the food industry (fish, meat and dairy products) or as antibiotics in animal nutrition, as well as for the hygienization of biohazardous waste (sewage sludge, compost) and for the elimination of mold infestations. They can also be used as odor and hygiene improvement in litter and as allergen control. It is certainly conceivable that the use of hops in these application areas will increase in the future. Therefore, developing hops with an increase in beta acids is also a breeding objective in Hüll. The current beta-acid record is around 20%. There is even a breeding line that produces only beta and no alpha acids. This variety is used for tea.

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

Of all the hop polyphenols, however, xanthohumol has received the most public attention. Scientific work on this polyphenol has exploded, which has led to the European Food Safety Authority (EFSA) of the European Union to recognize the health-promoting effects of xanthohumol. This means that xanthohumol can now be marketed with health claims for applications in food supplements and functional foods. Comprehensive information about the history of xanthohumol and its effects can be found on the homepage of T.A. XAN Development S.A.M. (https://www.xan.com). The benefits of xanthohumol cover a broad spectrum (Fig. 11), but its most important aspect, no doubt, is its anticarcinogen effect.

During the brewing process, prenylated flavonoid is constantly being transformed (Fig. 7.11). Xanthohumol is isomerized during wort boiling to iso-xanthohumol, as is dimethyl-xanthohumol to 8- and 6-prenylnaringenin. Similarly, desmethyl-xanthohumol is also not found in beer; and the concentrations of the prenylated naringenins are significantly higher in beer than in hops.

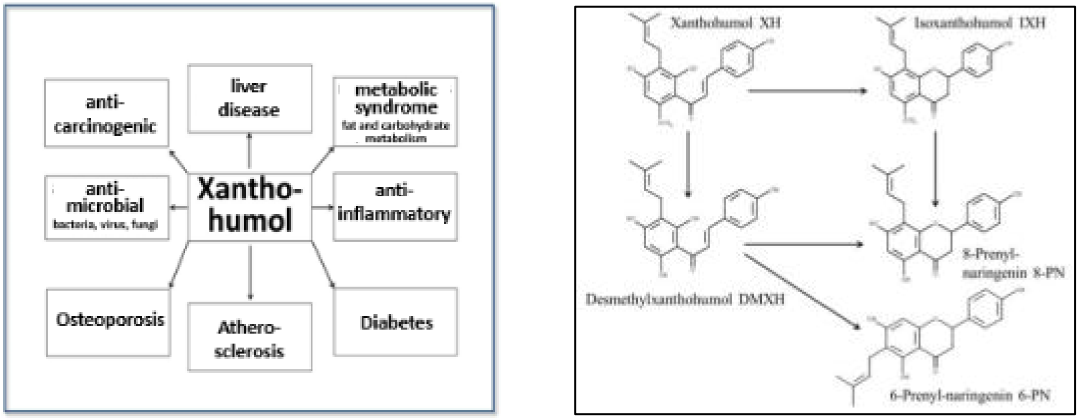


Fig. 7.11: Effects of xanthohumol and its transformations in the brewing process

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

Aroma hops usually have a higher polyphenol content than do bitter hops. If certain hop compounds are desired, Hüll can react at any time and breed for these substances, in collaboration with the analytics team.

7.3 Isolation, identification and analytics of multifidols in hops

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

Three multifidols occur in hops in the form of co-, n- and ad-multifidol glucoside (Fig. 7.12). The main homologue in hops, however, is co-multifidol glucoside, which is very readily soluble in water and is completely transferred into beer. Its taste threshold is 1.8 mg/l. In 54% of the beers examined in this study, the concentration was greater than 1.8 mg/l. This is why we are working on quantitative analytics for the compound in collaboration with Hopsteiner and the Technical University (TU) Berlin.

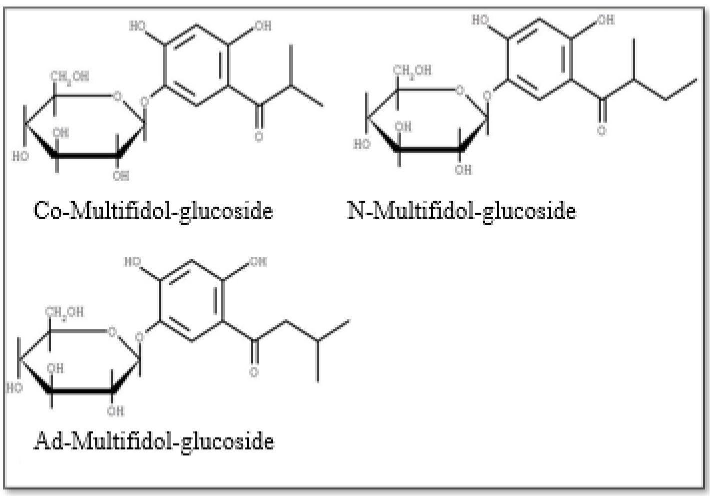


Fig. 7.12: The multifidols in hops

Dr. Wietstock of the TU Berlin isolated this compound with preparative HPLC at a purity level of 95%. The idea is to calibrate flavone as a secondary standard with the isolated co-multifidol glucoside. The co-multifidol glucoside has an absorption maximum at 280 nm. Flavone does not occur in hops, but has strong UV absorption at 280 nm (Fig. 7.13), which is why flavone is very well suited as an internal standard for co-multifidol glucoside (Fig. 7.14).

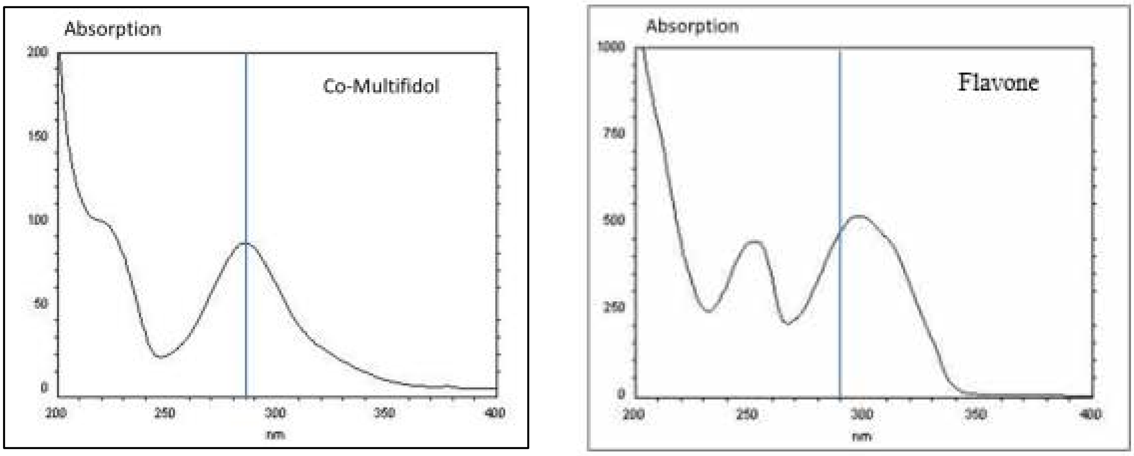


Fig. 7.13: UV spectra of co-multifidol glucoside and flavone

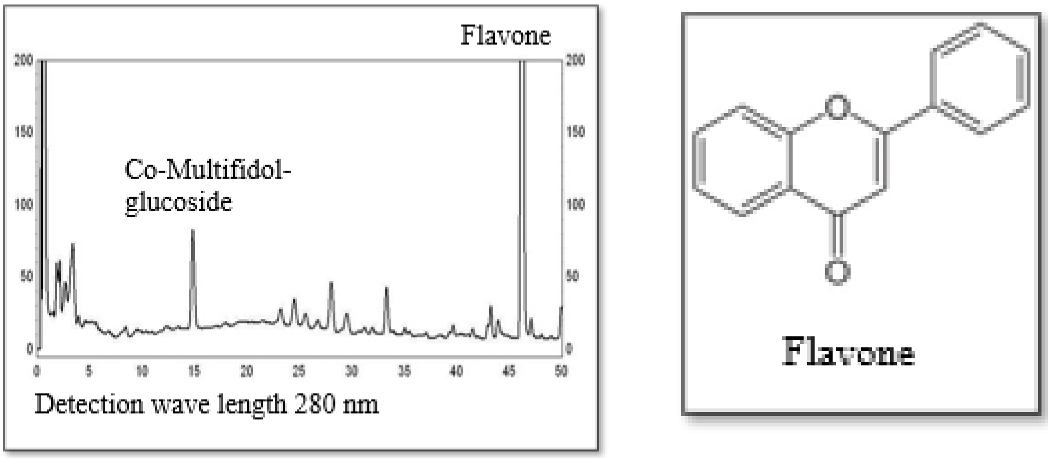


Fig. 7.14: Chromatogram of a hop sample at 280 nm and the structure of flavone

After an optimal sample preparation (extraction with liquid of 90-to-10 methanol-to-water) and the development of an appropriate HPLC method, it was the determined that Herkules contained 1.9 ‰; Hersbrucker Spät, 0.03 ‰; and Hallertauer Magnum, 0.5 ‰.

7.4 World hop portfolio (harvest 2018)

Every year, the essential oils are analyzed with headspace gas chromatography; and the bitter substances, with HPLC. Tab. 7.1 shows the results for the 2018 harvest year. It can be used as an aid to assign unknown hop varieties to a specific variety type.

Tab. 7.1: World hop portfolio (Harvest 2018)

Variety	Myrcene	2-M.-iso-butyrate	M.-iso-heptanoate	ß-O-cimene	Linalool	Aromadendrene	Undecanone	Humulene	Farnesene	g-Muurolene	ß-Selinene	a-Selinene	ß,g-Cadinene	Selinadiene	Geraniol	a-acids	ß-acids	ß/a	Cohumulone	Colupulone
Admiral	4717	1091	0	131	72	0	14	678	5	22	3	4	47	0	0	14.1	5.7	0.40	43.8	64.7
Agnus	2573	21	0	34	31	0	4	272	0	20	5	8	41	0	1	9.1	5.4	0.59	34.9	56.9
Ahil	1198	1448	68	47	79	0	27	408	123	14	4	8	32	0	9	7.4	3.2	0.44	29.0	50.4
Alliance	2251	96	2	7	35	0	11	588	4	17	3	5	38	0	0	3.1	1.6	0.53	30.1	56.8
Apolon	9093	165	88	75	66	0	4	428	144	20	5	8	41	0	6	6.5	3.1	0.48	21.4	41.3
Aquila	9487	325	0	1317	60	69	30	49	1	25	42	88	27	149	4	4.3	3.6	0.85	48.6	71.9
Ariana	2632	409	99	573	29	0	31	468	0	20	16	32	43	0	0	6.8	4.6	0.68	34.1	51.5
Aromat	4864	2	3	26	42	0	39	723	71	23	3	5	44	1	0	2.3	3.3	1.39	25.1	40.2
Atlas	7201	1160	62	45	33	0	3	373	148	16	6	10	34	0	7	6.8	3.3	0.48	36.0	59.7
Aurora	5605	423	1	182	98	0	49	607	74	16	3	4	37	0	1	7.3	2.9	0.40	22.9	54.8
Backa	1092	2212	0	147	115	0	21	586	36	20	3	5	40	1	0	7.4	4.6	0.62	43.6	65.7
Belgisch Spalter	3804	164	1	37	50	9	18	386	0	20	18	36	35	68	0	3.9	2.3	0.59	23.0	47.2
Blisk	5392	896	54	27	63	0	3	388	141	23	6	10	44	0	5	5.2	2.1	0.41	37.0	61.7
Bobek	8127	827	2	471	162	0	66	623	65	16	3	4	36	0	2	3.6	3.8	1.04	28.4	47.6
Bor	4990	245	1	198	25	0	18	680	0	14	5	10	34	0	1	5.6	2.7	0.49	22.0	43.1
Bramling Cross	4421	298	1	17	58	0	17	583	1	15	7	13	32	0	0	2.6	2.9	1.13	35.6	62.7
Braustern	2890	97	0	220	20	0	8	496	0	18	2	3	38	0	0	5.9	4.7	0.79	27.4	45.7
Brewers Gold	4704	545	4	206	35	0	2	415	0	15	5	9	34	0	6	7.0	4.5	0.64	38.3	63.5
Brewers Stand	1594	1402	131	320	157	30	36	208	2	108	58	115	211	175	10	6.6	3.2	0.48	21.3	42.7
Buket	4727	427	0	473	93	0	54	495	41	19	3	3	40	0	1	8.6	3.9	0.45	19.8	49.8
Bullion	4306	563	25	113	41	0	9	422	1	18	10	19	37	1	1	5.2	4.7	0.91	36.3	60.8
Callista	7854	232	55	34	128	3	22	671	0	23	19	38	49	5	0	3.2	5.9	1.86	17.1	38.4
Cascade	6852	497	10	114	43	0	12	587	65	24	5	9	46	0	3	5.1	6.4	1.26	32.1	48.6
Centennial	4435	556	121	28	56	0	4	439	0	23	3	4	43	1	14	7.3	2.7	0.37	26.4	50.3

Variety	Myrcene	2-M.-iso-butyrate	M.-iso-heptanoate	ß-O-cimene	Linalool	Aromadendrene	Undecanone	Humulene	Farnesene	g-Muurolene	ß-Selinene	a-Selinene	ß,g-Cadinene	Selinadiene	Geraniol	a-acids	ß-acids	ß/a	Cohumulone	Colupulone
Chang bei 1	6161	52	1	9	86	0	34	537	30	20	14	27	35	42	0	1.4	2.7	1.88	23.9	39.9
Chang bei 2	5900	8	0	14	75	0	30	535	21	18	13	26	31	41	0	1.4	2.4	1.78	23.8	39.4
Chinook	2134	420	19	21	17	0	7	384	0	61	11	18	119	27	2	9.1	3.0	0.33	30.1	53.4
Columbus	2127	270	44	89	22	0	2	275	0	44	9	15	87	24	1	15.1	4.8	0.32	31.0	54.3
Comet	3118	297	14	298	29	0	7	36	1	6	30	67	11	21	1	6.2	2.8	0.44	37.2	58.5
Crystal	4160	25	13	19	68	40	26	503	0	23	19	39	36	64	0	2.6	4.4	1.67	20.9	35.9
Density	6025	381	0	12	67	0	18	595	1	14	2	4	30	0	0	2.7	2.9	1.07	36.4	60.5
Diva	9317	1034	2	212	121	0	95	621	7	23	59	128	49	0	2	5.6	3.9	0.69	25.9	50.4
Dr. Rudi	9053	949	75	121	120	0	23	655	0	19	9	18	39	0	1	5.1	4.1	0.79	38.6	57.7
Early Choice	3149	174	1	55	13	0	11	488	0	14	28	61	29	0	0	1.7	1.0	0.62	33.0	58.3
Eastwell Golding	2756	168	1	39	37	0	18	589	0	17	3	4	37	0	0	2.8	1.7	0.60	26.7	53.1
Emerald	2593	105	4	85	15	0	18	671	0	16	2	4	37	0	0	3.9	3.6	0.93	30.1	47.3
Eroica	5278	1115	100	343	15	0	8	418	0	14	6	12	29	0	0	9.5	7.8	0.82	39.6	63.5
Estera	3609	212	0	15	53	0	12	604	22	16	2	4	37	0	0	2.9	2.0	0.67	29.9	51.5
First Gold	5943	904	0	137	78	0	34	584	16	19	56	126	45	1	1	6.0	2.7	0.45	29.8	54.3
Fuggle	2386	183	3	17	33	0	10	527	18	17	3	4	39	0	0	2.6	1.8	0.69	29.3	52.5
Galena	4023	1138	70	357	1	0	9	470	0	18	6	13	36	0	0	7.7	7.3	0.95	40.8	63.8
Ging Dao Do Hua	9913	1720	0	34	47	0	18	552	0	40	29	56	75	1	2	2.2	2.5	1.11	47.1	69.9
Glacier	4337	168	4	21	55	0	21	680	0	20	4	6	43	0	0	2.1	3.4	1.62	17.2	43.1
Golden Star	8424	1742	0	34	43	0	20	565	0	46	31	61	87	0	1	2.9	2.9	0.99	47.1	70.6
Granit	6031	338	5	102	23	0	34	564	2	14	5	8	30	0	1	4.8	2.9	0.60	22.7	43.9
Hallertau Blanc	7821	1038	256	106	127	0	24	99	1	16	249	544	35	0	2	9.5	6.0	0.63	21.5	38.6
Hallertauer Gold	4439	122	23	39	67	0	22	670	0	19	3	4	44	0	0	4.6	4.2	0.93	22.6	39.5
Hallertauer	4107	125	79	136	20	0	11	606	0	17	3	4	40	0	0	12.4	6.5	0.52	20.4	35.0
Hallertauer Merkur	3644	348	38	22	56	0	14	589	0	20	4	5	44	0	0	13.8	5.3	0.38	16.4	38.7

Variety	Myrcene	2-M.-iso-butyrate	M.-iso-heptanoate	ß-Ocimene	Linalool	Aromadendrene	Undecanone	Humulene	Farnesene	γ-Muurolene	ß-Selinene	α-Selinene	ß,γ-Cadinene	Selinadiene	Geraniol	α-acids	ß-acids	ß/a	Cohumulone	Colupulone
Hallertauer Mfr.	1245	228	6	1	52	0	28	664	0	43	4	7	74	0	0	3.0	3.6	1.23	22.8	38.5
Hallertauer Taurus	6472	45	49	85	105	0	23	608	0	18	36	81	42	0	1	13.5	4.3	0.31	18.5	36.5
Hallertauer	3748	172	2	28	74	0	17	636	0	20	3	4	45	0	0	5.8	4.2	0.72	25.6	44.5
Harmony	3428	63	2	63	51	0	21	524	0	20	43	95	46	0	0	6.8	5.8	0.86	19.2	37.2
Herald	4773	769	1	471	28	0	61	442	1	15	15	31	36	0	2	9.7	3.5	0.36	38.8	60.7
Herkules	6055	856	167	341	26	0	16	695	0	18	3	4	46	0	2	15.6	4.2	0.27	29.9	47.8
Hersbrucker Pure	5323	286	0	108	78	23	34	509	2	21	20	42	37	73	0	3.7	2.0	0.55	24.8	43.4
Hersbrucker Spät	4498	193	0	36	81	35	10	513	1	23	19	39	38	55	0	2.6	4.7	1.81	17.5	35.7
Huell Melon	9019	1714	0	292	42	0	36	61	105	45	160	339	80	213	1	4.9	8.2	1.67	29.1	49.6
Hüller Anfang	2126	110	13	3	39	0	19	644	0	26	3	5	48	0	0	2.3	3.1	1.37	24.8	38.4
Hüller Aroma	3184	79	4	4	65	0	22	670	0	24	3	4	45	0	0	2.8	3.6	1.30	24.6	41.1
Hüller Bitter	1003	1006	198	57	81	25	19	422	2	94	35	66	164	110	2	9.2	4.4	0.48	22.9	41.6
Hüller Fortschritt	2823	33	12	4	54	0	24	679	0	23	3	4	44	0	0	2.2	3.8	1.72	25.0	39.0
Hüller Start	2228	27	1	8	21	0	28	684	2	25	3	4	46	0	0	2.2	3.0	1.37	25.0	40.8
Kazbek	3472	527	34	119	38	0	5	420	0	19	6	12	38	0	1	5.3	5.0	0.95	33.8	58.1
Kirin 1	7920	1501	0	66	46	0	19	615	4	39	29	54	76	0	2	3.5	3.6	1.02	44.3	65.4
Kirin 2	6872	1327	1	40	35	0	14	543	2	40	21	42	75	5	1	3.0	3.0	1.00	47.6	70.6
Kitamidori	3199	70	14	232	14	0	9	654	29	21	2	4	43	0	1	6.4	4.2	0.65	22.1	43.8
Kumir	3626	140	1	111	67	0	23	585	12	18	4	6	40	0	1	7.5	3.4	0.45	18.5	39.8
Late Cluster	1313	1404	75	266	127	30	32	163	0	104	52	105	200	173	4	7.8	3.9	0.50	23.2	42.3
Lubelski	6412	8	4	12	55	0	37	739	59	21	3	4	39	0	0	2.5	4.1	1.67	25.0	38.7
Mandarina Bavaria	3456	512	2	233	41	0	16	493	23	26	25	66	56	2	2	8.7	7.2	0.82	36.5	54.1
Marynka	6680	551	0	217	30	0	14	235	155	13	4	9	30	0	3	7.2	3.3	0.46	20.6	45.8
Mt. Hood	1824	121	18	26	35	0	9	441	0	27	3	5	51	0	1	3.1	4.2	1.38	23.8	40.8
Neoplanta	4022	246	0	138	34	0	20	492	35	17	2	3	39	0	0	6.8	2.9	0.42	27.7	60.6

Variety	Myrcene	2-M.-iso-butyrate	M.-iso-heptanoate	ß-Ocimene	Linalool	Aromadendrene	Undecanone	Humulene	Farnesene	γ-Muurolene	ß-Selinene	α-Selinene	ß,γ-Cadinene	Selinadiene	Geraniol	α-acids	ß-acids	ß/α	Cohumulone	Colupulone
Neptun	1880	263	89	26	37	0	4	379	0	23	3	4	48	0	0	13.4	5.9	0.44	20.6	40.7
Northern Brewer	2855	184	0	205	21	0	10	445	0	17	3	3	39	0	1	7.3	4.2	0.58	25.5	44.6
Nugget	1669	234	3	137	44	0	6	280	0	12	5	10	27	0	0	11.0	4.1	0.37	27.0	50.1
NZ Hallertauer	5578	727	1	105	49	5	18	510	25	19	10	20	33	28	1	2.1	3.5	1.69	34.6	58.7
Opal	3902	8	12	266	59	0	17	485	5	16	1	3	37	1	0	6.6	4.7	0.71	14.0	30.7
Orion	2363	273	5	56	46	0	17	403	0	22	3	3	46	0	0	8.2	4.4	0.54	26.1	48.8
Perle	1811	138	0	121	10	0	8	496	0	16	3	4	40	0	0	4.8	3.0	0.63	32.4	51.6
Pilgrim	7287	1529	1	924	40	0	63	662	0	17	41	92	44	0	2	5.9	3.0	0.50	39.3	59.4
Pilot	3562	674	0	410	98	0	59	119	2	18	111	258	41	1	1	5.0	2.5	0.51	38.0	63.2
Pioneer	1785	513	2	393	20	0	69	269	1	14	12	25	34	0	2	7.1	2.5	0.36	36.0	68.3
Polaris	3104	216	47	230	12	0	11	416	0	18	3	3	41	0	1	18.4	4.2	0.23	21.4	36.1
Premiant	3044	123	1	93	55	0	21	580	9	18	3	5	42	1	0	6.0	3.4	0.56	20.1	39.9
Pride of Ringwood	4571	161	1	3	21	0	15	50	0	21	65	137	39	0	0	3.9	4.4	1.14	36.3	55.2
Progress	2284	1444	59	262	164	39	36	120	1	108	55	113	190	190	6	5.8	3.2	0.56	23.9	43.2
Record	5259	107	6	13	59	0	28	694	1	20	3	4	42	0	1	3.2	5.6	1.74	24.3	37.5
Relax	3710	120	14	19	19	0	40	696	2	30	4	6	50	0	3	0.1	9.6	67.2	59.9	27.8
Rottenburger	3817	187	8	8	36	0	23	677	9	22	6	12	42	0	1	1.7	3.4	2.06	27.8	38.6
Rubin	1308	447	118	3	40	0	18	616	0	43	77	156	76	0	4	10.7	3.5	0.32	26.6	44.9
Saazer	3984	1	2	20	61	0	47	712	65	28	3	5	54	0	1	4.1	4.6	1.12	23.2	38.4
Saphir	3816	8	1	160	54	9	57	474	0	19	13	28	37	46	0	3.4	5.0	1.47	13.4	41.2
Serebrianker	2516	101	2	9	55	0	16	419	2	37	26	47	59	0	1	1.5	3.5	2.29	23.9	36.1
Sladek	3620	101	0	119	71	0	23	577	11	18	3	4	40	0	1	7.8	3.4	0.44	18.7	39.7
Smaragd	4650	29	8	172	70	0	16	614	6	18	1	4	44	0	1	3.4	3.2	0.95	15.5	28.8
Sorachi Ace	4331	285	0	212	21	0	17	612	19	22	4	6	45	1	1	6.8	5.2	0.77	29.0	51.0
Southern Promise	2473	208	12	99	1	0	30	498	0	21	11	22	39	37	0	5.3	3.3	0.63	24.8	51.6

Variety	Myrcene	2-M.-iso-butyrate	M.-iso-heptanoate	ß-Ocimene	Linalool	Aromadendrene	Undecanone	Humulene	Farnesene	g-Muurolene	ß-Selinene	a-Selinene	ß,g-Cadinene	Selinadiene	Geraniol	a-acids	ß-acids	ß/a	Cohumulone	Colupulone
Southern Star	3619	119	11	14	8	0	19	565	37	23	3	4	44	0	1	9.5	4.6	0.49	30.5	51.0
Spalter	3896	1	2	14	61	0	44	747	48	29	3	5	54	0	1	3.3	4.7	1.41	24.8	39.8
Spalter Select	8287	109	5	31	149	16	37	504	146	23	21	46	41	60	0	4.2	3.6	0.88	22.6	41.1
Strisselspalter	4712	257	0	92	83	39	18	509	0	23	18	37	38	50	1	2.9	4.6	1.59	18.1	34.9
Südafrika	3170	53	1	10	7	0	10	474	0	23	40	83	43	0	1	4.2	3.5	0.84	31.8	48.7
Talisman	2858	137	0	182	24	0	0	461	0	17	3	3	38	0	1	5.9	3.5	0.59	25.0	44.9
Tettnanger	3894	1	2	21	58	0	47	728	58	29	3	5	54	0	1	3.6	4.6	1.28	24.3	40.7
Vojvodina	5013	348	0	141	19	0	21	564	5	15	2	3	35	0	1	3.1	1.8	0.57	30.1	65.3
WFG	6474	1	3	16	80	0	47	743	73	23	4	6	45	1	1	3.2	4.1	1.26	23.7	38.9
Willamette	2513	419	0	51	39	0	4	478	39	19	3	4	41	0	0	2.4	3.1	1.26	35.0	52.7
Wye Challenger	5289	809	2	150	61	1	32	554	20	20	25	55	43	7	0	3.8	3.2	0.84	28.2	52.6
Wye Northdown	3439	168	0	85	34	0	9	491	0	16	2	3	35	0	0	5.3	3.5	0.66	25.9	46.7
Wye Target	4149	627	1	96	69	0	24	379	0	34	8	13	75	13	1	9.9	4.0	0.40	34.6	58.4
Wye Viking	4073	351	23	79	42	0	64	555	44	30	36	68	55	0	0	4.3	3.2	0.74	25.0	42.1
Yeoman	3690	706	65	81	32	0	17	537	2	14	26	57	36	0	3	8.8	3.6	0.41	24.4	48.2
Zatecki	2947	168	0	36	41	0	9	571	17	16	2	3	35	0	0	2.4	2.7	1.15	29.5	46.2
Zenith	4549	208	0	89	84	0	25	621	1	15	42	98	39	0	1	4.7	2.0	0.43	25.9	49.5
Zeus	1869	295	51	79	21	0	2	269	0	46	9	15	82	24	1	13.6	4.7	0.34	32.7	54.5
Zitic	4666	1	0	54	25	0	25	682	9	18	3	4	40	0	2	3.4	3.0	0.89	20.7	38.7

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

7.5 Quality assurance in alpha-acid analytics for hop supply contracts

7.5.1 Chain analyses for the 2019 harvest

Since 2000, hop supply contracts contained a clause covering the alpha-acid content of shipments. The farm price agreed upon in a contract applies if the alpha-acid content is in the so-called neutral zone. If it exceeds or falls below the specified value, a surcharge or a discount applies. The instructions for the working group for hop analytics specify precisely how samples for alpha-acid tests are to be handled (sample taking, storage), which laboratories carry out follow-up examinations, and which tolerance ranges are permitted for the results of the analyses. In 2019 once again, the Working Group IPZ 5d was tasked to organize and evaluate chain tests in order to ensure the quality of the alpha-acid analytics.

The following laboratories took part in the chain tests in 2019.

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

The chain laboratory tests started on September 10, 2019 and ended on November 8, during which time the majority of the hop plots were examined in the laboratories. Overall, the chain tests were carried out nine times (9 weeks). The sample material was kindly provided by the Hallertau Hop Circle. All samples were taken from the same bale to ensure the greatest possible homogeneity. Every Monday, the samples in Hüll were ground up with a hammer mill, divided, vacuum-packed and taken to the individual laboratories. During the following days, one sample was analyzed per day. The results of the analyses were returned to Hüll a week later and evaluated there. A total of 34 samples was analyzed in 2019.

The evaluations were then passed on to the individual laboratories as quickly as possible. Fig. 7.15 shows an example of an ideal case of such a chain evaluation. Note: The numbering of the laboratories (1-7) does not correspond to the above list.

No. 1 HAL (September 10, 2019)

Labor	KW		Mean	s	cvr
1	4.39	4.36	4.38	0.021	0.5
2	4.29	4.34	4.32	0.035	0.8
3	4.40	4.35	4.38	0.035	0.8
4	4.37	4.31	4.34	0.042	1.0
5	4.40	4.40	4.40	0.000	0.0
6	4.44	4.39	4.42	0.035	0.8
7	4.33	4.37	4.35	0.028	0.7

mean	4.37
sr	0.031
sL	0.027
sR	0.041
vkr	0.71
vkR	0.94
r	0.09
R	0.12
Min	4.29
Max	4.44

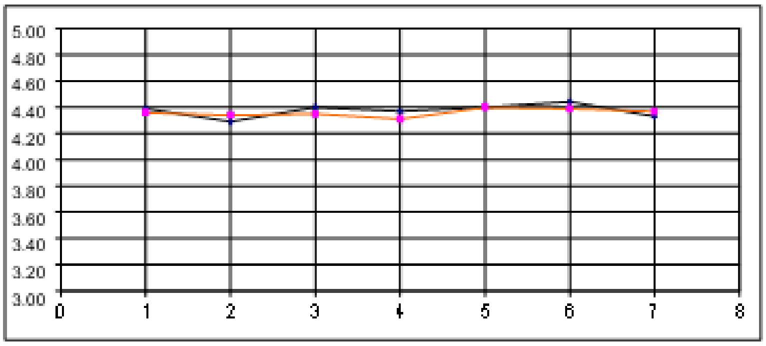


Fig. 7.15: *Example of an evaluation of a chain analysis*

The outlier tests are calculated in accordance with DIN ISO 5725. Within each laboratory, the Cochran test was calculated; and among the laboratories, the Grubbs test.

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

With 8 laboratories and a double determination, alpha = 1% C must be less than **0.794** and alpha = 5% C must be less than **0.680**, otherwise the value is an outlier.

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

With 8 laboratories and a double determination, alpha = 1% G must be less than **2.274** and alpha = 5% G less than **2.126**, otherwise the value is an outlier.

Tab. 7.2 lists the outliers in 2019.

Tab. 7.2: Outliers in harvest year 2019

	Cochran		**Grubbs**	
Sample	Alpha = 0.01	Alpha = 0.05	Alpha = 0.01	Alpha = 0.05
7	Laboratory 3			
29				Laboratory 6
Total:	**1**	**0**	**0**	**1**

Since 2013, there have been 5 alpha classes and new tolerance limits. Table 7.3 shows the new classification and the transgressions for 2019.

Tab. 7.3: Updated alpha-acid classes and tolerance limits as well as their transgressions in 2019

	< 5,0 %	5,0 % - 8,0 %	8,1 % - 11,0 %	11,1 % - 14 %	> 14,0 %
d-critical range	+/-0,3 0,6	+/-0,4 0,8	+/-0,5 1,0	+/-0,6 1,2	+/- 0,7 1,4
Transgression in 2019	0	0	0	0	0

In 2019, there were no values exceeding permitted tolerance ranges.

In Fig. 7.16, for each laboratory, the results of all analyses are summarized as relative deviations from the mean (= 100%), differentiated according to alpha-acid levels <5%, ≥5% and <10%, as well as ≥10%. This graphic clearly shows whether a laboratory exhibited a tendency to produce values that were too high or too low.

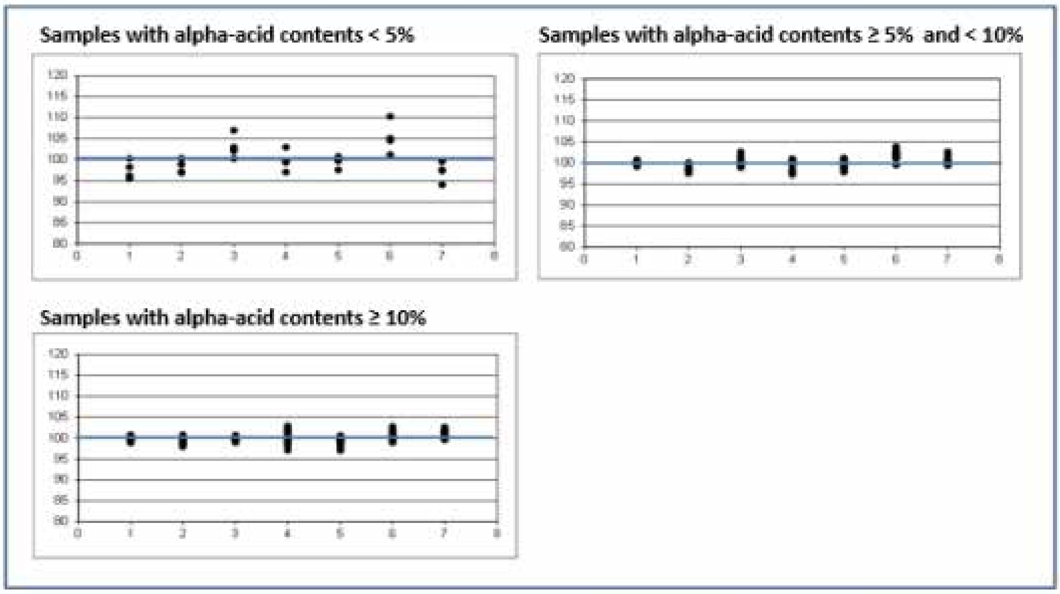


Fig. 7.16: The results of the laboratory analyses relative to the mean

The Hüll laboratory is number 5.

7.5.2 Evaluation of control examinations

In addition to the chain tests, control examinations have been conducted since 2005, which the Working Group IPZ 5d evaluated before passing the results on to the participating laboratories as well as to the hop growers and hop industry associations. For an initial examination, a laboratory selects three samples per week, which are then analyzed by three different laboratories in accordance with AHA specifications. The first examination value applies if the mean value of the follow-up examinations and the value from the initial examination fall within the tolerance limits. Tab. 7.4 shows the results for 2019. In all cases, the initial examination value was confirmed.

Tab. 7.4: Control evaluation in 2019

Sample name	Initial test laboratory	Initial test value	Follow-up tests			Median	Results confirmed
			1	2	3		
HTU No. 4214	Agrolab	16.6	16.0	16.4	16.4	16.27	yes
Perle No. 4303	Agrolab	8.1	7.7	7.7	7.8	7.73	yes
Saphir No. 4024	Agrolab	3.8	3.6	3.6	3.7	3.63	yes
KW 38 - NBR	HHV Au	8.3	8.3	8.4	8.4	8.37	yes
KW 38 - HMG	HHV Au	12.9	12.9	13.0	13.1	13.00	yes
KW 38 - HTU	HHV Au	16.7	16.7	16.7	17.0	16.80	yes
KW 39 -HTR	HV St. Johann	4.9	4.7	4.8	4.8	4.77	yes
KW 39 - PER	HV St. Johann	6.2	6.2	6.2	6.2	6.20	yes
KW 39 - HMG	HV St. Johann	11.9	11.5	11.6	11.7	11.60	yes
KW 40 - 3714 HPER	HVG Mainburg	7.0	6.9	7.0	7.0	6.97	yes
KW 40 - 28430 HHKS	HVG Mainburg	15.6	15.3	15.9	16.0	15.73	yes
KW 40 - 3864 HHTR	HVG Mainburg	5.4	5.3	5.4	5.5	5.40	yes
KW 41 - Spalter Select No. [illegible]	Agrolab	4.7	4.5	4.5	4.5	4.70	yes
KW 41 - Opal No. 35025	Agrolab	7.2	6.7	6.7	6.8	6.73	yes
KW 41 - Herkules No. 32580	Agrolab	15.5	15.5	15.6	15.6	15.57	yes
KW 42 - NUG	HHV Au	9.5	9.4	9.5	9.6	9.50	yes
KW 42 -HMG	HHV Au	12.7	12.5	12.9	13.1	12.83	yes
KW 42 - HKS	HHV Au	16.9	16.5	16.5	17.0	16.67	yes
KW 43 - H DE PER	HV St. Johann	5.3	5.2	5.3	5.4	5.30	yes
KW 43 - H DE HKS	HV St. Johann	13.3	13.2	13.3	13.6	13.37	yes
KW 43 - H DE HMG	HV St. Johann	10.5	10.3	10.5	10.8	10.53	yes
KW 44 28296 HPER	HVG Mainburg	5.3	5.2	5.2	5.4	5.27	yes
KW 44 32094 HNUG	HVG Mainburg	10.7	10.9	10.7	10.9	10.73	yes
KW 44 29839 HHKS	HVG Mainburg	17.8	17.6	17.8	17.8	17.73	yes

7.5.3 Follow-up evaluations of the 2019 harvest

The procedure for conducting follow-up evaluations for alpha contracts was changed for the 2019 harvest. The laboratory in Hüll is now always integrated as one of the follow-up laboratories (Tab.7.5). It also evaluates the results.

Tab. 7.5: 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

The evaluation of the follow-up tests is transmitted as an LfL follow-up report to the initial test laboratory within three working days after receipt of the follow-up test results. The initial test laboratory immediately forwards the report to the client who commissioned the follow-up tests. There was a total of 47 follow-up tests in 2019; and in only one case was the initial test result not confirmed. Tab. 7.6 shows the follow-up test results in ascending chronological order.

Tab. 7.6: Follow-up tests in 2019

Sample name	Initial test laboratory	Initial test value	Follow-up tests			Median	Results confirmed
			1	2	3		
5229 H DE PER	HV St. Johann	6.0	5.8	5.9	6.0	5.90	yes
Agrolab Nr: 7110 (Partie No. 1380759) HTU	HV St. Johann	14.9	14.6	14.9	14.9	14.80	yes
Agrolab No. 29431 H DE HKS	HV St. Johann	13.3	12.9	13.2	13.2	13.10	yes
Agrolab No. 5570 H DE HTR	HV St. Johann	5.6	5.3	5.5	5.5	5.43	yes
Agrolab No. 6917 H DE HTU	HV St. Johann	16.5	16.0	16.4	16.4	16.27	yes
Agrolab Analysis No. 3836, Plot No. 1497451 PER	HHV Au	6.5	6.5	6.6	6.6	6.57	yes
Analysis No. Agrolab 6331 HPER	HVG Mainburg	6.8	6.8	6.8	6.9	6.83	yes
Agrola Analysis No. 31469 HKS	HHV Au	14.7	14.6	14.6	14.8	14.67	yes
Analysis No. Agrolab 29314 H DE HKS	HV St. Johann	14.8	14.4	14.4	14.6	14.47	yes
Analysis No. Agrolab 31638 H DE HKS	HV St. Johann	14.6	14.5	14.5	14.5	14.50	yes
Analysis No. Agrolab 31788 H DE HKS	HV St. Johann	15.1	14.8	14.9	14.9	14.87	yes
Analysis No. Agrolab 32815 H DE HKS	HV St. Johann	15.3	15.1	15.2	15.3	15.20	yes
Analysis No. Agrolab 31124 H DE HKS	HV St. Johann	12.1	12.0	12.1	12.2	12.10	yes
Analysis No. Agrolab 31785 H DE HKS	HV St. Johann	15.3	14.9	15.1	15.2	15.07	yes
Agrolab Analysis No. 31489 HKS	HHV Au	14.7	14.6	14.7	14.8	14.70	yes

Sample name	Initial test laboratory	Initial test value	Follow-up tests			Median	Results confirmed
			1	2	3		
HHKS Analysis No. Agrolab 29559	HVG Mainburg	14.8	14.8	14.9	15.1	14.93	yes
HTR Agrolab No. 6365	Agrolab GmbH	4.8	4.2	4.4	4.4	4.33	yes
Analysis No. Agrolab 31538 H DE HKS, Plot 1391477	HV St. Johann	14.4	14.5	14.5	15.0	14.67	yes
Analysis No. Agrolab 31541 H DE HKS, Plot 1588677	HV St. Johann	14.2	14.1	14.2	14.6	14.30	yes
Analysis No. Agrolab 30029 H DE HKS, Plot 1411761	HV St. Johann	14.6	14.5	14.4	14.7	14.53	yes
Agrolab-Analysis No. 35454, Plot No. 1153577 HKS	HHV Au	14.1	15.2	15.2	15.9	15.43	no
Analysis No. Agrolab 35923 H DE HKS, Plot No. 1336945	HV St. Johann	15.7	15.8	16.0	16.3	16.03	yes
Analysis No. Agrolab 34352 H DE HKS, Plot No. 1844456	HV St. Johann	14.8	14.5	14.9	15.3	14.90	yes
Analysis No. Agrolab 35247 H DE HKS, Plot No. 1353098	HV St. Johann	14.7	14.6	14.7	15.1	14.80	yes
Analysis No. Agrolab 31380 H DE HKS, Plot No. 1373296	HV St. Johann	15.7	15.3	15.5	16.0	15.60	yes
Analysis No. Agrolab 34824 H DE HKS, Plot No. 1374112	HV St. Johann	14.1	13.8	13.9	14.3	14.00	yes
Analysis No. Agrolab 34827 H DE HKS, Plot No. 1374214	HV St. Johann	14.3	14.1	14.2	14.6	14.30	yes
HHKS Analysis No. Agrolab 31782	HVG Mainburg	15.6	15.6	15.8	16.2	15.87	yes
HHKS Analysis No. Agrolab 33582	HVG Mainburg	14.4	14.3	14.6	14.7	14.53	yes
HHKS Analysis No. Agrolab 32108	HVG Mainburg	18.1	18.0	18.1	18.3	18.13	yes
HHKS Analysis No. Agrolab 32565	HVG Mainburg	14.4	14.6	14.6	14.9	14.70	yes
HHKS Analysis No. Agrolab 31219	HVG Mainburg	14.8	14.9	15.1	15.3	15.10	yes
HHKS Analysis No. Agrolab 28948	HVG Mainburg	14.9	14.8	15.2	15.2	15.07	yes
Agrolab Analysis No. 35690, Plot No. 1098458 HKS	HHV Au	15.7	15.3	15.5	15.9	15.57	yes
Agrolab Analysis No. 33848, Plot No. 1538351 HKS	HHV Au	14.3	14.2	14.2	14.5	14.30	yes
Analysis No. Agrolab 33471 HHKS	HVG Mainburg	14.5	14.0	14.5	14.7	14.40	yes
Analysis No. Agrolab 32153 HHKS	HVG Mainburg	13.9	13.6	14.2	14.2	13.90	yes
Agrolab Analysis No. 29624 HKS	Agrolab GmbH	14.3	13.8	13.9	14.0	13.90	yes

Sample name	Initial test laboratory	Initial test value	Follow-up tests			Median	Results confirmed
			1	2	3		
Analysis No. Agrolab 31937 HHKS	HVG Mainburg	15.3	15.2	15.3	15.4	15.30	yes
Analysis No. Agrolab 35743 Plot No. 1877751 H DE HKS	HV St. Johann	15.3	15.1	15.5	15.5	15.37	yes
Analysis No. Agrolab 32692 Plot No. 1170945 H DE HKS	HV St. Johann	15.4	15.5	15.5	15.7	15.57	yes
Analysis No. Agrolab 35822 HHKS	HVG Mainburg	16.3	16.5	16.6	16.7	16.60	yes
Analysis No. Agrolab 1152 THKS Tettnang	HVG Mainburg	15.5	15.4	15.5	15.6	15.50	yes
Analysis No. Agrolab 34325 HHKS	HVG Mainburg	17.1	16.9	17.1	17.1	17.03	yes
Analysis No. Agrolab 1039 Plot, No. 6DE190009792 T DE HKS	HV St. Johann	12.9	12.7	12.9	13.0	12.87	yes
Analysis No. Agrolab 1039 Plot, No. 10DE191687221 H DE MBA	HV St. Johann	7.3	7.2	7.3	7.4	7.30	yes
Analysis No. Agrolab 31930 HHKS	HVG Mainburg	15.0	14.8	14.9	15.0	14.90	yes

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

7.6 Analyses concerning the bitter quality project

The Gesellschaft für Hopfenforschung (*Society for Hop Research*) was tasked with conceptualizing the differences in the quality of bitterness of common high-alpha varieties. Bitter quality depends not only on the amount of alpha acids, but on many other, rather imprecisely defined substances. The following hop varieties were selected for the project: Hallertauer Magnum (HHMG), Hallertauer Taurus (HHTU), Polaris (HPLA), Hallertauer Herkules (HHKS) and CTZ (Columbus, Tomahawk, Zeus). Tab. 7.7 and Tab. 7.8 show the results of the analyses.

Tab. 7.7: Analyses of “Bitter Quality"

Variable	HHMG	HHTU	HPLA	HHKS	CTZ
Total oil in ml/100 g	1.70	1.45	2.45	1.25	2.20
Linalool in mg/100 g	4	23	10	6	17
Total polyphenoles in %	3.31	3.57	3.73	4.46	3.50
HSI	0.272	0.350	0.325	0.330	0.392
Quercetin in ‰	0.294	0.487	0.299	0.728	1.158
Kaempferol in ‰	0.093	0.165	0.367	0.324	0.151
Sum in ‰	0.387	0.652	0.666	1.051	1.308

Tab. 7.8: Wöllmer data on "Bitter Quality"

Variety	Total resins	Alpha acids KW (conductivity meter value)	α-acids HPLC	Soft resins	Hard resins	ß-fraction	ß-acids HPLC	Xanthohumol HPLC	Water
HHMG	25.54	11.51	10.44	22.97	10.06	11.46	6.55	0.41	7.3
HHMG	25.56	11.58	10.61	22.99	10.05	11.41	6.64	0.42	
HHTU	25.75	13.33	11.85	22.87	11.18	9.54	3.74	1.00	7.4
HHTU	26.05	13.09	12.01	23.19	10.98	10.10	3.76	1.02	
HPLA	33.84	19.01	17.11	30.37	10.25	11.36	5.01	1.06	6.0
HPLA	33.90	19.10	17.16	30.87	8.94	11.77	5.02	1.06	
HHKS	27.59	14.99	12.84	23.79	13.77	8.80	3.73	0.98	7.4
HHKS	27.55	15.09	12.93	24.04	12.74	8.95	3.73	0.99	
CTZ	29.19	14.56	13.43	25.12	13.94	10.56	3.73	0.87	6.9
CTZ	29.33	14.65	13.6	25.22	14.01	10.57	3.78	0.88	

Total resins, α-acids KW, α-acids HPLC, Soft resins, ß-acids, Xanthohumol, Water in % Pellets, Hard resins as % of total resins, ß-fraction = Soft resins – α-acids KW

Fig. 7.17 shows the quotients of alpha acids KW to alpha acids HPLC. The size of these quotients provides an early indication of the non-specific bitter substances in hops. The second part of the figure shows the proportion of non-specific soft resins compared to total soft resins. Overall, there are no major differences among the analyzed hops, except for Hallertauer Taurus, which has slightly higher values.

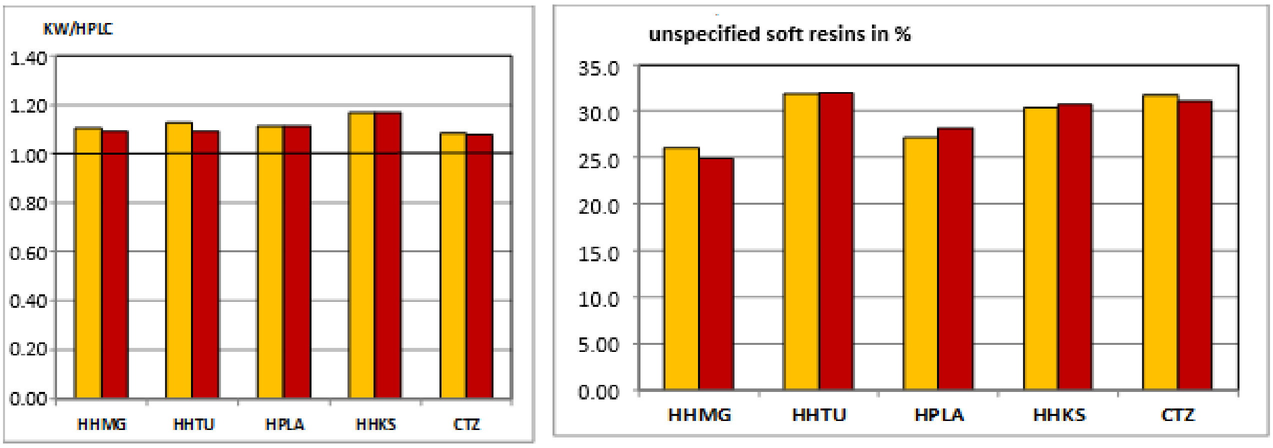


Fig. 7.17: Quotient alpha-acids KW to alpha-acids HPLC and proportion of non-specific soft resins as part of total soft resins

For sensory evaluations, each of these hop varieties were used in single-hop brews. Polaris and CTZ performed best. The probable reason is the fairly high oil content of these varieties, which caused them to be perceived more positively.

7.7 Comparison of green hops and dried hops

This project was executed by Tomonori Kano of Kirin. Its purpose was the analytical and sensory evaluation of the differences between green hops and conventionally dried hops. Tab. 7.9 shows the water and oil contents. Once the oil contents are recalculated for a fixed water content of 10%, it becomes clear that the drying removes oil contents, but at different rates for different varieties. Varieties with higher oil levels seem to lose more oil than do varieties with lower levels (Fig. 7.18).

Tab. 7.9: Water and oil content of green hops and conventionally dried hops

Hop variety		Water content in %		Oil content in ml/100g raw hops		Oil content in ml/100g hops with 10% water	
		Green	Dried	Green	Dried	Green	Dried
Hallertauer Tradition	HTR	76.7	8.9	0.33	1.20	1.29	1.19
Saphir	SIR	76.6	8.7	0.75	2.25	2.89	2.22
Spalter Select	SSE	76.9	7.6	0.53	1.90	2.06	1.85
Callista	CAL	79.3	7.1	0.53	1.90	2.30	1.84
Hallertau Blanc	HBC	78.9	7.0	0.60	1.70	2.56	1.65
Polaris	PLA	76.0	5.6	1.73	5.15	6.49	4.91
Hallertauer Magnum	HMG	75.4	6.5	1.38	4.10	5.05	3.95
Cascade	CAS	81.5	8.8	0.54	2.15	2.63	2.12
Diamant	DNT	80.4	7.0	0.60	1.85	2.75	1.79
2011/02/04		77.4	6.7	1.17	3.15	4.66	3.04
Mandarina Bavaria	MBA	78.8	8.3	0.73	2.90	3.10	2.85
Hersbrucker Spät	HEB	79.3	7.6	0.33	1.50	1.43	1.46

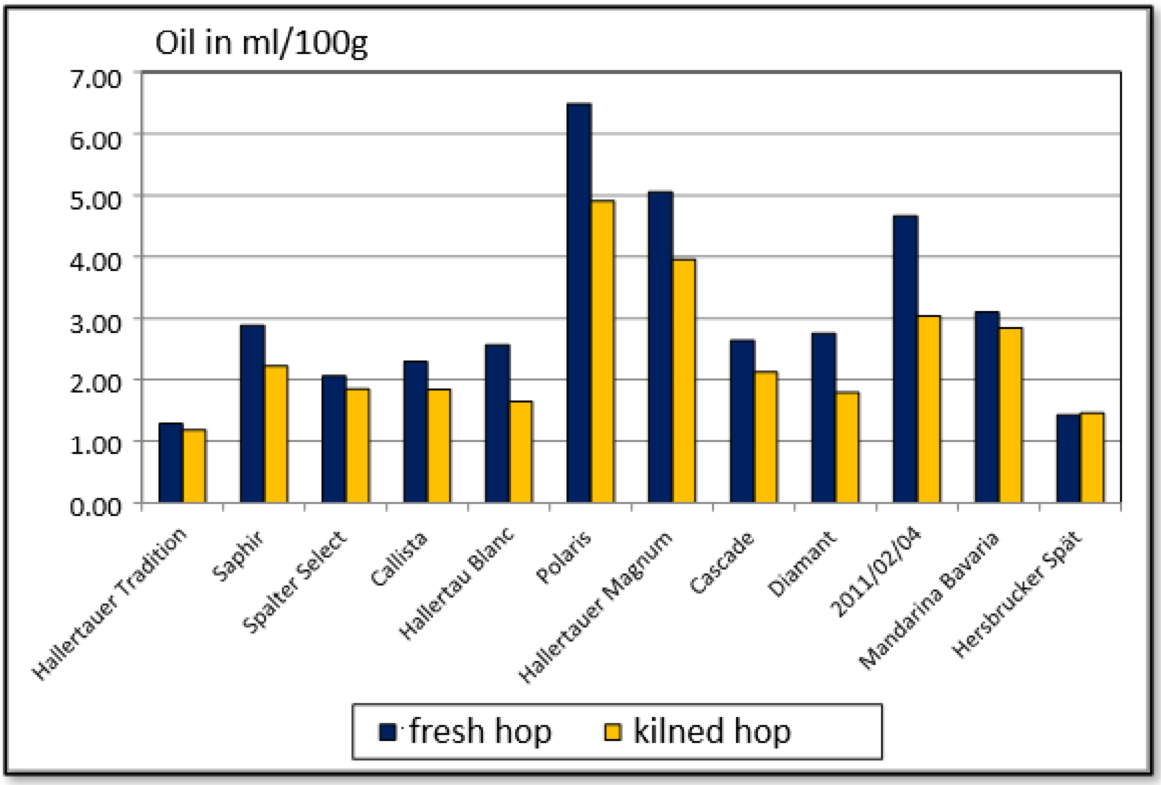


Fig. 7.18: Comparison of oil content of green and conventionally dried hops for different hop varieties standardized to 10% water content

The decrease is less for compounds with lower boiling temperatures, such as myrcene. The concentration of linalool changes hardly at all (Fig. 7.19).

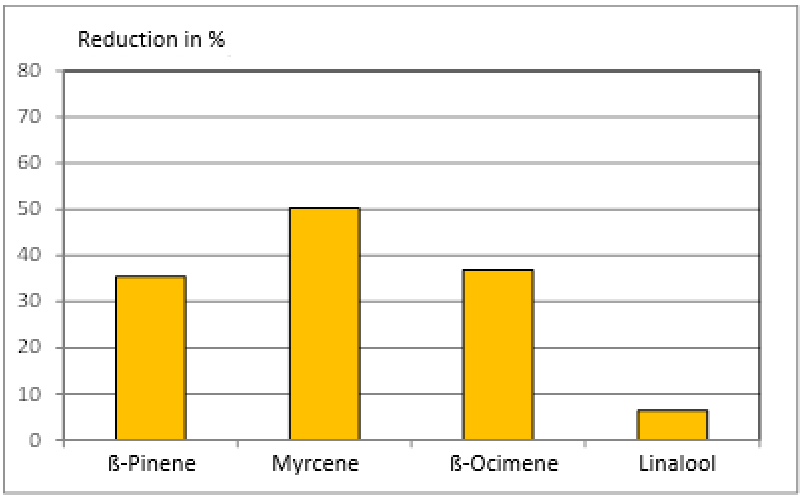


Fig. 7.19: Decrease of individual oil components during drying

7.8 Investigations of lupulin glands on leaves

Lupulin glands are concentrated in the hop cones, but there are also lupulin glands on almost all parts of the plant, including on the stems and leaves. Fig. 7.20 shows a leaf with clearly visible lupulin glands.

Fig. 7.20: Leaf surface with clearly visible lupulin glands

The leaf lupulin glands produce xanthohumol and beta acids but only traces of alpha acids. The objective of this project was to find out if there is a correlation between the compounds in cone and in leaf lupulin glands. This information could possibly be put to good use in assessing male plants as potential partners for crosses. Figure 21 shows the results. Though there are trends suggesting that there is a relationship between the two variables, the correlation coefficients are very small. Therefore, in order for this method to be useful, it would need to be more standardized.

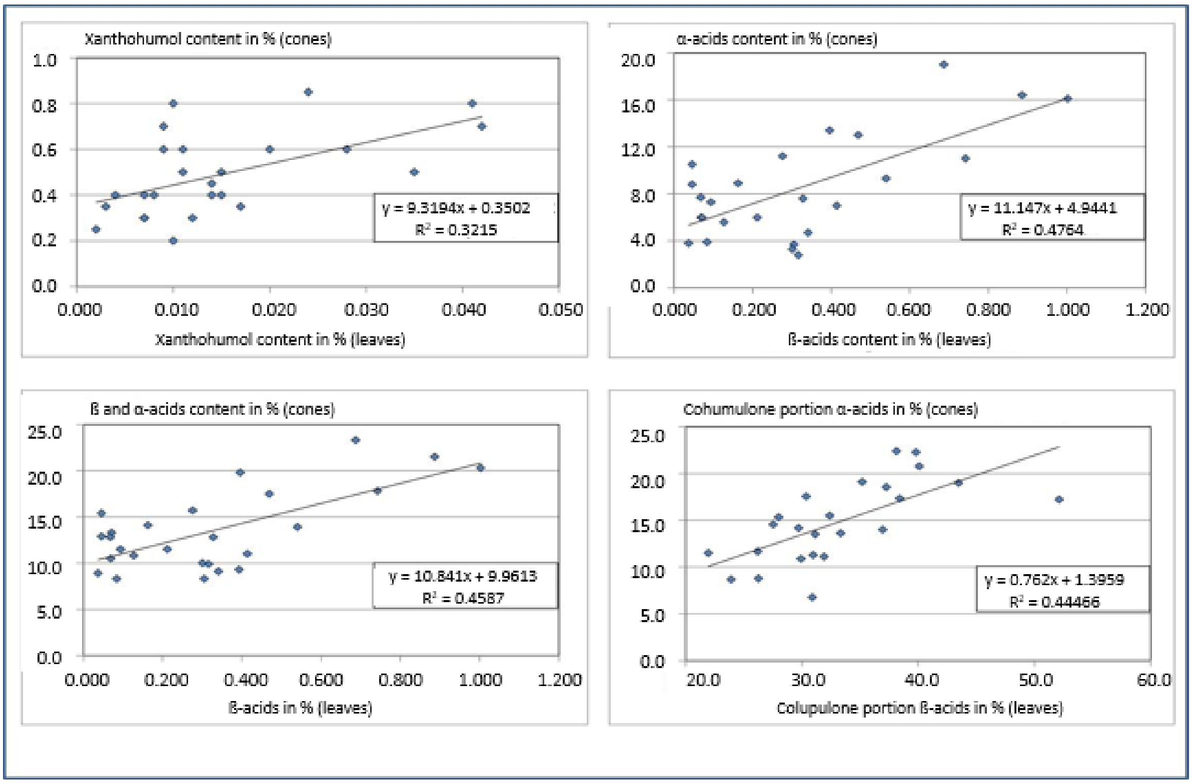


Fig. 7.21: Correlation between compounds in leaf and cone lupulin glands

7.9 Alpha-acid stability of new Hüll cultivars against fluctuations in different growing years

Alpha-acid data from 2012 to 2019 are now available for recently introduced Hüll cultivars (box-plot evaluations in Fig. 7.22 and Fig. 7.23). The data shows that the new Hüll cultivars have much more stable year-to-year alpha-acid values compared to, for instance, such older varieties as Perle and Northern Brewer.

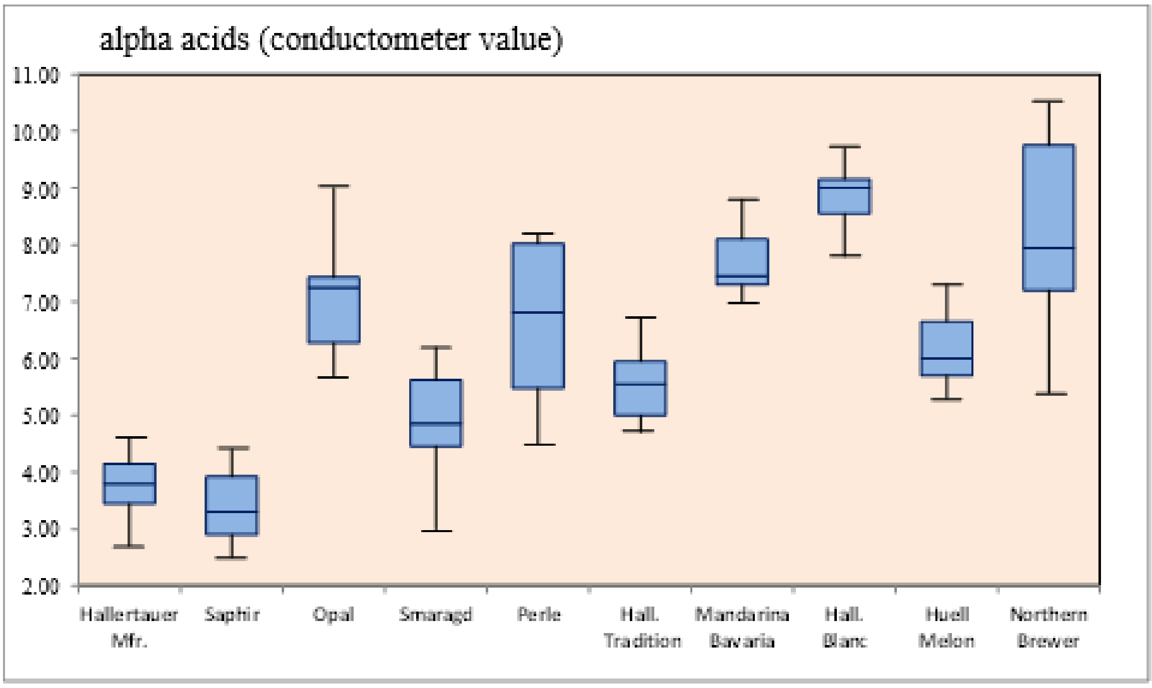


Fig. 7.22: Box-plot evaluation of aroma varieties

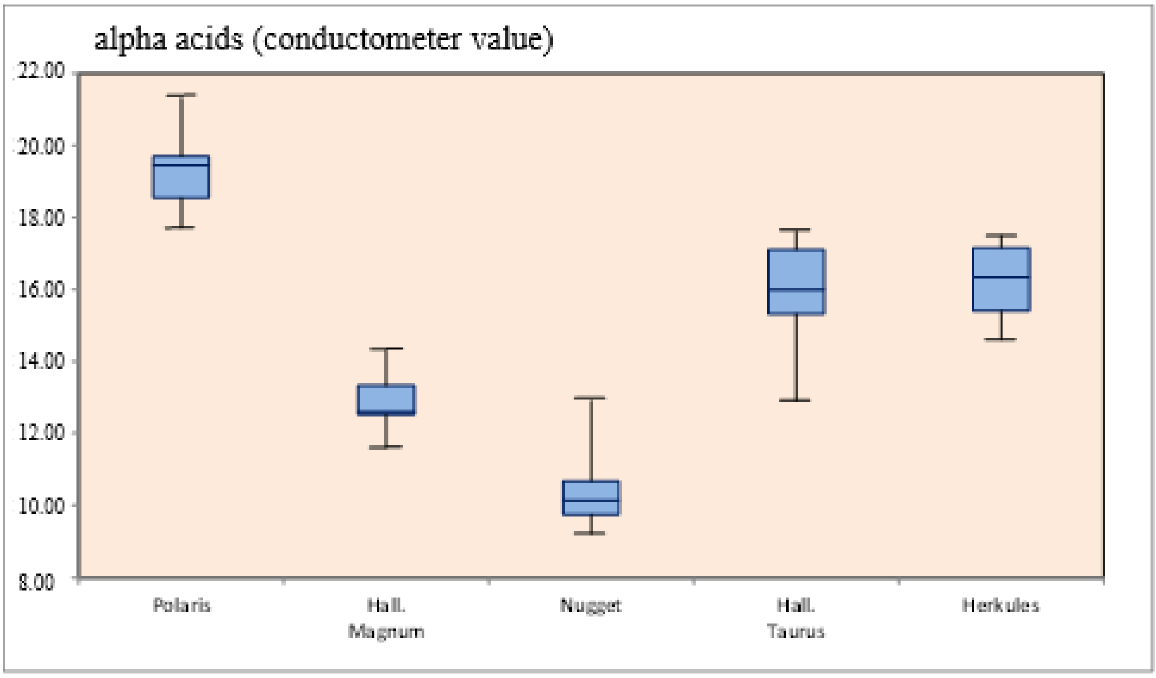


Fig. 7.23:

7.10 True-to-type verification in 2019

One of the mandatory tasks of the Working Group IPZ 5d is to verify the true-to-type authenticity of hop varieties for the German food safety authorities.

The number of variety checks on behalf of the district offices of the food safety authorities for the year 2019 was 26. Of these, 2 revealed issues that needed to be resolved.

8 Ecological Issues in Hop Production

Dr. Florian Weihrauch, Dipl.-Biol.

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

8.1 Minimizing the use of copper-containing crop protection agents in ecological and integrated hop cultivation

Sponsor:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) *[Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Ecology (IPZ 5e)]*
Financing:	Erzeugergemeinschaft Hopfen HVG e. G. *(HVG Hop Producer Group)*
Project Management:	Dr. F. Weihrauch
Team:	M. Obermaier, A. Baumgartner, M. Felsl, Dr. F. Weihrauch
Collaboration:	Betrieb (*Hop Farm*) Ludwig Gmeiner, Uttenhofen Agrolytix GmbH, Erlangen Forschungsinstitut für Biologischen Landbau *(The Research Institute of Organic Agriculture)* (FiBL), Frick Boku Wien, IFA-Tulln Institut für Umweltbiotechnologie *(University of Natural Resources and Life Sciences,* **Vienna** *(***BOKU***), Institute of Environmental Biotechnology)*
Duration:	March 1, 2014 to February 28, 2021 (project extension)

Objectives

After an environmental and toxicological assessment of plant protection products containing copper, the German Federal Environment Agency and other authorities have concluded that these products should no longer be used. At the EU level, too, this active ingredient has received an unfavorable classification in recent years (listing on Annex I) and has been permitted 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 from the market as soon as there are equivalent or better active ingredients available; and the member states are, therefore, obligated to work intensely on concepts that allow for the further reduction of the amount of copper in use.

Organic farms, however, still cannot do without copper as an active ingredient, regardless of the cultivated crop. A four-year test program that lasted from 2010 to 2013 and was sponsored by the German Federal Organic Farming Program (BÖLN), produced information on how much copper could be reduced in hop gardens before crop losses would ensue. The program concluded that the currently permissible amount of 4 kg /ha/year can be reduced by at least one quarter to 3 kg/ha/year.

After the successful conclusion of this early project, a follow-up project is now being conducted to study if further reductions in the use of copper in hop gardens below the current 3 kg/ha/year is feasible.

Results

In 2019, two copper agents (Funguran Progress as an approved agent and CuCaps as a testing agent) were applied in different quantities in 14 variants. In addition, different mixing media were used as synergists, some of which were also tested solo. Unlike in trials in previous years, this time the tests were conducted using the highly susceptible variety Herkules. This allowed for a better determination of differences between individual variants. The results show that a new plant extract from FiBL ('R2-D2'), a chitosan formulation from IFA Tulln and the Czech product Polyversum (a parasitic soil fungus), delivered exceptionally good success rates in the first year. The tests will be repeated in 2020 at a new location with an equally susceptible variety, and it will be interesting to find out if these positive results can be replicated.

8.2 Microencapsulated hop extracts as a novel biological fungicide to combat downy mildew in hop production

Sponsor:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenb. 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:	Wissenschaftsförderung der Deutschen Brauwirtschaft e.V., Berlin (Wifö) *(Scientific Funding from the German Brewing Industry)*
Project Management:	Dr. F. Weihrauch
Team:	M. Obermaier, A. Baumgartner, M. Felsl, Dr. F. Weihrauch
Collaboration:	Betrieb (*Hop Farm*) Ludwig Gmeiner, Uttenhofen Lehrstuhl für Prozessmaschinen und Anlagentechnik [*Chair of Process Technology and Machinery (iPAT)]* (iPAT), Friedrich-Alexander-Universität Erlangen-Nürnberg Agrolytix GmbH, Erlangen Hallertauer Hopfenveredelungsgesellschaft m.b.H., *(Hop Processing Society),* Mainburg
Duration:	July 1, 2016 to December 31, 2019

Objectives

In Germany, various efforts are being made to directly reduce the annual application rate of pure copper per hectare in crop protection and to look for alternative fungicidal agents. In this context, the Staatliches Weinbauinstitut *(State Wine Institute)* in Freiburg i.Br. discovered that hop extract has a good effectiveness rate against in vitro downy mildew that affects vineyards (*Plasmopara viticola*). The antimicrobial effect is mainly attributed to alpha acids and xanthohumol.

The objective of the project is the development of an easily feasible solution that would allow for the replacement, or at least for a further reduction, of the use of copper in hop production. This also implies that any new pesticide be not only applicable and effective, but above all, also affordable. The process of spray solidification is a very cheap production method; and the right choice of a suitable matrix or of auxiliary substances allows the costs of the end product to be kept within traditional limits.

The Wifö-funded project "Microencapsulated hop extracts as a novel biological fungicide to combat downy mildew in hop cultivation" started on July 1, 2016. Its mission is to find a sustainable alternative to the controversial use of copper-containing pesticides in the fight against downy mildew fungi (*Pseudoperonospora humuli*) in hop gardens. Originally, the research project ended on December 31, 2018.

The project proposal described how hop extract microcapsules should be developed using the spray solidification process in order to be able to offer a practical crop protection product in powder form (HopCaps). The critical properties of the powder had to include drip-irrigation capability, suspension stability, particle size distribution, release of the active ingredients in water and adhesion to leaves. These were to determine both the applicability and the biological effectiveness of the plant protection product. At the same time, the microcapsules in the field should be checked for their biological effectiveness in combating peronospora and their suitability for use in practice.

The work was divided into several tasks: The capsule prototypes were developed at the Chair for Process Machines and Plant Technology (iPAT) at the Friedrich Alexander University in Erlangen-Nuremberg. The biological effectiveness of the prototypes was examined and evaluated by the hop research center of the Bavarian State Research Center for Agriculture in Hüll. Since there were still residual funds available after the original two-year duration of the outdoor part of the research project, Wifö agreed to a cost-neutral project extension until December 31, 2019. Because of a lack of infestations during the first two years, the project was unfortunately unsuccessful. A third year of testing in the field, therefore, was intended to bridge that gap.

Experiments on biological effectiveness under practical conditions

To test the biological effectiveness, the hop extract capsules were used in a three-year trial in an ecologically managed hop garden in the Hallertau. In 2017 and 2018 the location was a Naturland operation in Schweinbach in the northern Hallertau. A hop garden planted with the peronospora-tolerant cultivar Hallertauer Tradition was selected as the test field. In 2019, the trial was continued in a field in Uttenhofen near Pfaffenhofen a.d. Ilm. This time, a hop garden of the susceptible high-alpha variety Herkules served as the test field.

In the course of the project, five different variants were compared in all three trial years, each of which was treated in the trial garden in two large plots (2017-2018: 590 m^2, 2019: 540 m^2). The two plots of each test were then rated twice as false repetitions in order to achieve statistically meaningful results with four repetitions per test element. The five variants with the respective pure copper applications were:

Test link	**Pure copper [kg Cu ha^{-1} a^{-1}]**
Untreated control	0.0
Fungarian progress (comparative)	3.0
CuCaps solo	2.0
CuCaps plus HopCaps	2.0
CuCaps plus HopCaps	1.0

All tests were carried out in parallel to tests of other low copper variants with biologicals and similar agents. The sprays were determined and calculated in advance for six treatments per growing season, as this corresponds to the customary procedures in practice.

Each year, the best variant of the HopCaps, which was selected by the collaboration partner iPAT, was sprayed in combination with encapsulated copper at a rate of 1 kg/ha/year. This should allow for a comparison with other copper-free agents, which were also sprayed in combination with copper. The hop extract capsules could be applied without complications using a conventional blower sprayer (Nobili blower sprayer Euro 105/2000, with UNI-Control dosing computer and Polmac 2 tank flow meter from Müller-Elektronik, equipped with Turbodrop nozzles). The same blower sprayer was used for all other applications, too. Each year, the sprayings were conducted by a test technician, who worked on a contract basis. All six applications in the three trial years were conducted with adjusted amounts of water and correspondingly split agents.

8.2.1 Results

Because of the dry and hot weather conditions in 2017, none of the trial plots, including the untreated control, showed any noteworthy infestations of downy mildew, which is why no graphic representations of results are shown here for these years. The situation in 2018 was even more extreme. Starting in the spring, damage caused by hop fleas, hop aphids, common spider mites and powdery mildew began to build up in the ecologically managed garden, but peronospora infestations remained entirely unrecognizable (Fig. 8.1).

Fig. 8.1: View of the Schweinbach experimental garden in 2018. The ecologically managed garden showed severe damage caused by hop fleas, hop aphids, common spider mites and powdery mildew, but no infestations of peronospora.

In 2019, a switch in hop gardens to the susceptible Herkules variety finally brought the hoped-for results. After the first evaluation on August 7, 2019 (leaf and flower infestations) there were practically no peronospora infestations. With an increase in zoosporangia numbers, however, a significant differentiation in cone infestations began to emerge, starting in early September (Fig. 8.2, Fig. 8.3.).

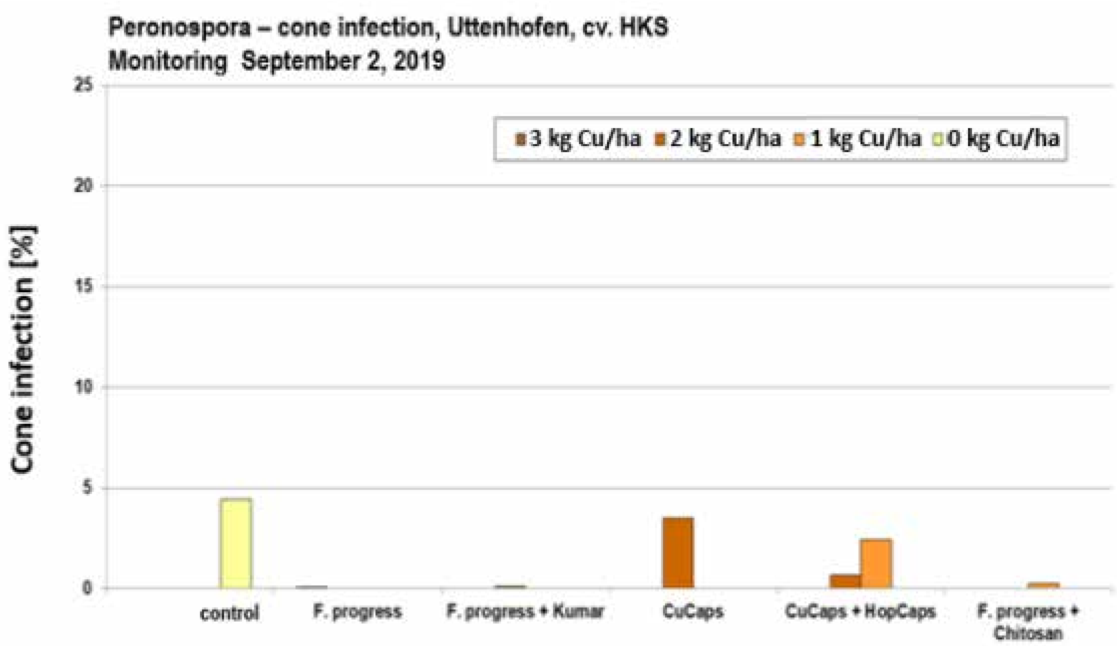


Fig. 8.2: *Results of the cone evaluation at the beginning of September 2019. Kumar is an approved, ecologically compatible fungicide and chitosan is an ecologically compatible base material.*

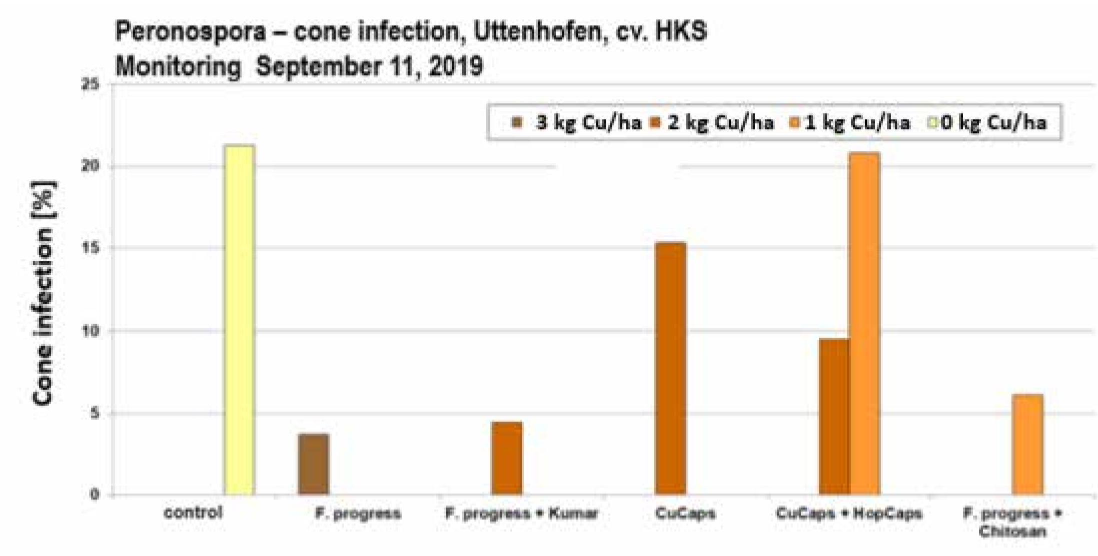
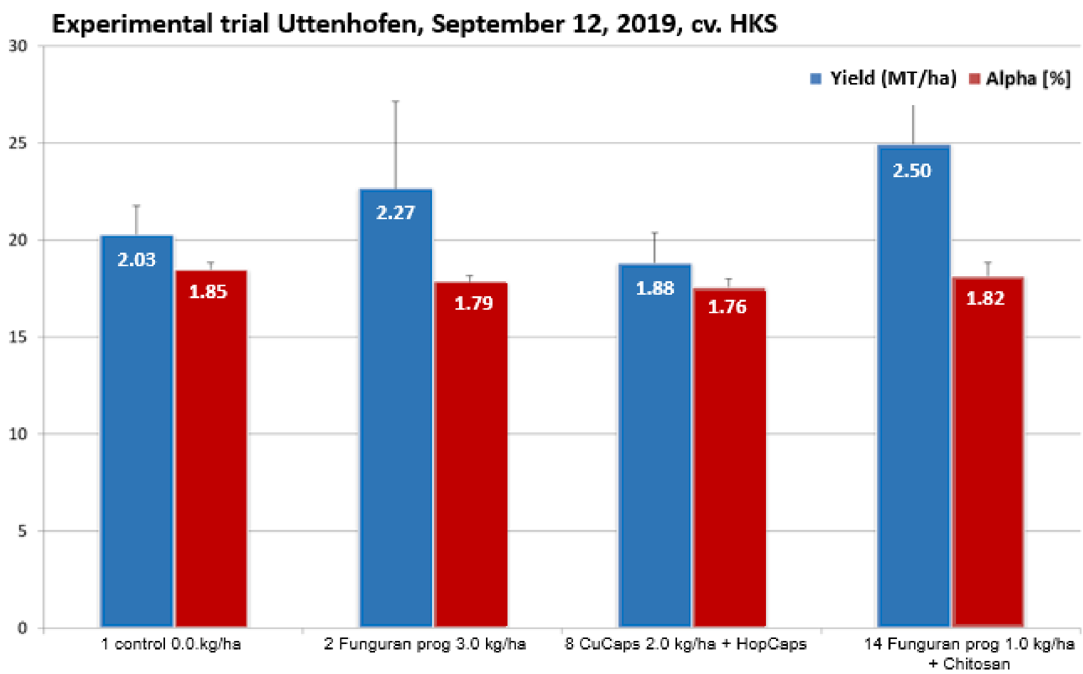


Fig. 8.3: Results of the cone evaluation one day before the 2019 harvest. Kumar is an approved, ecologically compatible fungicide and chitosan is an ecologically compatible



base material.

Fig. 8.4: Results of the trial harvest 2019 in Uttenhofen. There were no significant differences between the individual variants, not in yield and not in alpha acids.

Compared to the percentage of cones in the untreated control (21.3%), as well as to the comparison agent Funguran Progress (copper hydroxide; 3.7%), the combination of CuCaps and HopCaps in the 2 kg variant performed relatively well (9.5%) and was clearly better than the 2 kg variant of the CuCaps without HopCaps (15.4%). In the 1 kg variant, however, the combination of CuCaps and HopCaps was hardly better than the untreated control, at 20.8%, while other synergists such as, for instance, chitosan with 1 kg copper (6.1%) performed significantly better. In another 2 kg variant, the combination with

Kumar (potassium hydrogen carbonate; 4.5%) almost reached the level of the comparative agent (Fig. 8.3).

It is noteworthy, however, that, just as in 2017, the different infestations had once again no significant influence on the yield or the content of alpha acids (Fig. 8.4).

Discussion and identified problems

Basically, the HopCaps are to be rated as a good synergist for low copper use and they definitely have fungicidal properties, as was also proven in the laboratory experiments by the iPAT. In our field trials, the HopCaps were also tested for their biological effectiveness and, when used in combination, they were able to increase the efficiency of the copper fungicide CuCaps by about 60%. The efficiency of the CuCaps in the 2019 tests, which is not convincing in relation to the comparative agent Funguran Progress, can be explained by the fact that, for reasons of regulatory approval, the formulation of copper(II)-sulfate-pentahydrate in the fat capsules was no longer possible.

Instead, a copper hydroxide formulation had to be used here as well, which led to a lower release rate of the fungicidally active Cu^{2+}-ions (S. Schwab, Agrolytix, pers. Mitt.).

With regard to practical aspects of the application of HopCaps, the ability to spray was affected by a few initial difficulties — especially in the area of clumping in combination with copper products — which, however, were significantly ameliorated by the manufacturer as time went on; and eventually problems with gummed-up filters in the blower spray nozzle showed up only in exceptional cases. Nevertheless, before filling the sprayer, it was still necessary to dissolve the HopCaps in a bucket with a few liters of water and dissolve them using a whisk operated by a drill (Fig. 8.5). Direct filling of the hop caps powder into the sprayer still led to clumping and then had to be reworked by hand in order to actually get the capsules into the tank for the blower spray nozzle (Fig. 8.6). There are definitely still major issues with the practicality of the capsules, since no farmer will accept such time-consuming preliminary work. It should also be noted that the amount of HopCaps required in practice is relatively large and, depending on the BBCH, could be between 15 and 25 kg per hectare. This is a problem that also requires a solution.

In addition to the described problems with the practical handling of HopCaps, we must also point out that, in 2019, we were able to examine other synergists for low copper use (chitosan, polyversum and a plant extract). For this year, these were able to deliver more convincing results than HopCaps. Of course, such single-year results still need to be further tested and verified, but at least in terms of handling, these test products had advantages over HopCaps.

Fig. 8.5: *When applying HopCaps outdoors, it was still necessary to mix the powder in a few liters of water in advance to avoid clumping when filling the sprayer.*

Fig. 8.6: Direct filling of the sprayer with hop caps without first stirring them in water continued to form lumps

8.3 Further development of cultivation-specific strategies for ecological plant protection with the help of division networks - hops division

Sponsor:	Bund Ökologische Lebensmittelwirtschaft (BÖLW e.V.) und Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) *[Organic Food Production Alliance (BÖLW e.V.) and Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Ecology (IPZ 5e)]*
Financing:	Bundesanstalt für Landwirtschaft und Ernährung (BLE) über Bundesprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft (BÖLN-Projekt 2815OE095) (*Federal Agency for Agriculture and Food (BLE) through Federal Organic Farming Programme including other forms of sustainable agriculture) (BÖLN Project 2815OE095)*
Project Management:	Dr. F. Weihrauch
Team:	Dr. F. Weihrauch, M. Obermaier
Collaboration:	Bund Ökologische Lebensmittelwirtschaft (BÖLW e.V.) [*Organic Food Production Alliance (BÖLW)]*
Duration:	August 15, 2017 to August 14, 2020

Approach and objectives

The objective of the entire research project is to set up six cultivation-specific networks (arable farming, vegetables, hops, potatoes, fruit and viticulture) focused on plant health in organic farming, with divisional coordinators serving as central contacts. The overall coordination is in the hands of the BÖLW, the hops division is coordinated by IPZ 5e in Hüll.

The tasks of the coordinator include building the cultivation-specific network as a stable group of commercial farms that are interested in obtaining advice from operations that have already transitioned to organic farming; in compiling information relating to plant health of the respective cultivars; in compiling and disseminating innovation and research needs; and in the formulation of phytosanitary strategies for each crop. Within the Öko-Hopfen *(organic hops)* network, communication takes place mostly via two to three meetings of the parties each year, including a special workshop for all farms. Finally, there is one workshop per year for the exchange of ideas between the different cultivar networks and the overall coordination of the projects.

From the perspective of the hops division, therefore, the most important events in 2019 were the Hopfenbautag (*Hop Cultivation Day*) as part of the Bioland Week in Ploster Plankstetten (February 5, 2019); the summer excursion of the Working Group Öko-Hopfen in the Hersbruck region, with a total of 80 interested participants, including from conventional hop production (July 24, 2019); the network meeting with the BÖLW in Kassel (October 15, 2019); and especially the “Round Table on Current Problems of Plant Protection in Organic Hop Production” in Hüll on November 25, 2019.

The main goal of the research project is to pursue management strategies rather than to rely on the inputs of phyto-medically active substances into the cultivation system. The expectations of BLE and BMEL as clients with respect to the result of the overall project are in the areas of progress and innovation, that is, ideally in the development of new management or cultivation systems and a coherent work program.

8.4 Development of a catalog of measures that promote biodiversity in hop production: what is possible?

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
Collaboration:	TU München, Lehrstuhl für terrestrische Ökologie (Prof. Weisser) *(Munich Technical University, Chair of Terrestrial Ecology)*
Duration:	March 1, 2018 to September 30, 2020 (Project Extension)

Background and objectives

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

Method

The first step is the establishment of a collaborative network of as many stakeholder federations, organizations and institution as possible to work together in finding constructive approaches and solutions. In addition to the LfL and the TUM, the BBV, the AELF Pfaffenhofen (Fachzentrum Agrarökologie (*Center of Expertise for Agroecology*), the LBV, the IGN Niederlauterbach and all organizations in the Haus des Hopfens *(House of Hops)* were involved.

The series of measures to be initiated includes, among others, the abandonment of marginal, unproductive and critical plots (such as those in the immediate vicinity of water sources); the weighting of existing, landscape-defining small structures (such as field drains, tendrils) for targeted ecological upgrading; the creation of buffer strips to bodies of water, border strips and flowering strips or areas; the rededication of such auxiliary green spaces as road or railway embankments or traffic islands; the establishment of multi-year set-aside areas; the preservation or creation of uncovered soil areas, such as demolition edges. Basically, the goal is not to affect productivity or interfere with productive spaces.

As a concrete sub-project, a 2019 master's thesis at the TUM focused on investigating whether or not there are qualitative or quantitative differences in insect colonies between organic and conventionally cultivated hop gardens. The evaluation was only completed in 2020.

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

Sponsor:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) *[Bavarian State Research Center for Agriculture, Institute for Plant Production and Plant Breeding, AG Hop Ecology (IPZ 5e)]*
Financing:	Bundesanstalt für Landwirtschaft und Ernährung (BLE) über Bun-desprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft (*Federal Agency for Agriculture and Food (BLE) through Federal Organic Farming Programme including other forms of sustainable agriculture) (BÖLN Project 2815NA131)*
Project Management:	Dr. F. Weihrauch
Team:	M. Obermaier
Collaboration:	Various companies practicing ecological and integrated hop production
Duration:	May 1, 2018 to April 30, 2021

Objectives

The key objective of planting suitable winter-hardy undersowings in the furrows of hop gardens should be to create a refuge for wintering predatory mites. From this refuge, the mites can re-colonize the hop plants in the spring. A permanent establishment of predatory mites in hop gardens represents a functioning, sustainable and economical method of spider mite control as an ecological form of crop protection, as well as an essential component of integrated crop protection.

Results

The common spider mite *Tetranychus urticae* is one of the main pests in cultivated hops, and an infestation can lead to severe losses in yield and quality, or even to total crop failures. Especially in organic hop growing, the possibility of carefully and effectively managing spider mites with alternatives to the preventive use of whey and sulfur is particularly important because these latter substances can potentially impair the thriving of beneficial fauna. This also applies to pesticides against the common spider mite in regular agricultural production, because the goals of environmental compatibility and bee protection are becoming ever greater concerns. A look at other special crops shows that, in German orchards and vineyards, the successful management of predatory mites can control spider mites without the use of acaricides.

The main goal is to establish the indigenous predatory mite species *Typhlodromus pyri*. This predatory mite is a native species common in German viticulture and fruit growing, which is able to use various types of harmful mites (spider mites, grape rust mites, bud mites) as well as grass pollen as a food source. This low level of specialization or the use of alternative food sources enables *T. pyri* to build stable populations over time. The permanent settlement of *T. pyri* is intended to cause a continuous reduction in spider mite populations and thus to contribute to the prevention of harmful attacks on hops.

Fig. 8.7: Frost cuttings from a vineyard with predatory mites (T. pyri) placed to "inoculate" the hop garden at the wire or string

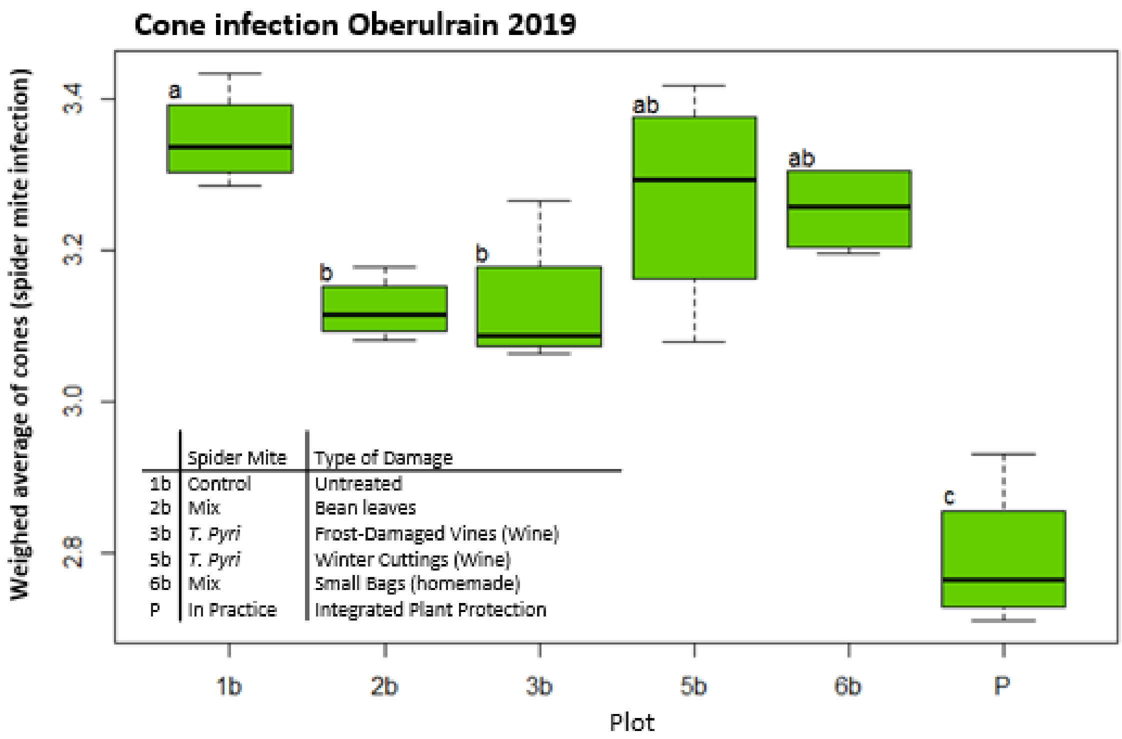
Fig. 8.8: Bean leaf with predatory mite mix at the wire or string

In addition, the use of farmed allochthonous, that is, non-native, predatory mites should be optimized, which can be used as a supplement whenever there is fear of an extreme spider mite proliferation. In the trials, a mix of *Phytoseiulus persimilis* and *Neoseiulus californicus* was used. This mixture of two predatory mite species has shown promising results in previous experiments. The next step is to answer questions regarding the best possible application method, as well as the timing and the amount of the application.

Several hardy undersowings were used as cover crops, including tall fescue (*Festuca arundinacea*), as well as a grass mixture containing foxtail (*Alopecurus pratensis*), meadow spike (*Poa pratensis*) and meadow fescue (*Festuca pratensis*). The reason for this selection is the different grass pollens, on which the predatory mites can feed. This ensures their survival between the end of their winter resting phase and the start of spider mite infestations in hops in the spring. Furthermore, these undersowings are said to have a positive effect on the microclimate in the hop gardens year-round, which is favorable to predatory mites.

An additional test element is the planting of strawberries as woody plants between the furrows of the hop garden. This technique is often used in vineyards and orchards instead of undersowing cover crops. The strawberries provide a place for the predatory mites to winter.

In the second year of the project, a noteworthy spider mite infestation was found at only one of the five test locations. In the four other areas, spider mite pressure started only shortly before harvest time, which is why there was no relevant damage; and why no effects of the use of predatory mites could be investigated. At the Oberulrain site, on the other hand, which had significant spider mite pressure, the differences between the treatment options became obvious: Early leaf assays (counting spider mites and eggs per leaf) did not show significant differences, but trends were already noticeable. The trial harvest stage in representative plots revealed that the plot treated conventionally with acaricides was significantly less damaged than all other trial plots. Two of the predatory mite variants showed significantly less cone damage than did the untreated control variants, which is the one that was infected at the young shoot stage in the spring with predatory mites taken fresh from a vineyard’s frost cuttings. In addition, a predatory mite mix of *P. persimilis* and *N. californicus*, taken from bean leaves, was able to significantly reduce the cone damage caused by the common spider mite compared to the untreated control variants. For a comparison, the predatory mites taken from a vineyard during winter pruning were less effective. The same applies to a predatory mite mix purchased as spreading material. In the second year of the project, this mix was packed in small bags from which the predatory mites were expected to migrate into the hops, considering that the spreading process with the Mini Airbug device had proven unsatisfactory the previous year.



$$\frac{1 \times n\ sound\ cones + infected\ cones\ (2\ \times n\ mild + 3 \times\ n\ medium\ + 4\ \times n\ strongly)}{all\ cones}$$
$$= Weighted\ Average$$

Fig. 8.9: *Weighted averages of the intensity of spider mite infestations during cone assay (4,500 cones per variant). Comparison between an untreated control (1b) and four predatory mite variants (2b, 3b, 5b and 6b), as well as a sampled commercial plot (P). 1b shows significantly higher cone damage than 2b and 3b. Cone damage was significantly less in the commercial plot than in the other test samples.*

9 Publications and Technical Information

9.1 Overview of public relations

Activity	Number	Activity	Number
Practice-relevant information and scientific papers	52	Guided tours	43
LfL publications	2	Exhibitions/shows and posters	7
Specialist information	12	Expert assessments and opinions	10
Radio and TV broadcasts	2	Internships	9
Internet features	1	Participation in working groups	38
Internal events	5	Participation in seminars, congresses, workshops	2
Seminars, symposia, trade conferences, workshops	12	Lectures and Talks	149

9.2 Publications

9.2.1 Practice-relevant information and scientific papers

Euringer, S. (2019): Hopfen 2018 - Grünes Heft - Pflanzenschutz, 2019, Hrsg.: LfL

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Fuß, S. (2019): Pflanzenstandsbericht Mai 2019. Hopfen-Rundschau, 70. Jahrgang, Nr. 6, Hrsg.: Verband dt. Hopfenpflanzer, 207

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Lutz, K., Euringer, S.; Seigner, E.; von Tucher, S. (2019): Effect of lethal hop wilt strains (*Verticillium nonalfalfae*) and different nitrogen fertilizer levels on the indicator plant eggplant (Solanum melongena L.). Tagungsband der Wissenschaftlich-Technischen Kommission, Tagungsband der Wissenschaftlich-Technischen Kommission, Hrsg.: Scientific-Technical Commission, 42 - 44

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Münsterer, J., Raith, L. (2019): "In der obersten Lage wird der Hopfen getrocknet!". Hopfen-Rundschau, 70. Jahrgang, Nr. 9, Hrsg.: Verband dt. Hopfenpflanzer, 326 - 327

Obermaier, M. (2019): Establishment of predatory mites on undersown crops in hop cultivation. Entomologenatgung 2019 in Halle (Saale), Programm und Zusammenfassungen, Hrsg.: Deutsche Gesellschaft für allgemeine und angewandte Entomologie, 51 - 51

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Portner, J. (2019): Leitlinien zum integrierten Pflanzenschutz im Hopfenanbau, 1. Auflage September 2019, Hrsg.: LfL und Verband deutscher Hopfenpflanzer

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Seigner, E.; Lutz, A.; Albrecht, T.; Volker, M. (2019): Mehltauresistenz für die genomweite Assoziationskartierung - Präzisionszüchtung Hopfen, 1 - 31

Seigner, E.; Lutz, A.; Kammhuber, K., König, W. (2019): DIAMANT - Hochfeine Hüller Aromasorte der Spitzenklasse - Noble Hüll Aroma cultivar. Hopfenrundschau International, 2019/2020, Hrsg.: Verband der Deutschen Hopfenpflanzer, 86 – 87

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Stampfl, J., Fuß, S.; Schlagenhaufer, A.; Portner, J. (2019): Bewässerung und Fertigation von Hopfen. Hopfen-Rundschau, 70. Jahrgang, Nr. 10, Hrsg.: Verband dt. Hopfenpflanzer, 356

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Weihrauch, F. (2019): Die Markeule Hydraecia micacea (Lepidoptera: Noctuidae) als Hopfenschädling: Geschichte und ein rezenter Ausbruch in der Hallertau. Entomologentagung 2019 in Halle (Saale): Programm und Zusammenfassungen, Hrsg.: Deutsche Gesellschaft für allgemeine und angewandte Entomologie, 53 - 53

Weihrauch, F. (2019): Herbsttreffen 2018 der CEG Minor Uses in Hops in Slowenien. Hopfen-Rundschau, 70(02), Hrsg.: Verband deutscher Hopfenpflanzer e.V., 56 - 57

Weihrauch, F. (2019): Sortenliste 2018 des Internationalen Hopfenbaubüros (IHB). Hopfen-Rundschau, 70(01), 20 - 28

Weihrauch, F., Baumgartner, A.; Laupheimer, S.; Mühlbauer, M. (2019): Hop-flea beetle revisited: In search for attractants. Proceedings of the Scientific-Technical Commission, I.H.G.C., Proceedings of the Scientific-Technical Commission, Bischoffsheim, Alsace, France, 07-11 July 2019, Hrsg.: Scientific-Technical Commission of the International Hop Growers' Convention I.H.G.C., 70 - 70

9.2.2 LfL-Publications

Name(s)	Working Group	LfL Publication	Title
Hops Department	IPZ 5	LfL-Information	Annual Report 2019 – Specialty Crop Hop
Portner, J.	IPZ 5a	LfL-Information	Hop 2018 - Grünes Heft *(Green Pamphlet)*
Euringer S.	IPZ 5b	LfL-Information	Hop 2018 - Grünes Heft *(Green Pamphlet)* Pflanzenschutz *(Plant Protection)*

9.2.3 Contributions to radio and TV broadcasts

Date	Name(s)	Title	Channel/Program
March 12, 2019	Lutz, A.	Wunderdolde *(Miraculous Cone)*	3SAT
August 29, 2019	Weihrauch, F.	Hopfen in Bioqualität - geht das? *(Organic quality hops – is that possible?)*	Regionalnachrichten aus Oberbayern/BR (*Regional News from Upper Bavaria/ Bavarian Radio)*

9.2.4 Internet Contributions

Author(s)	Title	Target Group
Seigner, E.	Entwicklung von leistungsstarken, gesunden Hopfen mit hohen Alphasäuregehalten und besonderer Eignung für den Anbau im Elbe-Saale-Gebiet *(Development of high-performance, healthy hops with high alpha-acid contents and particular suitability for cultivation in the Elbe-Saale region)*	

9.3 Conferences, Talks and Lectures, Guided Tours, Exhibitions/ Shows

9.3.1 Seminars, Symposia, Trade Conferences, Workshops

Date	Speakers(s)	Event	Venue	Target Group
January 29, 2019	Münsterer, J	Seminar "Optimal Conditioning of Hops"	Hüll	Hop growers
January 24, 2019	Münsterer, J	Seminar "Optimizing hop drying”	Hüll	Hop growers
January 25, 2019	Münsterer, J	Workshop "Hop drying - Kiln"	Hüll	Hop growers
February 22, 2019	Münsterer, J	Workshop "Belt Dryer"	Hüll	Hop growers
August 28, 2019	Münsterer, J	Workshop “Drying”	Hüll	Hop growers
November 11, 2019	Seigner; E.; Lutz, A.	Hop Advisory Board	Hüll	Hop and brewing industries
February 21, 2019	Stampfl, J.; Fuß, S.	Basic seminar "Irrigation"	Hüll	Hop growers
February 27, 2019	Stampfl, J.; Fuß, S.	Workshop “Irrigation and Fertigation”	Hüll	Hop growers
March 26, 2019	Weihrauch, F.	Meeting of the Commodity Expert Group (CEG) Minor Uses in Hops	Brussels, Belgium	Plant protection experts from the EU and USA
October 31, 2019	Weihrauch, F.	Meeting of the Commodity Expert Group (CEG) Minor Uses in Hops	Dublin, Ireland	Plant protection experts from the EU and USA

Date	Speakers(s)	Event	Venue	Target Group
November 25, 2019	Weihrauch, F.	Round table on current problems of crop protection in organic hop growing	Hüll	Organic hop growers, farms interested in converting, specialist advisors to organic farming associations
July 7, 2019 to July 11, 2019	Weihrauch, F.	Meeting of the Scientific-Technical Commission (STC) of the International Hop Growers' Convention (IHGC)	Bishoffs-heim, Alsace, France	International hop and brewing scientists

9.3.2 Attendance at seminars, symposia, conferences, workshops IPZ 2019

Date	Event	Place	Target Group
March 21, 201	Beer tasting to assess the bitter quality of high-alpha varieties	Freising	Brewing and hop industry
July 7, 2019 to July 11, 2019	Meeting of the Scientific and Technical Commission (WTK) of the Internationalen Hopfenbaubüros *International Hop Agency (*IHB)	Bischoffsheim, Alsace, France	International hop researchers

9.3.3 Internal events

Date	Event	Place	Target group
January 22, 2019	Information event regarding groundwater-related issues in hop cultivation	Wolnzach	Hop organizations water management project partners
February 15, 2019	Final meeting of the DIPS hop pilot project	Hebrontshausen	Demonstration farms, integrated crop protection, hops
September 17, 2019	Meeting: "Green Book of Hops"	Hüll	Staff of state hops institutes
September 17, 2019	Hop assaying	Moosburg	Members of the assessment committee
October 24, 2019	Roundtable: Hop Fertilizer Ordinance	Wolnzach	Hop organizations and consultants, StMELF, FZ agroecology

9.3.4 Education, training and continuing education

Date	Event	Place	Target group
August 6, 2019	Hop field trip	Hüll and Hallertau	Hop growers
August 7, 2019	Hop field trip	Hüll and Hallertau	Hop growers
August 8, 2019	Hop field trip	Hüll and Hallertau	Hop growers

9.3.5 Expert opinions and assessments

Date	Expert	Title	Client
August 1, 2019	Euringer, S.	Approval of Art. 53 Actara 2019	Association of German Hop Growers
August 1, 2019	Euringer, S.	Approval of Art. 53 Movento SC 100 2019	Association of German Hop Growers
Februay 27, 2019	Euringer, S.	Current report on the situation of crop protection in hop growing in Germany	BMEL *Federal Ministry of Food and Agriculture*
April 23, 2019	Euringer, S.	Continued application of the “hop cleaning” method (*Hopfenputzen*) with sheep as part of the list of “minor uses” in Germany	LfL
July 31, 2019	Euringer, S.	Answer to fellow citizens concerned with crop protection in hop growing	StMELF
August 2, 2019	Euringer, S.	Use of crop protection products in hops	StMELF
April 11, 2019	Portner, J.	EU hop harvest report 2018	BMEL and StMELF
June 28, 2019	Portner, J.	Hop farms work on Sunday	LRA Eichstätt
May 9 2019	Weihrauch, F.	Peer review	Journal *BrewingScience*
October 24, 2019	Weihrauch, F.	Peer review	Journal *BrewingScience*

9.3.6 Specialist Information

Lutz, A.; Seigner, E., Kneidl, J.; Ismann, D.; Kammhuber, K.: 'Züchtung von robusten Hochalpha-Hopfensorten für das Elbe-Saale Gebiet', Hüll, 11.05.2019, Exkursion des Vorstandes des Thüringer Braugerstenvereins (Poster)

Portner, J.: 'Aktuelle Hopfenbauhinweise und Warndienstmeldungen', Wolnzach

Portner, J.: 'Fortbildungsveranstaltungen der LfL; KuLaP-Antragstellung 2020; Aktualisierung der Antragsflächen', 25.11.2019

Seigner, E., Lutz, A.: 'Entwicklung von leistungsstarken, gesunden Hopfen mit hohen Alphasäuregehalten und besonderer Eignung für den Anbau im Elbe-Saale-Gebiet' (Internet-Beitrag)

Seigner, E., Lutz, A.: Genombasierte Präzisionszüchtung für zukunftweisende Qualitätshopfen', Freising, 26.04.2019 (Projekt-Zwischenbericht)

Seigner, E.; Forster, B., Lutz A.; Eckl, Th.: 'Detached leaf assay to evaluate downy mildew tolerance of hops', Bischoffsheim, 10.07.2019, Tagung der Wissenschaftlich-Technischen Kommission, Wissenschaftlich-Technischen Kommission des Internationalen Hopfenbaubüros (Poster)

Seigner, E.; Lutz, A., Kammhuber, K.: 'The new Hüll Noble Aroma Cultivars - Breeding Line 96/01/24 - Breeding Line 89/02/25', Denver, 10.04.2019, Craft Brewer Conference, US Brewers Association (Poster)

Seigner, E.; Lutz, A.: 'Entwicklung von leistungsstarken, gesunden Hopfen mit hohen Alphasäuregehalten und besonderer Eignung für den Anbau im Elbe-Saale-Gebiet - 3. Sachbericht', 24.06.2019 (Projekt-Zwischenbericht)

Seigner, E.; Lutz, A.: 'Hopfenbau mit den neuen Hüller Zuchtsorten - fit für die Zukunft', Hüll, 08.08.2019, Besuch der Elbe-Saale Hopfenpflanzer (Poster)

Seigner, E.; Lutz, A.: 'Züchtung von robusten Hochalphasorten für das Elbe-Saale Gebiet', Hüll, 08.08.2019, Besuch der Elbe-Saale Hopfenpflanzer, LfL (Poster)

Seigner, E.; Seigner, L., Haugg, B.; Hager, P.; Enders, R.; Kneidl, J.; Lutz A.; Einberger, K.; Absmeier, C.; Keckel, L.; Liebrecht, M.: 'Realtime PCR based diagnostics and meristem culture - essential tools for healthy hops', Bischoffsheim, 10.07.2019, Tagung der Wissenschaftlich-Technischen Kommission, Wissenschaftlich-Technischen Kommission des Internationalen Hopfenbaubüros (Poster)

Sugimura, T.; Kammhuber, K.; Lutz, A.; Seigner, E.; Gastl, M.; Becker, T.: 'Analysis of hop aroma components after fermentation based on close genetic background', Antwerpen, 03.06.2019, 37. EBC Congress, European Brewery Convention (EBC) (Poster)

9.3.7 Lectures (No. = number of participants)

Speaker(s)	Subject/Title	Event	Venue/Date	No.
Baumgartner, A.; Obermaier, M., Euringer, S.	Pflanzenschutz im Hopfenbau 2019	Hopfenbau-versammlung	Osselts-hausen February 14, 2019	95
Baumgartner, A.; Obermaier, M.; Euringer, S.	Pflanzenschutz im Hopfenbau 2019	Hopfenbau-versammlung	Lindach, February 13, 2019	85
Baumgartner, A.; Obermaier, M.; Euringer, S.	Pflanzenschutz im Hopfenbau 2019	Hopfenbau versammlung	Tettenwang February 8, 2019	35
Doleschel, P.; Euringer, S.; Weihrauch, F.	Pflanzenschutz im Hopfenbau heute und morgen - Quo vadis?	Niederlauterbacher Hopfentag	Oberpindhart August 22, 2019	165
Euringer, S.	Die *Verticillium*-Welke des Hopfen - Anbauhinweise	JHV Förderkreis Jura e.V.	Marching January 15, 2019	45
Euringer, S.	Pflanzenschutz im Hopfenbau 2019	BayWa - Tischgespräch	Bruckbach January 31, 2019	15
Euringer, S.	Pflanzenschutz im Hopfenbau 2019	Tischgespräch	Hebrontshausen February 1, 2019	25
Euringer, S.	Pflanzenschutz im Hopfenbau 2019	LfL – Hopfen-bauversammlung	U‘pindhart February 7, 2019	85
Euringer, S.	Pflanzenschutz im Hopfenbau 2019	LfL – Hopfen-bauversammlung	Spalt February 11, 2019	40
Euringer, S.	Pflanzenschutz im Hopfenbau 2019	LfL – Hopfen-bauversammlung	Hedersdorf February 11, 2019	20
Euringer, S.	Pflanzenschutz im Hopfenbau 2019	LfL – Hopfen-bauversammlung	Mainburg February 12, 2019	160
Euringer, S.	Fachgespräch Bonn - Pflanzenschutz im Hopfenbau	Fachgespräch Pflanzenschutz im Hopfenbau	Bonn February 14, 2019	20

Speaker(s)	Subject/Title	Event	Venue/Date	No.
Euringer, S.	Pflanzenschutz im Hopfenbau: Überblick und aktuelle Projekte	GfH Connecting Day	Hüll February 28, 2019	15
Euringer, S.	Pflanzenschutz im Hopfenbau: Überblick und aktuelle Projekte	GfH Connecting Day	Hüll May 22, 2019	22
Euringer, S.	Introducing the Working Group 'Plant protection in hop cultivation'	GfH Connecting Day	Hüll July 15, 2019	20
Euringer, S.	Aktueller Stand der *Verticillium*-Forschung	Rundfahrt Förderkreis Jura e.V.	Hüll July 17, 2019	40
Euringer, S.	Erster Nachweis von CBCVd im deutschen Hopfenbau	Erster Nachweis von CBCVd im deutschen Hopfenbau - Besprechung	Hüll July 26, 2019	18
Euringer, S.	Virosen und Viroide im Hopfenbau	VlF-Rundfahrt	Hüll August 6, 2019	50
Euringer, S.	CBCVd - Consultant training	Consultant training: CBCVd	Hüll August 6, 2019	10
Euringer, S.	Viroses and viroids in hop growing	VlF-Tour	Hüll August 7, 2019	40
Euringer, S.	Viroses and viroids in hop growing	RjH-Tour	Hüll August 8, 2019	50
Euringer, S.	CBCVd - Multiplier training	Consultant training: CBCVd	Hüll August 9, 2019	15
Euringer, S.	CBCVd - Multiplier training	Consultant training: CBCVd	Hüll August 13, 2019	15
Euringer, S.	CBCVd - Multiplier training	Consultant training: CBCVd	Hüll August 16, 2019	4
Euringer, S.	CBCVd - Multiplier training	Consultant training: CBCVd	Hüll August 19, 2019	8
Euringer, S.	Plant protection in hop growing: today	Niederlauterbacher Hop Day	Oberpindhart August 22, 2019	165
Euringer, S.	Conference on plant protection in German hop production	Plant protection day hops	Pfaffenhofen/ Ilm August 31, 2019	150
Euringer, S.	Dealing with the CBCVd in hop growing	ISO event Hopfenring e.V.	Aiglsbach September 13, 2019	60
Euringer, S.	Expert discussion Bonn - CBCVd	Expert discussion CBCVd	Bonn December 17, 2019	15
Euringer, S. Lutz, K.	Research on Verticillium wilt in hops	Conference of the Scientific and Technical Commission of the International Hop Growers Office	Bischoffsheim July 8, 2019	60
Euringer, S.;	GfH project for	Meeting of the board and technical	Wolnzach	25

Speaker(s)	Subject/Title	Event	Venue/Date	No.
Lutz, K.	Verticillium research	Working Committee of the GfH	March 28, 2019	
Euringer, S.; Obermaier, M.	Plant protection in hop production 2019	LfL hop production conference	Oberhatzkofen February 4, 2019	30
Euringer, S.; Obermaier, M.	Plant protection in hop production 2019	LfL hop production conference	Biburg February 6, 2019	45
Euringer, S.; Lutz, K.	Presentation of the results of Verticillium research	Supervisory board meeting of the HVG grower group	Wolnzach December 11, 2019	20
Kammhuber, K.	Presentation of the hop analysis in Hüll		Hüll February 28, 2019	15
Kammhuber, K.	Alternative uses of hops	Spring service meeting IPZ AELF	Freising March 27, 2019	23
Kammhuber, K.	The tasks of IPZ 5d for quality assurance in alpha-acid analysis	Technical-scientific committee of the Society for Hop Research TWA	Wolnzach March 28, 2019	25
Kammhuber, K.	Presentation of the hop analysis in Hüll	GfH Connecting Days	Hüll May 22, 2019	15
Kammhuber, K.	Presentation of the hop analysis	Visit of the Thuringian Minister of Agriculture	Hüll August 12, 2019	26
Kammhuber, K.	Presentation of projects and application for procurement centrifuge	Annual meeting of the Society for Hop Research	Hüll November 21, 2019	9
Kammhuber, K.	Phenotyping of the reference hop range - chemical analyzes	Project meeting of genome-based precision breeding	Wolnzach December 3, 2019	9
Laupheimer, S.; Euringer, S.	Hop cleaning - alternatives to conventional measures	VlF-Tour	Wolnzach August 6, 2019	50
Laupheimer, S.; Euringer, S.	Hop cleaning - alternatives to conventional measures	VlF-Tour	Wolnzach August 8, 2019	40
Lutz, A.	Hop aroma in beer	Session of the Association of Chambers of Agriculture	Hüll May 22, 2019	30
Lutz, A.	Aroma evaluation of current harvest samples from selected Hüll breeding lines	Meeting of the Hop Advisory Board	Hüll November 11, 2019	20
Lutz, A.	Hop evaluation of biogenesis experiments after harvest times	IGN round table	Hüll November 29, 2019	40
Lutz, A. Kneidl, J.; Seigner, E	Trials on the clones of the Hersbrucker variety		Munich February 21, 2019	10
Lutz, A. Seigner, E.	New aroma breeding lines from the Tettnang crossbreeding program	Service meeting Hops of the MLR, Baden-Württemberg	Strass August 14, 2019	15

Speaker(s)	Subject/Title	Event	Venue/Date	No.
Lutz, A.; Seigner, E.	Diamond - the new high-quality aroma variety of the top class	Hop tour 2019	Hüll August 29, 2019	150
Lutz, A.; Seigner, E.	New promising Hüll high-alpha and aroma strains	Board meeting of the GfH	Hüll November 21, 2019	9
Lutz, A.; Euringer, S.	High-alpha breeding lines for brewing trials and large-scale trial cultivation	Project meeting Genome-based precision breeding for quality hops	Wolnzach December 3, 2019	9
Lutz, A.; Kneidl, J.; Seigner, E.	Cultivation and yield situation of the Hersbrucker land variety	Discussion with interest groups	Hüll June 26, 2019	5
Lutz, A.; Seigner, E.	Hop breeding research	GfH Connecting Days	Hüll February 28, 2019	15
Lutz, A.; Seigner, E.	Breeding of robust high-alpha varieties for the Elbe-Saale area	Visit of the Thuringian Minister of Agriculture	Hüll August 12, 2019	26
Lutz, A.; Seigner, E., Kneidl, J.	Federal awards for hops - an important marketing tool	BrauBeviale Forum	Nuremberg November 14, 2019	50
Lutz, K.	GfH research project on Verticillium wilt - current status and outlook for 2019	JHV Förderkreis Jura e.V.	Marching January 15, 2019	45
Lutz, K.	Effect of lethal hop withering strains (Verticillium nonalfalfae) and different nitrogen fertilizer levels a. d. Pointer plant aubergine (Solanum melongena L.)		Freising June 13, 2019	20
Lutz, K.; Euringer, S.	GfH project for Verticillium research	Meeting of the board and technical GfH Working Committee	Hüll November 21, 2019	20
Lutz, K.; Euringer, S.	GfH project for Verticillium research	ISO event Hopfenring e.V.	Aiglsbach December 12, 2019	60
Lutz, K.; Euringer, S., Laupheimer, S.	Hop cleaning - alternatives to conventional measures	RjH tour	Wolnzach August 8, 2019	50
Muensterer, J.	Belt drying optimization	Informational event	Marching August 17, 2019	60
Muensterer, J.	Procedure and assistance in optimizing hop drying	Informational event	Mitterstetten August 20, 2019	65
Obermaier, M.	Establishment of predatory mites via undersowing	Bioland hop growing day	Kloster Plankstetten February 5, 2019	55
Obermaier, M.	Establishment of predatory mites in hop growing practice via undersowing	Entomologist conference 2019	Martin-Luther-Universität, Halle March 12, 2019	60
Obermaier, M.	Establishment of predatory	Round table 2019 on	Hüll	27

Speaker(s)	Subject/Title	Event	Venue/Date	No.
	mites in hop growing practice via undersowing	current crop protection topics in organic hops	November 25, 2019	
Obermaier, M.; Weihrauch, F.	Establishment of predatory mites on undersowned crops in hop cultivation	Meeting of the Scientific-Technical Commission, I.H.G.C.	Bischoffsheim, Alsace, France July 9, 2019	55
Obermaier, M.; Weihrauch, F.	Establishment of predatory mites in hop-growing practice via undersowing	37th meeting of the AK, 'useful arthropods and entomopathogenic nematodes'	Karlsruhe, LTZ Augustenberg November 27, 2019	47
Obermaier, M; Laupheimer, S.	Rating aids and useful items in hop growing	Jura Association tour	Hüll July 17, 2019	40
Portner, J.	Technical critique hops	Opening of the barley and hops exhibition	Moosburg September 13, 2019	100
Portner, J.	Alpha-acid values and alpha analysis 2018	AK meeting	Wolnzach January 29, 2019	15
Portner, J.	Results and evaluations of the pilot project "Demonstration farms integrated crop protection"	BayWa table discussion	Bruckbach January 31, 2019	25
Portner, J.	Results and evaluations of the pilot project "Demonstration farms integrated crop protection"	LfL hop production meeting	Oberhatzkofen February 4, 2019	30
Portner, J.	Results and evaluations of the pilot project "Demonstration farms integrated crop protection"	LfL hop production meeting	Biburg February 6, 2019	45
Portner, J.	Results and evaluations of the pilot project "Demonstration farms integrated crop protection"	LfL hop production meeting	Unterpindhart February 7, 2019	85
Portner, J.	Results and evaluations of the pilot project "Demonstration farms integrated crop protection"	LfL hop production meeting	Tettenwang February 8, 2019	35
Portner, J.	First experiences with the implementation of the new fertilizer regulation as well as add‘l requirements in the "red areas" from 2019	LfL hop production meeting	Spalt February 11, 2019	40
Portner, J.	First experiences with the implementation of the new fertilizer regulation as well as add‘l requirements in the "red areas" from 2019	LfL hop production meeting	Hedersdorf February 11, 2019	20
Portner, J.	Results and evaluations of the pilot project	LfL hop production meeting	Spalt February 11, 2019	40

Speaker(s)	Subject/Title	Event	Venue/Date	No.
	"Demonstration farms integrated crop protection"			
Portner, J.	Results and evaluations of the pilot project "Demonstration farms integrated crop protection"	LfL hop production meeting	Hedersdorf February 11, 2019	20
Portner, J.	Results and evaluations of the pilot project "Demonstration farms integrated crop protection"	LfL hop production meeting	Mainburg February 12, 2019	160
Portner, J.	Results and evaluations of the pilot project “Demonstration farms of integrated plants protection "	LfL hop production meeting	Lindach February 13, 2019	80
Portner, J.	Results and evaluations of the pilot project "Demonstration farms integrated crop protection"	LfL hop production meeting	Osseltshausen February 14, 2019	105
Portner, J.	Evaluation of N fertilization	AK meeting	Wolnzach February 21, 2019	12
Portner, J.	Arguments for hop irrigation	Information event for community irrigation	Aiglsbach April 4, 2019	35
Portner, J.	Presentation of running hop products for nutrient efficiency	Meet AS nutrient balance	Freising April 11, 2019	12
Portner, J.	We research hops	Connecting Day	Hüll May 22, 2019	30
Portner, J.	Plant protection news	Information event Spalter hop growers	Spalt May 29, 2019	35
Portner, J.	PSM application and user protection in hop cultivation	Expert discussion on user protection in hop growing	Braunschweig June 17, 2019	10
Portner, J.	Erosion protection measures in hops	AK soil fertility	Wolnzach June 27, 2019	15
Portner, J.	Erosion protection measures in hops	Information event in the context of "ground-constant"	Niederumelsdorf July 3, 2019	20
Portner, J.	Plant protection news	LfL trial tour	Niederlauterbach August 6, 2019	50
Portner, J.	Plant protection news	LfL trial tour	Hüll August 7, 2019	50
Portner, J.	Plant protection news	LfL trial tour	Niederlauterbach August 8, 2019	40
Portner, J.	Tasks and research projects of the Hop Production Technology Group	Information event for new employees	Wolnzach November 7, 2019	15

Speaker(s)	Subject/Title	Event	Venue/Date	No.
Portner, J.	Guidelines for integrated crop protection and sustainability in hop growing	Global Hop Summit	Brussels November 18, 2019	100
Portner, J.	All about alpha-acid testing	IGN round table	Gebrontshausen November 29, 2019	25
Schlagenhaufer, A.	Current research projects on the nitrogen balance in hops	Information event for water management - projects to optimize nitrogen fertilization in hops	Wolnzach, January 22, 2019	30
Schlagenhaufer, A.	Insight into research projects on nitrogen fertilization	AK Meeting	Wolnzach February 21, 2019	12
Schlagenhaufer, A.	Nitrogen fertilization in hops	RjH Tour	Versuchsfläche Starzhausen August 6, 2019	50
Schlagenhaufer, A.	Nitrogen fertilization in hops	VlF Tour	Versuchsfläche Starzhausen August 6, 2019	40
Schlagenhaufer, A.	Nitrogen fertilization in hops	Vlf Tour	Versuchsfläche Starzhausen August 6, 2019	50
Schlagenhaufer, A.; Stampfl, J.	Presentation of current projects in the area of N fertilization and irrigation	Open House (HdH)	Wolnzach July 21, 2019	
Seigner, E.; Lutz, A.	Citrus viroid in hops	Ministry of Landl. Room (MLR), Baden-Württemberg	Strass August 14, 2019	15
Seigner, E.; Lutz, A.	Crossbreeding with the regional variety Tettnanger	Service meeting of the Ministry of Rural Areas, BW	Tettnang February 28, 2019	15
Seigner, E.; Lutz, A.	Genome-based precision breeding for quality hops	Beer tasting to evaluate the request quality of high-alpha varieties	Freising March 21, 2019	52
Seigner, E.; Lutz, A.	The new Hüll aroma varieties demonstrate climate and stress tolerance as well as variety of brewing	Meeting of the board and the technical GfH Working Committee	Wolnzach March 28, 2019	25
Seigner, E.; Lutz, A.	Fit for the future - the new Hüll cultivars demonstrate climate tolerance	Hop tour 2019	Hüll August 29, 2019	150
Seigner, E.; Lutz, A.	Assessment of the bitter quality of high-alpha varieties for GHop brewing tests	Meeting of the Hop Advisory Board	Hüll November 11, 2019	20
Seigner, E.;	Breeding research hops: overview and current	GfH Connecting	Hüll	22

Speaker(s)	Subject/Title	Event	Venue/Date	No.
Lutz, A.	research focus	Days	May 22, 2019	
Seigner, E.; Lutz, A.	The new Hüll aroma cultivars - resilience to climatic stress and versatility in brewing	Conference of the Scientific and Technical Commission of the International Hop Growing Office	Bischoffsheim July 8, 2019	60
Seigner, E.; Lutz, A.	Hop breeding at the Hop Research Center Hüll with focus on new cultivars	Connecting Day of the Society for Hop Research	Hüll July 15, 2019	20
Seigner, E.; Lutz, A.	The new Hüll aroma and high-alpha varieties - fit for the future	Visit of the Thuringian Minister of Agriculture	Hüll August 12, 2019	26
Seigner, E.; Lutz, A.	Powdery mildew resistance breeding in hops has top priority	Annual meeting of the Society for Hop Research and the LfL	Hüll November 21, 2019	15
Seigner, E.; Lutz, A.	Continuation of the phenotyping of the reference hop range	Project meeting Genome-based precision breeding for quality hops	Wolnzach December 3, 2019	9
Stampfl, J.	Possibilities of using irrigation and fertigation in hop production	Information event for water management - projects to optimize nitrogen fertilization	Wolnzach January 22, 2019	30
Stampfl, J.	The latest findings on irrigation and production in hops	BayWa table discussion	Bruckbach (Rohrbach) January 31, 2019	25
Stampfl, J.	The latest findings on irrigation and production in hops	LfL Hop Growing Assembly	Oberhatzkofen February 4, 2019	30
Stampfl, J.	The latest findings on irrigation and production in hops	LfL Hop Growing Assembly	Biburg February 6, 2019	45
Stampfl, J.	The latest findings on irrigation and production in hops	LfL Hop Growing Assembly	Unterpindhart February 7, 2019	85
Stampfl, J.	The latest findings on irrigation and production in hops	LfL Hop Growing Assembly	Tettenwang February 8, 2019	35
Stampfl, J.	The latest findings on irrigation and production in hops	LfL Hop Growing Assembly	Spalt February 11, 2019	40
Stampfl, J.	The latest findings on irrigation and production in hops	LfL Hop Growing Assembly	Hedersdorf February 11, 2019	20
Stampfl, J.	The latest findings on irrigation and production in hops	LfL Hop Growing Assembly	Mainburg February 12, 2019	160
Stampfl, J.	The latest findings on	LfL Hop Growing	Lindach	85

Speaker(s)	Subject/Title	Event	Venue/Date	No.
	irrigation and production in hops	Assembly	February 13, 2019	
Stampfl, J.	The latest findings on irrigation and production in hops	LfL Hop Growing Assembly	Osseltshausen February 14, 2019	95
Stampfl, J.	The latest findings on irrigation and production in hops	Spring consultation, Elbe-Saale	Querfurt March 13, 2019	40
Stampfl, J.	Influence of irrigation and fertigation on the yield and quality of hops	GfH Technical Scientific Working Committee meeting	Wolnzach March 28, 2019	30
Stampfl, J.	Optimization of groundwater protection through hop irrigation	Hop tour	Hüll August 29, 2019	140
Stampfl, J.	Approaches to climate change - irrigation and fertigation of hops	Global Hop Summit	Brüssel November 18, 2019	120
Stampfl, J.	Current findings from the Fertigation research project	AR meeting of the HVG	Wolnzach, December 12, 2019	25
Stampfl, J.; Fuß, S.	Use irrigation and fertigation in hop production	Information event for hop growers	Wolnzach February 8, 2019	25
Stampfl, J.; Fuß, S.	Possibilities of using irrigation in hop growing	Irrigation seminar	Hüll February 21, 2019	25
Stampfl, J.; Fuß, S.	Use of fertigation for targeted N fertilization in hop growing	Workshop Fertigation	Hüll February 27, 2019	25
Stampfl, J.; Schlagenhaufer, A.	Presentation of current projects in the area of N fertilization and irrigation	Open house (House of Hops)	Wolnzach July 21, 2019	
Weihrauch, F.	Issues and approaches of plant protection in organic hop cultivation	Colloquium Phytomedicin, winter semester 2018/2019	Göttingen January 23, 2019	40
Weihrauch, F.	News from hop research: 2018 results and outlook for 2019 projects	Bioland hop growing day	Kloster Plankstetten February 5, 2019	55
Weihrauch, F.	Current research projects on crop protection in hop growing	Expert discussion on plant protection in hop cultivation at the BMEL	Bonn February 14, 2019	20
Weihrauch, F.	Ecological questions of hop growing: overview and current projects	GfH Connecting Days	Hüll February 28, 2019	15
Weihrauch, F.	The brandy Hydraecia micacea (Lepidoptera: Noctuidae) as a hop pest: history and a recent outbreak in the Hallertau	Entomologist conference 2019	Halle (Saale) March 12, 2019	60

Speaker(s)	Subject/Title	Event	Venue/Date	No.
Weihrauch, F.	Biodiversity in hop cultivation - state and thought games after the popular request	Meeting of the board and the technical and scientific working committee of the GfH	Wolnzach March 28, 2019	30
Weihrauch, F.	Ecological questions of hop growing: overview and current projects	GfH Connecting Days	Hüll May 22, 2019	22
Weihrauch, F.	Introduction to the Working Group 'Ecological issues of hop cultivation'	GfH Connecting Days	Hüll July 15, 2019	20
Weihrauch, F.	Report on the 2019 Meeting of the Scientific-Technical Commission	57th Congress of the International Hops Bureau (IHB)	Ljubljana, Slovenia August 1, 2019	160
Weihrauch, F.	Plant protection in organic farming using the example of hops: problems and opportunities	Lecture series by the Kreis-IN group of the Bund Naturschutz	Ingolstadt September 26, 2019	7
Weihrauch, F.	Presentation of the IHB's current 2019 varieties list	Executive Committee meeting d. International hop growing offices (IHB)	Nuremberg November 11, 2019	45
Weihrauch, F.	Results of the German organic movement's monitoring programme of copper applications and implications on copper minimization strategy: section hops	4th European Conference on Copper	Berlin November 14, 2019	85
Weihrauch, F.; Baumgartner, A.; Laupheimer, S.; Mühlbauer, M.	Hop-flea beetle revisited: In search for attractants	Meeting of the Scientific-Technical Commission, I.H.G.C.	Bischoffsheim, Alsace, France July, 9, 2019	55
Weihrauch, F.; Obermaier, M.	Copper reduction strategy in hops: newsworthy results of 2019 trials	4th European Conference on Copper	Berlin November 15, 2019	80

9.3.8 Internships

Theme	Supervisor	Intern(s)	Start	Finish
Research concerning hops	Lutz, Anton	Student	March 4, 2019	March 8, 2019
Analytics concerning hops	Kammhuber, K.	FOS	September 17, 2019	February 15, 2019
Research concerning hops	Lutz, A.	Student	July 8, 2019	July 12, 2019
Research concerning hops	Lutz, A.	Student	July 8, 2019	July 12, 2019
Research concerning hops	Lutz, A.	FOS Scheyern	March 11, 2019	July 26, 2019
Molecular *Verticillium* detection, peronospora tolerance test	Seigner, E. (Hager, P.; Enders, R.; Forster, B.)	ATA Apprentice	June 24, 2019	July 10, 2019
Research concerning hops	Lutz, A.	Student	July 8, 2019	July 12, 2019
Research concerning hops	Lutz, A.	Student	July 15, 2019	July 19, 2019
Research concerning hops	Lutz, A.	FOS Scheyern	February 28, 2019	July 5, 2019

9.3.9 Guided tours (No. = number of participants)

Date	Name	Subject/Title	Guest(s)	No.
July 21, 2019	IPZ 5a	Open House (House of Hops)	Hop grower families and guests	500
March 21, 2019	Lutz, A.	Hop breeding, hop cultivation strains aroma ratings	AB InBev	3
May 22, 2019	Lutz, A.	LfL hop research, hop breeding, hop production, hop analysis	Weihenstephan-Triesdorf University of Applied Sciences, Brewing Faculty	30
May 29, 2015	Lutz, A.	LfL hop research, hop breeding, hop aroma, hop production	Pfaffenhofen Vocational School	65
July 2, 2019	Lutz, A.	LfL hop research, hop breeding	Landesverband Bayer. Red Cross	50
July 24, 2019	Lutz, A.	LfL hop research, hop breeding, hop aroma	Heineken, Barth-Haas Group	6
August 21, 2019	Lutz, A.	Information about the upcoming hop harvest	ISO hop growers	80
August 23, 2019	Lutz, A.	Detection of hop varieties	Hop ambassadors	10
September 22,	Lutz, A.	LfL hop research, hop	President's guests	43

Date	Name	Subject/Title	Guest(s)	No.
2019		breeding and hop aroma, beer tasting		
September 24, 2019	Lutz, A.	LfL hop research, hop breeding, variety characteristics, ratings	Agrolab	2
October 2, 2019	Lutz, A.	Hop breeding, hop varieties	US, hop dealer	1
October 17, 2019	Lutz, A.	LfL hop research, hop breeding and varieties	Hop bloggers	15
October 18, 2019	Lutz, A.	LfL hop research, hop breeding and varieties	AB InBev	2
November 5, 2019	Lutz, A.	LfL hop research, hop breeding and varieties	Heimatmuseum Hersbruck	25
November 8, 2019	Lutz, A.	LfL hop research, hop breeding and varieties	HVG employees	2
January 25, 2019	Lutz, A.; Kneidl, J.	Harvest pattern 2018 for the biogenesis of the most important hop varieties grown in the Hallertau	Hop traders, hop growers	30
January 28, 2019	Lutz, A.; Kneidl, J.	2018 harvest pattern for the biogenesis of the most important hop varieties grown in Hallertau	Hop traders, hop growers	20
July 17, 2019	Lutz, A.; Münsterer, J.	Hop breeding, hop varieties, hop drying	Brauerei Veltins, hop grower	4
May 11, 2019	Lutz, A.; Seigner, E.	LfL hop research, hop breeding, Elbe-Saale breeding project, hop analysis, hop production,	Thuringian Brewing Barley Association, Board of Directors	10
June 5, 2019	Lutz, A.; Seigner, E.	Hop research, variety development	Brewing Journalist	1
June 26, 2019	Lutz, A.; Seigner, E.		Augustiner Brauerei	3
August 12, 2019	Lutz, A.; Seigner, E. Kammhuber, K.	Hop breeding and hop analysis	Thuringian Minister of Agriculture, TMIL, Thuringian State Office for Agriculture, hops economy	25
July 26, 2019	Muensterer, J.	Plant protection updates	Agricultural school students	12
August 2, 2019	Muensterer, J.	News on hop research	Winegrowers	50
May 22, 2019	Seigner, E.	LfL hop research, hop breeding, hop production, hop analysis	Association of Agricultural Chambers	30
June 26, 2019	Seigner, E.	LfL hop research, hop breeding, hop growing, crop protection, hop analysis	Brewery course, TUM, Freising-Weihenstephan Science Center	7

Date	Name	Subject/Title	Guest(s)	No.
July 15, 2019	Seigner, E.	Hop breeding, development and selection of new varieties	Barth-Haas Group	15
July 16, 2019	Seigner, E.	LfL hop research, hop breeding, hop cultivation, hop analysis	Students of TUM, LS beverage and brewing technology	16
August 8, 2019	Seigner, E.	LfL hop research, Elbe-Saale breeding project, climate tolerance d. Hüll varieties	Elbe-Saale hop growers	45
August 15, 2019	Seigner, E.	LfL hop research, hop breeding, hop analysis	AB InBev, interns	22
August 28, 2019	Seigner, E.	LfL hop research, hop breeding, new varieties, aroma analysis	Boston Beer Company	6
September 17, 2019	Seigner, E.	Hop research of the LfL, hop breeding, new hop cultivars	Hop growers	55
September 18, 2019	Seigner, E.	LfL hop research, hop breeding	Beer journalist	1
November 11, 2019	Seigner, E.	LfL hop research, hop breeding, hop analysis	EFES Brauerei and US Brewers Association	4
March 15, 2019	Seigner, E. Kammhuber, K.	Hop research LfL, hop breeding, hop analysis	ABInBev	4
August 30, 2019	Seigner, E. Kammhuber, K.	Hop research LfL, hop breeding, aroma analysis	Craft brewer, Barth Haas Group	30
September 12, 2019	Seigner, E. Kammhuber, K.	Hop research LfL, hop breeding, hop analysis	Molson Coors, raw materials purchasers	3
March 22, 2019	Seigner, E.; Euringer, S.	LfL hop research, hop breeding, hop cultivation and crop protection	US Agrarstudenten, Fachrichtung Smart Farming	20
May 10, 2019	Seigner, E.; Euringer, S.	Hop research of the LfL, hop breeding, chemical analysis, hop production, hop protection	ABInBev, Global Brewmaster Course	60
September 20, 2019	Seigner, E.; Lutz, A.	Hop breeding programs, climate resilience, hop harvest 2019	ABInBev, Management	15
August 13, 2019	Weihrauch, F.	Ecological and integrated hop cultivation, inspection of trials for plant protection in organic hops	Beiselen GmbH	3
August 5, 2019	Weihrauch, F. Seigner, E.	LfL hop research, hop breeding, questions about organic hop growing	ALLIANCE 90 / The Greens, Member of State Parliament	2
July 25, 2019	Weihrauch, F.; Obermaier, M.	Organic hop growing	Prof. Dr. Ignacio Guerra, Univ. León	2

9.3.10 Exhibitions/shows and posters

Author(s)	Title	Event/Venue	Organizer
Lutz, A.; Seigner, E.	Breeding robust high-alpha hop varieties for the Elbe-Saale area	Excursion of the board of the Thuringian brewing association, Hüll	
Seigner, E.; Forster, B.	Detached leaf assay to evaluate downy mildew tolerance of hops	Conference of the Scientific and Technical Commission, Bischoffsheim	Scientific and technical commission of the international hop growing office
Seigner, E.; Lutz, A.	Hopfenbau mit den neuen Hüll Zuchtsorten fit für die Zukunft	Visit of Elbe-Saale hop growers in Hüll	
Seigner, E.; Lutz, A.	Züchtung von robusten Hochalphasorten für das Elbe-Saale Gebiet	Visit of Elbe-Saale hop growers in Hüll	LfL
Seigner, E.; Lutz, A.	The new Hüll Noble Aroma Cultivars	Craft Brewers Conference, Denver	Brewers Association (USA)
Seigner, E.; Seigner, L.	Realtime PCR based diagnostics and meristem culture - essential tools for healthy hops	Conference of the Scientific and Technical Commission, Bischoffsheim	Scientific and technical commission of the international hop growing office
Sugimura, T.; Kammhuber, K. Lutz, A.; Seigner, E.; Gastl, M.; Becker, T.	Analysis of hop aroma components after fermentation based on close genetic background	37th EBC Congress, Antwerp	European Brewery Convention (EBC)

9.4 Participation in working groups, memberships

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

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

10 Our Team

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

(*State Institute for Agriculture - Institute for Crop Production and Plant breeding – Hüll/Wolnzach/Freising*)
(AG = working group)

IPZ 5

Overall Management: Director at the LfL Dr. Peter Doleschel

Alexandra Hertwig
Birgit Krenauer

IPZ 5a
AG Hopfenbau, Produktionstechnik
(*Hop Cultivation, Production Technology*)
Manging Director (LD): Johann Portner

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

IPZ 5b

AG Pflanzenschutz im Hopfenbau
(*Plant Protection in Hop Cultivation*)
Head: Simon Euringer

Anna Baumgartner	
Maria Felsl	
Korbinian Kaindl	(from August 1, 2019)
Kathrin Lutz	
Georg Meyr	(to May 31, 2019)
Marlene Mühlbauer	
Georg Thalmaier	(April 15, 2019 – September 30, 2019)
Johann Weiher	
Laura Wörner	(to March 10, 2020)

IPZ 5c

AG Züchtungsforschung Hopfen
(*Hop Breeding Research*)
Head: Bureau Director (RD) Dr. Elisabeth Seigner

Brigitte Brummer
LTA Renate Enders
CTA Brigitte Forster
Herbert Graßl (to March 8, 2019)
Hermann Grebmair (to July 31, 2019)
CTA Petra Hager
LTA Brigitte Haugg
Maximilian Heindl (from August 1, 2019)
Elfriede Hock
Agr.-Techn. Daniel Ismann
LTA Jutta Kneidl
LAR Anton Lutz
Margret Maier (to June 30, 2019)
Katja Merkl (from July 1, 2019)
Sonja Ostermeier
Ursula Pflügl
Andreas Roßmeier (from November 1, 2019)

IPZ 5d
AG Hopfenqualität und -analytik
(*Hop Quality and Analytics*)
Head: Bureau Director (RD) Dr. Klaus Kammhuber

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

IPZ 5e
AG Ökologische Fragen des Hopfenbaus
(*Ecological Issues in Hop Cultivation*)
Head: Dipl.-Biol. Dr. Florian Weihrauch

M.Sc. Maria Obermaier