LfL

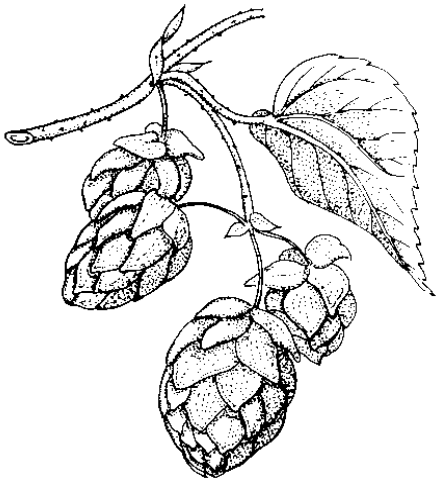
Bayerische Landesanstalt für Landwirtschaft

GfH

Gesellschaft für Hopfenforschung e.V.

Annual Report 2017

Special Crop: Hops



Bavarian State Research Center for Agriculture

- Institute for Crop Science and Plant Breeding -

and

Society of Hop Research e.V.

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Foreword

In 2017, hop got off comparatively lightly. Thanks to the rain that set in in August, an average harvest was brought in, although the alpha acids levels were slightly below average. The implications of this indicate that it is crucial that research into irrigation combined with nutrient input is now stepped up. After the yield losses caused by drought in 2013 and 2015, irrigation has once more gained in significance. Feeding in nutrients helps efforts to provide selectively delivered, needs-based fertilization and ensures that nutrient uptake is more efficient, especially in terms of implementing the fertilizer ordinance. Applying the fertilizer ordinance in hop will be a daunting challenge with regard to production techniques. In answer to this challenge, research looking into the nitrogen dynamics in hop-growing soils and the utilization of bine chaff is being intensified.

In the field of plant protection, operations were hampered by staffing constraints; nevertheless, thanks to the commitment of the Working Group, it was possible to realize an ambitious programme of work. Approval of the available plant protection agents is becoming increasingly difficult across the EU, and this is having a critical effect with respect to herbicide use and hop stripping.

With the appointment of Mr. Euringer in June 2017, the project "Forschung zur Verticilliumwelke" (*Research into Verticillium Wilt Disease*) was initiated. This work is vital to allow the successful breeding of wilt-tolerant hop cultivars. Preparations were also made to begin soil sanitation on hop-growing land affected by *Verticillium*. For decades now, Hop Breeding Research has been developing hops selected for their efficient nitrogen uptake.

Working Group Hop Quality/Hop Analytics carries out the testing required in support of all the other Working Groups. Successful hop breeding would not be possible without analytics. In 2017, the GfH (*Society of Hop Research*) funded the purchase of a new near infrared spectral photometer, with which fast determination of α acids and moisture content can be performed. Funding for new HPLC equipment was also approved and this will be purchased and put into operation early in 2018.

The Conference of the Scientific-Technical Commission (WTK) of the International Hop Growers' Convention (IHB) was held from 25 to 29 June 2017 in the health resort of St. Stefan am Walde in the Mühlviertel, Upper Austria. Participating in the conference, which was successfully organized by Dr. Florian Weihrauch, were 61 scientists from 14 different countries.

Meanwhile, there has been no decline in the pressures and issues that hop growing is faced with, but hop research at the LfL is well-placed to handle the challenges, to the advantage of hop cultivation in Bavaria and in Germany. The following annual report describes in detail the research activities taking place at the Hop Research Center at Hüll. At this point, we would especially like to thank all the staff at Hüll, Wolnzach and Freising for their outstanding commitment, creativity and hard work, without which successful research would not be possible.

Dr. Michael Möller
Chief Executive,
Society of Hop Research

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

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1.1 Current Research Projects

Model Project: *Demonstration Farms – Integrated Plant Protection,* sub-project *Hop Growing in Bavaria* (ID 5108)

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding*)
Funded by:	Bundesministerium für Ernährung und Landwirtschaft (BMEL) über die Bundesanstalt für Landwirtschaft und Ernährung (BLE) (*Federal Ministry of Food and Agriculture (BMLE), managed by the Federal Institute for Food and Agriculture (BLE*)
Project lead:	J. Portner
Project staff:	M. Lutz (until 2016), R. Obster (from 2017)
Collaboration:	Julius Kühn-Institut (JKI) Zentralstelle der Länder für EDV-gestützte Entscheidungshilfen und Programme im Pflanzenschutz (ZEPP) (*Central Institution for Decision Support Systems in Crop Protection and Crop Production* (ZEPP)) 5 Demonstration farms (growing hops) in the Hallertau region

Scheduled to run: 01.03.2014 – 31.12.2018

Objective

As part of the national plan of action to promote the sustainable use of plant protection products, the scope of the ongoing nationwide model project Demonstration Farms – Integrated Plant Protection was expanded to include hop growing, and in 2014 a sub-project entitled Hop Growing in Bavaria was set up in the Hallertau region.

Its objective is to minimize deployment of plant protective chemicals on hop through regular crop inspections and detailed recommendations. At the same time, the fundamentals of integrated plant protection must be adhered to and non-chemical plant protection measures given preference – inasfar as these are available and their use is practicable.

Methodology and action taken

Three demonstration plots, each with an average acreage of around 2 hectares, were managed on each of five traditionally run hop farms in the Hallertau region (locations: Geibenstetten, Buch, Einthal, Dietrichsdorf and Mießling). The cultivars chosen were HA, HE, HM, HS, HT, PE and SR. Each plot underwent a weekly assessment during the growing season to ascertain the precise extent of disease and pest infestation. If necessary, the incidence of infestation or infection in plot subsections was examined separately. The member of staff in charge based her recommendations regarding counter measures on damage thresholds, information from warning services and forecasting models.

If non-chemical treatments were available as a possible alternative to chemical agents, these were the preferred choice. The assessment data gathered, the time requirement, and the protective measures undertaken were recorded on a special app and in online programs and then sent on to the JKI for evaluation.

In order to demonstrate integrated plant protection measures to interested hop growers, an on-farm demo day was organized at the Moser farm in Geibenstetten, where, in four different places, an opportunity was provided to see plant protection technology in action. Among the key aspects covered this year were: how to fill the tank on the application equipment while preventing contamination, the correct method of cleaning the equipment, the new nozzle technology, and user protection.

Fig. 1.1: User protection

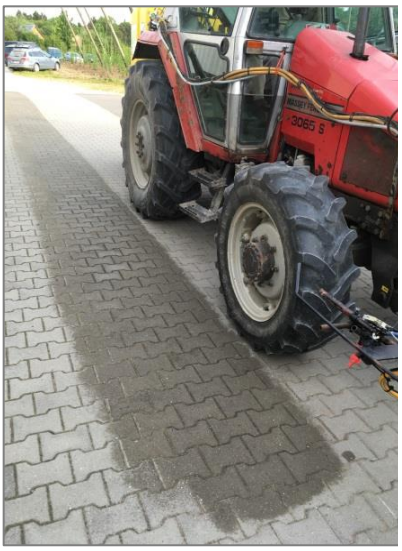

Fig. 1.2: Well-defined edges

(Photos: Dr. Peter Doleschel)

Bavarian Minister of Agriculture Helmut Brunner also took the time, while on his regular rounds of farm visits, to call in at the demo farm of Bartholomäus and Eleonora Obster in Buch near Aiglsbach. There he was able to take a closer look at how sensor-controlled plant protection equipment can be used to treat rows of hops and to appreciate its potential for reducing by over 50 % the amount of plant protection product required, as against conventional plant protection equipment.

Fig. 1.3: Demonstration of a stationary induction hopper (Photo: Johann Portner)

Fig. 1.4: Demonstration on hops of the sensor-controlled plant protection equipment (Photo: StMELF, Nicolas Armer)

Results

The combination of consultation and the implementation of non-chemical plant protection measures was successful across the board. The expedient treatments with chemical protection agents were also satisfactory. The on-farm demo day was very well received by hop growers and expert circles alike and cogently showed how integrated plant protection can work.

At this juncture, no analyses of the collected data are yet available, so that it is not possible to say whether intensive surveillance and in-depth consultation have led to any reduction in the use of plant protection products.

Improvement of nutrient use efficiency in hop via fertilization systems combined with fertigation (ID 5612)

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenbau, Produktionstechnik (IPZ 5a) (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, Working Group (IPZ 5a) Hop Farming/ Production Techniques*)
Funded by:	Erzeugergemeinschaft HVG e. G. (*HVG Hop Producer Group*)
Project lead:	J. Portner
Project staff:	J. Stampfl, S. Fuß
Collaboration:	Prof. Dr. T. Ebertseder, Hochschule Weihenstephan-Triesdorf
	Prof. Dr. F. Wiesler, LUFA Speyer
	Hop farms in the Hallertau region
Scheduled to run:	2017 – 2020

If it is to achieve stable yields, hop as a speciality crop requires high-maintenance treatment when it comes to the water supply; and what is crucial is not the absolute amount of water, but the way precipitation is spread out over time.

Irrigation can thus play an important role in safeguarding yields and minimizing risks, not only in drought years but also in years when rainfall is unevenly distributed.

Apart from ensuring that plants are supplied with water, irrigation systems can also act as a vehicle for the application of plant nutrients together with the water. This fertilization technique, known as fertigation, is used predominantly in agriculture in extremely arid regions of the world (e.g. the Yakima Valley, USA). The practice of fertigation makes it possible to adjust nutrient supply selectively according to plant requirements with optimum effectiveness during the growing season and it has an added advantage in that it can avoid adverse environmental effects by reducing leaching into other ecosystems (into the groundwater, for example) to a minimum. In the Hallertau region, most of the plant nutrients are applied by spreading granulate fertilizer over the surface of the soil. Especially if conditions are dry, this means that the fertilizer is not taken up when it is needed and stays in the ground unused.

In the next few years, an LfL research project will be looking into nitrogen use efficiency in hop, conducting trials involving irrigation and fertigation.

Objective

- to improve N utilization by applying nitrogen via irrigation water at the point when intake is highest
- to analyse the rate of growth and nutrient uptake in current hop cultivars
- to apply nitrogen fertilizer in the appropriate quantities and at the right time according to location and cultivar
- to examine and establish methods of measuring the level of a hop plant's current N supply level
- to use climate models so that the operation of drip irrigation systems can be suited to the requirements of the location
- to assess what impact the positioning of the drip hose has ─ above ground or below ground

Fig. 1.5: Drip irrigation of hops

Fig. 1.6: Fertilizer input device for fertigation of hops

Method

- setting up and conducting fertilization and irrigation trials; harvesting within different cultivars and in different locations
- weekly inputs of given quantities of fertilizer via fertigation in trial variants, in the period end of June to end of July/August (see Fig. 1.7)
- exact determination of dry matter of cones and residual plant matter at harvest
- analysis of nutrient content in samples of cones and residual plant matter and calculation of the amounts of nutrients extracted
- assessment of nitrogen use efficiency in different fertilization systems
- examination of nitrate content in leaf stems from divergently fertilized plots, over the course of the year
- SPAD chlorophyll meter measurements in leaves on different dates; results in relation to the leaf's total N content

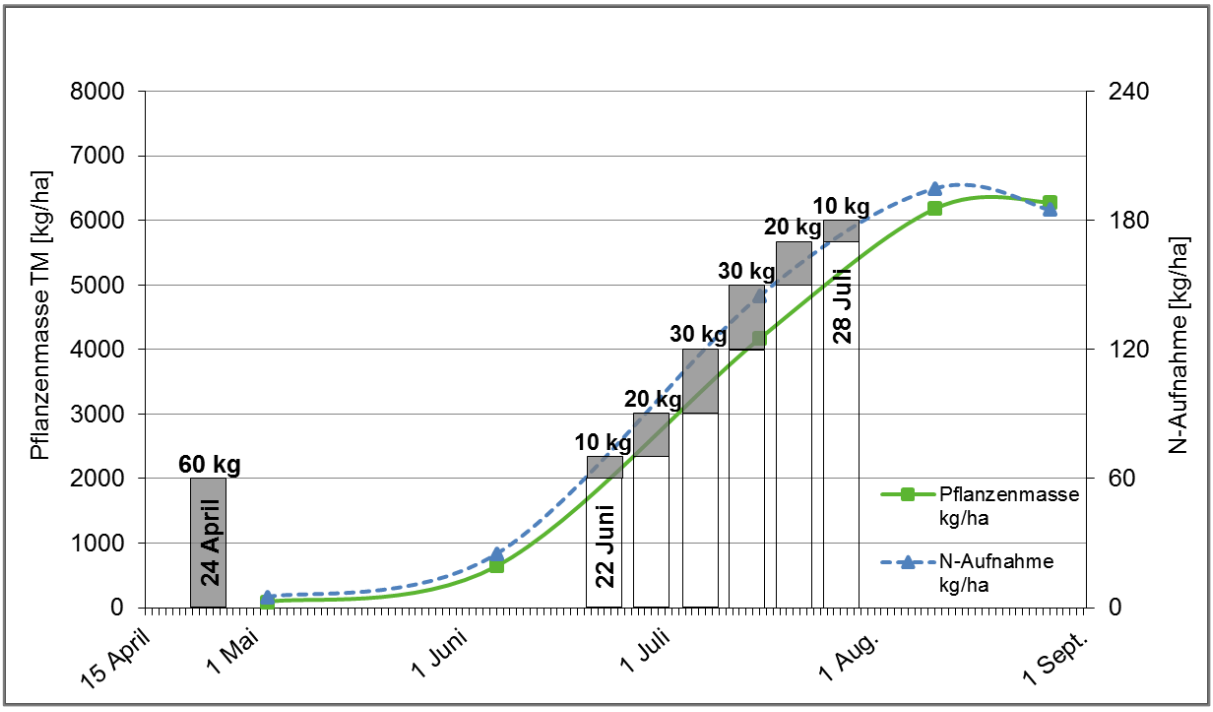

Fig. 1.7: Needs-based N fertilization (1/3 scattered, 2/3 via fertigation), progress of biomass formation and N uptake in hop.

Results

First results to come out of the project in 2017 show higher cone yields and alpha acids contents in the bespoke fertilization system combined with fertigation. Also, the amount of residual plant matter was greater in the variants with fertigation, which meant there was a bigger overall N uptake with the same amounts of nitrogen. It can be assumed that the level of N fertilizer uptake is greater when it is applied via fertigation, so that this method has the potential to reduce any possible N losses, as well as lowering the risk of groundwater contamination.

Cross-breeding with Tettnanger landrace

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen (IPZ 5c) und AG Hopfenqualität/Hopfenanalytik(IPZ 5d) (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Breeding Research (IPZ 5c) and WG Hop Quality/ Hop Analytics (IPZ 5d*)
Funded by:	Ministerium für Ländlichen Raum und Verbraucherschutz (*Ministry for Rural Affairs and Consumer Protection*), Baden-Württemberg Hopfenpflanzerverband (*Hop Growers' Association*), Tettnang; Erzeugergemeinschaft Hopfen HVG e.G. (*Hop Producer Group*) Gesellschaft für Hopfenforschung e.V. (2011-2014) (*Society of Hop Research*)
Project leads:	Dr. E. Seigner, A. Lutz
Project staff:	AG Züchtungsforschung Hopfen (*WG Hop Breeding Research*): A. Lutz, J. Kneidl, D. Ismann, H. Graßl and breeding team AG Hopfenanalytik (*WG Hop Analytics*): Dr. K. Kammhuber, C. Petzina, B. Wyschkon, M. Hainzlmaier und S. Weihrauch
Collaboration:	Hopfenversuchsgut Straß des Landwirtschaftlichen Technologiezentrums (LTZ) (*Straß Hop Experimental Station of the LTZ*), Baden-Württemberg: F. Wöllhaf, B. Bohner, G. Bader
Scheduled to run:	01.05.2011 - 31.12.2019

Objective

The aim is to develop a cultivar with a fine classical aroma similar to that of Tettnanger through classical cross-breeding with Tettnanger landrace and, at the same time, significantly to improve yield potential and fungal resistance in the new breeding stock as compared with the original Tettnanger.

For details of methods and results, see 4.3

Development of healthy, high yielding hops with high alpha acids content, particularly suited to cultivation in the Elbe-Saale region

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen (IPZ 5c) (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Breeding Research (IPZ 5c))*
Funded by:	Thüringer Ministerium für Infrastruktur und Landwirtschaft (*Thuringia Ministry for the Environment and Agriculture*)
	Ministerium für Landwirtschaft und Umwelt Sachsen-Anhalt (*Ministry for Agriculture and the Environment in Saxony-Anhalt*)
	Staatsministerium für Umwelt und Landwirtschaft Sachsen (*State Ministry for the Environment and Agriculture in Saxony*)
	Erzeugergemeinschaft Hopfen HVG e.G.(*HVG Hop Producer Group*)
Project leads:	Dr. E. Seigner, A. Lutz
Project staff:	AG Züchtungsforschung Hopfen (*WG Hop Breeding Research*): A. Lutz, J. Kneidl, D. Ismann, H. Grebmair and breeding team
	AG Hopfenanalytik (*WG Hop Analytics*): Dr. K. Kammhuber, C. Petzina, B. Wyschkon, M. Hainzlmaier, S. Weihrauch
Collaboration:	Hopfenpflanzerverband Elbe-Saale e.V. (*Elbe-Saale Hop Growers' Association*)
	Thüringer Landesanstalt für Landwirtschaft (TLL) (*State Center for Agriculture, Thuringia*)
	Hopfenbetrieb Berthold (*Berthold hop farm*)
Scheduled to run:	01.01.2016 - 31.12.2019

Objective

The objective is to breed and test new robust and high yielding hop breeding lines with high alpha acids content and broad spectrum resistance characteristics, making the hops resistant chiefly to crown rot pathogens, which are also suitable for cultivation in the prevailing conditions of the Elbe-Saale region. To achieve this, high alpha breeding lines are being created, while, at the same time, already pre-selected lines from the ongoing Hüll high alpha breeding programme are being tested by a grower in the Elbe-Saale region to establish their suitability for that particular location.

For details of implementation and insights gained so far see 4.4

Powdery mildew isolates and their use in breeding for PM resistance in hop

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen (IPZ 5c) (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Breeding Research (IPZ 5c*))
Funded by:	Gesellschaft für Hopfenforschung e.V. (2013 – 2014; 2017-2018) *(Society of Hop Research*) Erzeugergemeinschaft Hopfen HVG e.G. (2015 - 2016) (*HVG Hop Producer Group*)
Project leads:	Dr. E. Seigner, A. Lutz
Project staff:	AG Züchtungsforschung Hopfen (*WG Hop Breeding Research*): A. Lutz, J. Kneidl EpiLogic: S. Hasyn
Collaboration:	Dr. F. Felsenstein, EpiLogic GmbH, Agrarbiologische Forschung und Beratung, Freising
Scheduled to run:	01.01.2013 – 31.12.2018

Objective

Increased resistance to diseases, in particular to powdery mildew, continues to be the top priority in developing new breeding lines. To this purpose, seedlings from all the breeding programmes are screened every year for powdery mildew resistance in the greenhouse at Hüll, and then in the laboratory by means of a detached leaf assay. Powdery mildew isolates of all the currently known virulence genes are made available by EpiLogic, Agrarbiologische Forschung und Beratung, Freising, allowing the diverse work in connection with breeding for resistance to powdery mildew to be performed.

Description of the work

Eleven previously characterized single-spore isolates of *Sphaerotheca macularis*, the fungus causing powdery mildew on hop, are used every year in conjunction with the greenhouse and laboratory resistance testing systems for the following:

- Maintenance of the PM isolates and characterization of their virulence properties
- Testing of all seedlings for resistance to powdery mildew in the greenhouse at Hüll
- Testing for resistance to powdery mildew, using the detached leaf assay in the EpiLogic laboratory
- Assessment of the virulence situation in the hop growing region and evaluation of the resistance sources via the detached leaf assay

For details of resistance to powdery mildew see
http://www.lfl.bayern.de/ipz/hopfen/116878/

Tab. 1.1: Overview of PM resistance testing with defined virulence PM isolates in 2017

2017	Greenhouse tests		Leaf test in the lab at EpiLogic	
	Plants	**Assessments**	**Plants**	**Assessments**
Seedlings from 91 crosses	ca. 100 000 by mass screening		-	-
Breeding lines	112	369	112	689
Cultivars	25	104	6	30
Wild hop	1	3	1	8
Virulences, PM isolates	-	-	13	635
Total (individual tests)	**138**	**476**	**132**	**1 362**

Mass screening in plant trays; individual tests = selection as individual plants in pots

In the 2017 season, greenhouse PM screening and the leaf assays at Epilog were severely handicapped by the emergence of a super-virulent strain of powdery mildew, which was first discovered on 20 February on a *Wye Target* plant in the greenhouse at Hüll, in an annexe to the actual PM testing section. This strain spread with frightening speed in the greenhouse and led to the premature termination of PM resistance screening, due to the fact that all the plants set up for screening had been infected with powdery mildew.

The virulence analysis of the PM strain carried out by EpiLogic confirmed the dangerous nature of this isolate with eight different virulences, which can attack all R2 and R18 resistance-based cultivars and breeding lines. However, judiciously applied fungicides were able to put a complete stop to the infection and it did not flare up again in the course of the summer.

Research into and work on the problem of *Verticillium* on hop

Managing *Verticillium* wilt disease in the German hop growing regions is a long-term undertaking. Research and the guidance provided by the LfL are of crucial importance in supporting hop growers in their struggle to control *Verticillium*.

Research into and work on molecular techniques for detecting *Verticillium* on hop and the production of healthy hops through meristem culture

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding*) AG Züchtungsforschung Hopfen und (IPZ 5c) (*WG Hop Breeding Research*)
Funded by:	Erzeugergemeinschaft Hopfen HVG e.G.(*HVG Hop Producer Group*)
Project lead:	Dr. E. Seigner (until Oct. 2015 Dr. S. Seefelder)
Project staff:	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 Dr. S. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia
Scheduled to run:	since 2008 – 30.05.2020

For details of this research see 4.5 and 4.6.

Sanitation of soils infected with *Verticillium* and selection of breeding material for tolerance to *Verticillium*

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding*) AG Pflanzenschutz im Hopfenbau (IPZ 5b) (*WG Hop Plant Protection*)
Funded by:	Gesellschaft für Hopfenforschung (GfH) e.V. (*Society of Hop Research*) Erzeugergemeinschaft Hopfen HVG e.G. (*Hop Producer Group*)
Project leads:	**Not yet appointed,** Dr. E. Seigner, A. Lutz, S. Fuss, S. Euringer
Project staff:	S. Euringer, IPZ 5 b
Collaboration:	AG Züchtungsforschung Hopfen (*WG Breeding Research*): A. Lutz, J. Kneidl AG Hopfenbau/Produktionstechnik (*WG Hop Farming/Production Techniques)*: S**.** Fuss Dr. S. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia
Scheduled to run:	01.06.2017 – 30.05.2020

See 6.2 for further information.

Monitoring for dangerous viroid infections on hop in Germany

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenschutz, AG Virologie (IPS 2c) und Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen (IPZ 5c) (*Bavarian State Research Center for Agriculture, WG Virology (IPS 2c) and Institute for Crop Science and Plant Breeding, WG Hop Breeding Research (IPZ 5c)*)
Funded by:	Wissenschaftliche Station für Brauerei in München e.V. (*Scientific Station for Brewing in Munich*)
Project leads:	Dr. L. Seigner, Institut für Pflanzenschutz (IPS 2c) (*Institute for Plant Protection*); Dr. E. Seigner, A. Lutz (IPZ 5c)
Project staff:	L. Keckel, J. Hüttinger (IPS 2c); A. Lutz, J. Kneidl (IPZ 5c)
Collaboration:	Dr. S. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia AG Hopfenbau und Produktionstechnik, IPZ 5a (*WG Hop Farming/ Production Techniques, IPZ 5a*) AG Pflanzenschutz im Hopfenbau, IPZ 5b (*WG Hop Plant Protection, IPZ 5b*) Local hop consultants Hopfenring e.V. Commercial hop farms Eickelmann propagation facility, Geisenfeld
Duration:	March - December 2017

Objective

For some years now, hop production in Germany has been under threat of infection from two dangerous viroid diseases, namely the hop stunt viroid (HpSVd) and the citrus viroid IV (CVd IV). These viroids are easily spread, as well as being untreatable, and can seriously threaten profitability.The nationwide LfL monitoring scheme in place since 2008, with financial support since 2011 from the Scientific Station for Brewing in Munich (*Wissenschaftliche Station für Brauerei in München e.V.*), goes a long way towards preventing disease and safeguarding hop production in Germany. It means that primary sources of infection can be detected and eliminated, thus preventing the spread of the dreaded pathogens.

As part of the scheme, hop micro-plants produced by means of meristem tissue culture were also screened for virus and viroid infections in order to verify the success of the pathogen elimination process. Furthermore, hops resulting from new research strategies for eliminating pathogens were also screened.

Method

Samples were taken from different growing regions in Germany, from commercial farms, LfL breeding yards and a GfH propagation facility. Because of the high costs involved, monitoring was carried out on a random basis rather than universally, with representative samples being screened in crucial locations, whereby plants that looked particularly problematic were chosen. Foreign cultivars were also examined, as well as plants from abroad held in quarantine for EU plant variety registration testing at Hüll.

Screening of the samples for HpSVd and CVd IV was done by RT (reverse transcriptase)-PCR. An internal hop-specific mRNA-based positive control was always run parallel to the RT-PCR (Seigner et al., 2008) to make sure that it was functioning correctly.

Tab. 1.2: Monitoring samples were tested for the following viroids:

Viroid German name	Viroid English name	Abbreviation	Detection method
Hopfenstauche-Viroid	Hop stunt viroid	HpSVd	RT-PCR*
Zitrusviroid IV	Citrus viroid IV	CVd IV = CBCVd	RT-PCR#

* Using primers from Eastwell und Nelson (2007) and from Eastwell (personal communication, 2009); # Primer published by Ito et al. (2002).

Tab. 1.3: Plantlets from meristem culture were tested for the following viruses and viroids:

Virus/Viroid German name	Virus/Viroid English name	Abbreviation	Detection method
Latentes Hopfen-Viroid	Hop latent viroid	HpLVd	RT-PCR[2]
Latentes Hopfenvirus	Hop latent virus	HpLV	RT-PCR[2]
Latentes Amerikanisches Hopfen-Carlavirus	American hop latent carlavirus	AHpLV	RT-PCR[2]
Apfelmosaik-Ilarvirus	Apple mosaic ilarvirus	ApMV	DAS-ELISA* RT-PCR[2]
Hopfenmosaik-Carlavirus	Hop mosaic carlavirus	HpMV	DAS-ELISA* RT-PCR[2]

[2] Primers for HpLVd, HpLV, AHpLV, HpMV according to Eastwell & Nelson 2007 and for ApMV according to Menzel et al. 2003; primers for internal check according to Seigner et al. 2014

* DAS-ELISA using commercially available polyclonal antibodies; Seigner et al. 2014

In order to check whether virus elimination had been successful, the hops were screened after meristem culture for AHpLV, ApMV, HpMV and HpLVd, but not for HpSVd and CVd IV because the latter two have hitherto not been widespread in Germany. HpLVd occurs in nearly all hops; for this reason, screening for HpLVd to represent the viroids was done in order to check the effectiveness of the different variants of the technique used in viroid elimination.

It was decided to dispense with testing for apple mosaic virus (ArMV), since the results from the last few years have shown that ArMV has no relevance in Germany.

Results

A total of 350 hop samples screened in 2017 yielded no positive results for either viroid. Since 2008, around 2 600 samples have been screened for HpSVd, and, since 2013, approx. 1 150 samples for CVd IV. The nine cases of HpSVd infection found in one location in 2010 remain the only positive results to date. At the time, the source of infection was eradicated.

Nevertheless, the viroid threat is still considerable, due to the global infestation situation, importation, the transferring of plant material from affected areas within the hop community, and the lack of quarantine regulation. It is conceivable that nests of infection already in place have not yet been detected because of the relatively coarse grid used in the monitoring process.

German hop growers are really keen to import and grow flavour hops from the USA, a country where HpSVd on hop is known to be rife, and this greatly increases the risk of introducing it into Germany. The fact that HpSVd was found in the summer of 2016 in various cultivars imported from the USA and subsequently grown in Spain serves to corroborate this. In future, monitoring for HpSVd and CVd IV must therefore continue to be conducted as strictly and as closely as possible.

In order to verify their virus- and viroid-free status following meristem culture, young tissue-culture plants were examined for the various pathogens before being transferred to soil. Hops resulting from new research strategies for virus and viroid elimination were also tested as part of the project.

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Acknowledgement

Our thanks go to Dr. Sebastian Radišek, Slovenia, for his support in this work.

Precision breeding for hop

Stage 1: Optimizing hop breeding by means of genome and metabolite analysis

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding*)
	Universität Hohenheim Pflanzenbiotechnologie und Molekularbiologie (*Hohenheim University Plant Biotechnology and Molecular Biology)*
	Max-Planck-Institut für Entwicklungsbiologie (*Max Planck Institute for Developmental Biology*)
Funded by:	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (*Bavarian State Ministry for Food, Agriculture and Forestry*)
	Ministerium für Ländlichen Raum und Verbraucherschutz (*Ministry of Rural Affairs and Consumer Protection*), Baden-Württemberg
	Hopfenpflanzerverband Tettnang (*Hop Growers'Association Tettnang*); Erzeugergemeinschaft Hopfen HVG e.G. (*HGV Hop Producer Group*)
	Universität Hohenheim
Funding code:	A/15/20
Project leads:	Dr. M. H. Hagemann, Universität Hohenheim (project overall) Dr. E. Seigner (LfL)
Project staff:	AG Züchtungsforschung Hopfen (IPZ 5c) (*WG Hop Breeding Research*): A. Lutz, J. Kneidl, E. Seigner and breeding team
	AG Hopfenqualität/Hopfenanalytik (IPZ 5d) (*WG Hop Quality/ Hop Analytics)*: Dr. K. Kammhuber, C. Petzina, B. Wyschkon, M. Hainzlmaier und S. Weihrauch
	AG Genom-orientierte Züchtungsmethodik (IPZ 1d) (*WG Genome-oriented Breeding Methodology*), Prof. Dr. V. Mohler
	AG Züchtungsforschung Hafer und Weizen (IPZ 2c) (*Breeding Research Oats and Wheat*), Dr. Th. Albrecht
Collaboration:	Universität Hohenheim: Dr. M. H. Hagemann, Prof. Dr. J. Wünsche, Prof. Dr. Piepho, Dr. Möhring Pflanzenbiotechnologie und Molekularbiologie: Prof. Dr. G. Weber
	Max-Planck-Institut für Entwicklungsbiologie: Prof. Dr. D. Weigel
	Hopfenpflanzerverband Tettnang (*Hop Growers'Association Tettnang*)
Duration:	01.07.2015 - 31.03.2017

Stage 2: Genome-based precision breeding for quality hops of the future

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding*)
Funded by:	Funding from the Federal Government's earmarked capital at the Landwirtschaftliche Rentenbank
Funding code:	Landwirtschaftliche Rentenbank: 837 150 (BLE Aktenzeichen: 28RZ4IP025)
Project leads:	Dr. M. H. Hagemann, Universität Hohenheim (project overall) Dr. E. Seigner (LfL)
Project staff:	AG Züchtungsforschung Hopfen (*WG Breeding Research*) (IPZ 5c): A. Lutz, J. Kneidl, E. Seigner and 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 Genom-orientierte Züchtungsmethodik (*WG Genome-oriented Breeding method,* (IPZ 1d), Prof. Dr. V. Mohler AG Züchtungsforschung Hafer und Gerste (*WG Breeding Research Oats and Barley*) (IPZ 2c), Dr. T. Albrecht
Project partners:	Universität Hohenheim, Institut für Nutzpflanzenwissenschaften, FG Ertragsphysiologie der Sonderkulturen (*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 Science and Population Genetics*): Prof. Dr. G. Weber em. Gesellschaft für Hopfenforschung e.V.: W. König (*Society of Hop Research*) Hopfenverwertungsgenossenschaft HVG e.G.: Dr. E. Lehmair *(Hop Sales Cooperative*)
Scheduled to run:	01.08.2017 - 31.07.2020

Stage 3: Genome-based selection of new high alpha varieties in collaboration with the hops and brewing industries

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding*)
Project leads:	Dr. M. H. Hagemann, Universität Hohenheim (project overall) Dr. E. Seigner (LfL)
Project staff:	AG Züchtungsforschung Hopfen (*WG Hop Breeding Research*) (IPZ 5c): A. Lutz, J. Kneidl, E. Seigner and 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 Genom-orientierte 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
Project partners:	Universität Hohenheim, Institut für Nutzpflanzenwissenschaften, FG Ertragsphysiologie der Sonderkulturen (*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 Science and Population Genetics)*: Prof. Dr. G. Weber em. Gesellschaft für Hopfenforschung e.V.: W. König (*Society of Hop Research*) Hopfenverwertungsgenossenschaft HVG e.G.: Dr. E. Lehmair (*Hop Sales Cooperative*)
Scheduled to run:	begins 2019

Objective

In marker-assisted breeding procedures the German hop breeding will have at their disposal an innovative tool designed as an addition to the conventional selection process. By combining conventional selection with the new genome-based technique, it becomes possible for new and robust, high yielding cultivars to be made available sooner and more efficiently to the hops and brewing industries.

See 4.8 for more details and the latest information on implementation and findings.

Marker-assisted breeding for hop – sub-project PM resistance for genome-wide association mapping

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen (IPZ 5c) (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Breeding Researc*h) (IPZ 5c)
Funded by:	Wissenschaftsförderung der Deutschen Brauwirtschaft (Wifö) (*Science Funding from the German Brewing Industry*)
Funding code:	R444
Project leads:	Dr. E. Seigner, A. Lutz
Project staff:	AG Züchtungsforschung (*WG Breeding Research*): A. Lutz, J. Kneidl, E. Seigner and breeding team AG Züchtungsforschung Hafer und Weizen (*WG Breeding Research Oats and Wheat*) (IPZ 2c), Dr. T. Albrecht
Collaboration:	EpiLogic Agrarbiologische Forschung und Beratung, Freising Dr. F. Felsenstein und Stefanie Hasyn
Duration:	01.01.2016 - 31.12.2017

Objective

Thanks to the reliable screening systems for PM resistance both in the greenhouse and via the detached leaf assay in the lab, it is possible to make meaningful assessments of individual plants in the mapping population. These phenotypic data are then combined with the genetic data from the project *Marker-assisted Breeding for Hop* in order to develop preliminary QTL (quantitative trait loci) mapping for various different PM resistance genes.

Method

- PM resistance screening system in the greenhouse
- Detached leaf assay in the EpiLog lab (see Seigner et al., 2002)
- QTL analysis of resistance data and SNP data

Results

In the spring of 2016, 300 F1 individual plants from a special mapping population were examined in the greenhouse for resistance, using virulence-defined PM isolates. The leaves of seedlings which had not shown PM infections in the greenhouse were distinguished with two special PM strains via the EpiLogic leaf assay system. In order to verify the assessments done so far, one hundred and forty-three of the F1 hops once more underwent screening for PM resistance in the greenhouse and at EpiLogic in 2017. However, due to the appearance of a super-virulent PM strain in the greenhouse at Hüll, which was able to break all R2- and R18-based resistances in the mapping population, only few results could be used. The outbreak at Hüll, which could only be stopped thanks to the application of a fungicide, seriously obstructed completion of the leaf assays at EpiLog, with the result that only relatively few useful resistance estimations for the F1 population were able to be verified during the 2018 screening season.

It has so far not been possible to start QTL analyis of the PM resistance data because provision of the genetic (SNP) data for the mapping population by the Max Planck Institute has been considerably delayed.

Reference

Seigner, E., S. Seefelder und F. Felsenstein (2002): Untersuchungen zum Virulenzspektrum des Echten Mehltaus bei Hopfen (*Sphaerotheca humuli*) und zur Wirksamkeit rassen-spezifischer Resistenzgene. Nachrichtenblatt des Deutschen Pflanzenschutzdienstes, 54 (6), 147-151.

Minimizing the use of copper-containing plant protection agents in organic and integrated hop farming

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Ecology (IPZ 5e*))
Funded by:	Erzeugergemeinschaft Hopfen HVG e.G. (*HVG Hop Producer Group*)
Project lead:	Dr. F. Weihrauch
Project staff:	Dr. F. Weihrauch, A. Baumgartner, M. Felsl, M. Mühlbauer, S. Wolf
Collaboration:	Naturland-Hof Loibl (organic farm), Schweinbach; Agrolytix GmbH, Erlangen
Scheduled to run:	01.03.2014 - 28.02.2019

Objective

According to an assessment by the Umweltbundesamt (*German Federal Environment Agency*), inter alia, of the toxological impact on both environment and users, plant protection agents containing copper should no longer be in general use. At the European level, copper as an active ingredient is also considered to be highly critical and its availability for plant protection (see listing in Annex 1) is currently only extended piecemeal from one year to the next, at present until the end of January 2019. However, as things stand at the moment, organic operations growing all kinds of produce cannot yet do without copper as an active agent. A first four-year test programme running from 2010 to 2013 and managed by BÖLN (*Federal Organic Farming Programme*) investigated how far copper levels in hop could be reduced per season, without yields and crop quality being adversely affected.

The application rate of 4.0 kg Cu/ha/per year permitted at present in hop growing needed to be reduced by at least a quarter to 3.0 kg Cu/ha/per year. In the wake of the successful completion of the programme, the current follow-up project aims to take a good look at the 3.0 kg Cu/ha/per year achieved thus far (as an achievable average over a five-year period) and to ascertain with a critical eye whether a further reduction in the use of copper is possible. However, the results from 2016 have shown that exceptions must be made in years with extreme conditions, and the amount of copper available for suppressing downy mildew should in such cases be allowed to exceed 3 kg/ha. It would be necessary to create a five-year 'copper account' (15 kg/ha over five years) for all farms, as a record of their use of copper across all cultivars *(Hoftorbilanz).*

Results

In 2017, 12 variants were once more set up and two copper-based agents used (Funguran progress as an approved product and CuCaps as a test product) in various different application dosages and in combination with different partners as synergists. Unfortunately, 2017 was the third year running without normal downy mildew levels, and, like 2015, a year with virtually no incidence of infection. Of the 12 000 hop cones assessed from this hop yard, only one single cone was infected with downy mildew! However, what this year's trial has, above all, shown is that neither the new HopCaps (microencapsulated extract of hop) nor any other mixing partners cause problems due to clumping during application in combination with copper.

Developing methods of controlling the hop flea beetle *Psylliodes attenuatus* in organic hop farming

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Ecology (IPZ 5e*))
Funded by:	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (BioRegio 2020 – Landesprogramm Ökologischer Landbau) (*Bavarian State Ministry for Food, Agriculture and Forestry (BioRegio 2020 ─ State-wide Ecological Farming Scheme*)
Project lead:	Dr. F. Weihrauch
Project staff:	Dr. F. Weihrauch, A. Baumgartner, M. Felsl, M. Mühlbauer, J. Weiher, S. Wolf
Collaboration:	Wageningen University & Research, Netherlands; Julius Kühn-Institut, Institut für Biologischen Pflanzenschutz (*Institute for Biological Plant Protection*), Darmstadt
Scheduled to run:	01.03.2015-30.06.2018

Objective

The hop flea beetle (*Psylliodes attenuatus)* is steadily becoming a major concern for organic hop growers. The damage it causes can be divided into two phases. In early spring, the shoots of the young plants are the first source of food for the overwintering hop flea beetles, and, where infestation is severe, the leaves are reduced almost to skeletons and plant growth is noticeably slowed.

From July onwards, even worse damage is done by the new adult generation of beetles, which nibble in mid to late summer at the hop flowers and the gradually developing cones, reaching up as far as 5 to 6 metres on the trellises, causing significant yield losses in places where there is a greater degree of infestation. For the time being, there is no effective practice method of controlling the hop flea beetle in organic hop growing, and growers have no option but to bear the losses. Since pest pressure has increased considerably in the last ten years, an effective flea beetle control method for hop which is suitable for use in organic agricultural systems would therefore play a key role in integrated plant protection management.

Methods and Results

In the third year of the trial, the effectiveness of the most promising mechanical methods was again tested. In 2017 once again, it was found that catching the beetles using yellow trays was the most effective method. This time, R+-limonene, linalool and IS-ß-pinene were tried out as a lure. Linalool was the first volatile substance to deliver some significantly greater numbers of trapped hop flea beetles when compared to the untreated control; it obviously attracts them in some way. The quantitative assessment at midsummer of the numbers of the new beetle generation hatching out, carried out by means of photoeclectors, delivered even more surprising results than it did in 2016. A projection of the 'annual hop flea beetle production' for 2017 in the trial yard - this time Laipersdorf in Hersbruck - arrived at 6 million animals per hectare, or 3 000 beetles per hop plant (see 7.1).

The most important sub-project in collaboration with Wageningen U&R remains the attempt to pin down the hitherto unidentified sexual pheromone (or other active kairomone) of the hop flea beetle so that it can be used as a highly effective lure to attract the pests. Once again, at the beginning of May 2017, approximately 6 000 hop flea beetles were caught and taken to the Netherlands, where, in the laboratories at Wageningen, numerous analyses of the odoriferous substances exuded by male and female beetles and infested hop plants were carried out. The information from the analyses has not yet been completely evaluated.

The use of microencapsulated extracts of hop as a novel biological fungicide to combat downy mildew in hop cultivation

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Ecology (IPZ 5e))*
Funded by:	Wissenschaftsförderung der Deutschen Brauwirtschaft e.V., Berlin (*Science Funding from the German Brewing Industry*)
Project lead:	Dr. F. Weihrauch
Project staff:	Dr. F. Weihrauch, A. Baumgartner, M. Felsl
Collaboration:	Naturland-Hof Loibl, Schweinbach
	Lehrstuhl für Prozessmaschinen und Anlagentechnik (iPAT) (*Chair of Process Technology and Machinery*), Friedrich-Alexander-Universität Erlangen-Nürnberg
	Hallertauer Hopfenveredelungsgesellschaft m.b.H. (Hopsteiner) *(Hop Processing Society Ltd),* Mainburg
Scheduled to run:	01.07.2016 - 31.12.2018

Objective

In Germany, various efforts are underway to try to reduce the quantities of pure copper applied per hectare every year as plant protection and to seek alternative active fungicide agents to replace copper. In this context, the discovery was made at the Staatliches Weinbauinstitut (*State Viticulture Institute*) in Freiburg i. Br. that extract of hop works well in vitro in controlling the downy mildew *(Plasmopara viticola*) prevalent in grape vines. It is thought that the alpha acids and xanthohumol have an antimicrobial effect.

The purpose of the project is to develop a viable alternative to copper or to bring about a further reduction in its use in hop cultivation. At the same time, the resulting plant protection agent must be not only effective and practicable to apply, it must also, above all, be affordable in practice. As a method of production, spray congealing is a low-cost option, and, if suitable matrix substances and adjuvants are used, the cost of the end product can be kept down to normal market levels.

Methods

The current research project envisages developing through to the approval stage a prototype biological plant protection agent, based on microencapsulated extract of hop, to control downy mildew fungi in hop cultivation. The desired outcome of the research work is to be the optimal formulation of the ingredients for the capsule prototypes and, in parallel, alongside the chemical optimization, the further development of microparticle production to ensure that manufacture of the hop capsules is economically viable and as efficient as possible. The prototypes which fulfil the aforementioned requirements for plant protection agents were tested for the first time in the open in the trial yard at Schweinbach in 2017. In addition, the hop research centre at Hüll analysed the biological efficacy of these HopCaps for the first time in 2017 partly outdoors, sadly without result ─ for want of any incidence of infection. The trials will be repeated in 2018 and a spray recommendation devised which is suitable for implementation by organic hop farmers.

Ongoing development of crop-specific strategies for ecological plant protection through dedicated networks ─ hops network

Sponsored by:	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)*)
Funded by:	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 (BÖLN Project 2815OE095))*
Project lead:	Dr. F. Weihrauch
Project staff:	Dr. F. Weihrauch
Collabortion:	Bund Ökologische Lebensmittelwirtschaft (BÖLW e.V.) (*Organic Food Production Alliance*)
Scheduled to run:	15.08.2017-14.08.2020

Objetive and Procedure

The aim of the research project is to establish six crop cultivation networks (field crops, vegetables, hops, potatoes, fruit, and grapes) focused on plant health in organic farming, with coordinators for each section functioning as a central point of contact for the section.

BÖLW is responsible for overall coordination; IPZ 5e at Hüll will be tasked with coordination for the hops division.

It is the job of the coordinator to set up the crop network as a fixed group of working farms, to advise farms interested in converting, to collate issues relevant to plant health in the crop in question, to pick up and pass on information on innovation and any research needed, and to formulate plant health strategies for the respective crops. Within the organic hops network, communication takes place mainly through meetings of those involved 2 or 3 times a year, including a special workshop for all farms. Exchange of information between the crop networks and the overall coordinator is by way of an annual workshop.

The main aim is to adhere to strategies for management rather than relying on the introduction of phytomedicinal substances into the crop system. The expectations of the sponsors BLE and BMEL are centred around progress and innovation; i.e. ideally, as the overall outcome of the project, they would like to see the development of new management and cultivation systems and a joined-up work programme.

1.2 Key Research Priorities

1.2.1 Research focus: hop farming, production techniques

Improvement of drying processes through a more even air and temperature distribution in commercial kilns

Project staff: Jakob Münsterer
Scheduled to run: 2016 – 2018

Objective

A further step towards optimizing hop drying involves taking account of the different ways the various types of hop react to drying. It is essential that a uniform distribution of air and temperature throughout the whole drying area is guaranteed.

Method

Data loggers were used in commercial kilns to record the temperature conditions in the air distribution space, between the tiers and above the top tier. Using the recorded details of the temperatures and moisture levels, it is possible to work out the absolute humidity of the drying air and thus to determine how much moisture is removed from the different levels by the drying air in the course of the drying process.

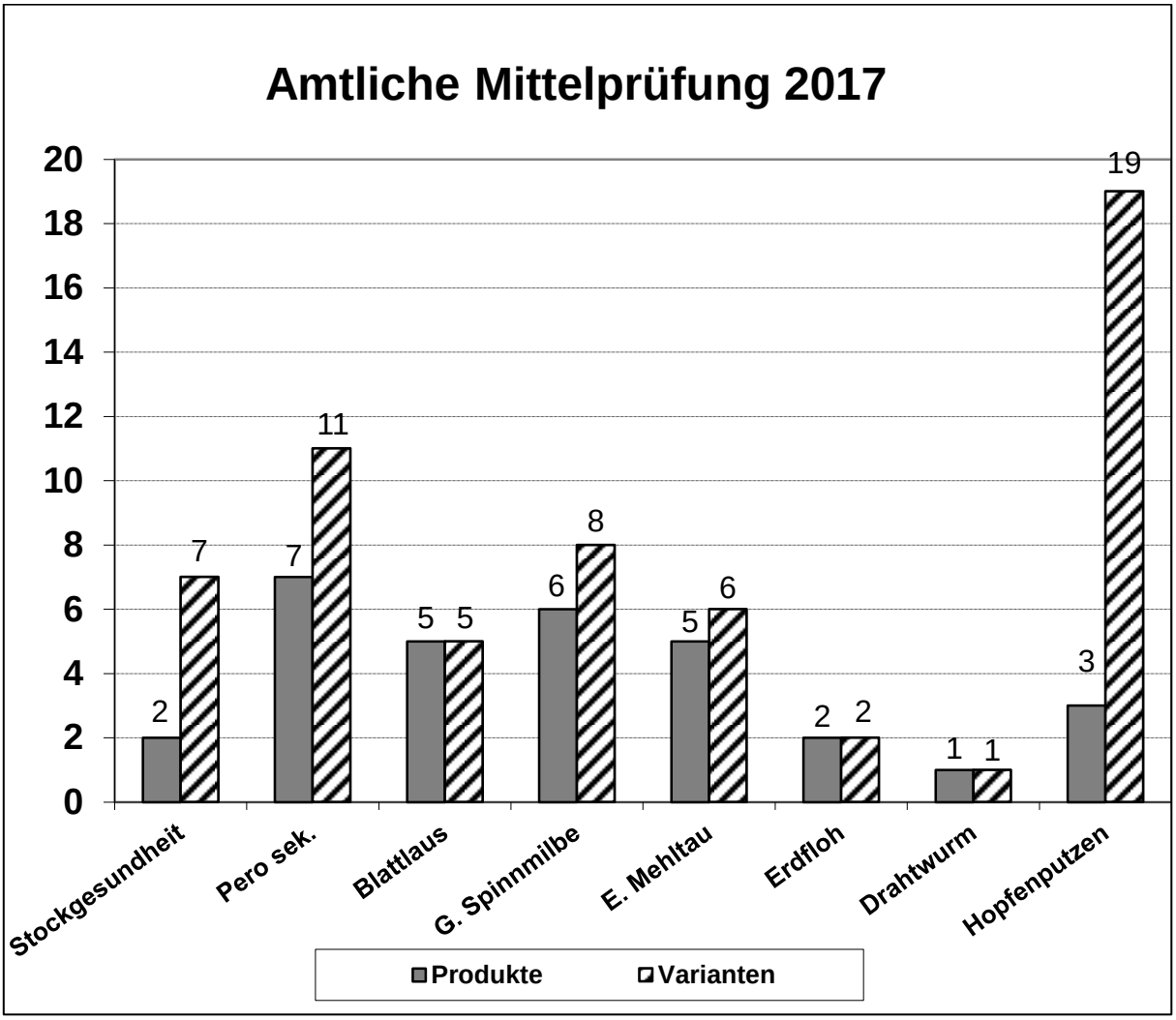
Results

A diagram of the absolute humidity of the drying air was able to show clearly how different varieties react differently during the drying process. It becomes clear, especially in the case of aroma hops, that excessively high temperatures in the first drying section lead to the released moisture being removed too slowly from the top level. The hops poured onto the middle tier then have a much higher moisture content than is the case with bittering hops.

1.2.2 Research focus: plant protection in hop

2017 trials of plant protection products for approval/registration and advisory service documentation

Lead: W. Sichelstiel (until 22.10.2017)
F. Weihrauch (acting lead from 23.10.2017)
Staff: S. Wolf, A. Baumgartner, M. Felsl, G. Meyr, M. Mühlbauer, J. Weiher



In the course of the 2017 official testing of agents for hop, a total of 53 products were tested in 97 variants. 208 plots (6,7 ha) were designated as trial areas.

1.2.3 Research focus: hop quality and analytics

Performance of all analytical studies in support of the Working Groups in the Hops Department, in particular Hop Breeding

Project lead:	Dr. K. Kammhuber
Project staff:	E. Neuhof-Buckl, S. Weihrauch, B. Wyschkon, C. Petzina, M. Hainzlmaier, Dr. K. Kammhuber
Collaboration:	AG Hopfenbau/Produktionstechnik, AG Pflanzenschutz Hopfen, AG Züchtungsforschung Hopfen *(WG Hop Farming/Production Techniques, WG Hop Plant Protection, WG Hop Breeding Research*)
Scheduled to run:	Ongoing

Hop is cultivated and farmed, above all, for its compounds. Therefore, analytical testing of its constituent components is key in ensuring successful research into hop. WG IPZ 5d carries out all the analytical work necessary to resolve issues relating to trials run by the other groups. WG Hop Breeding, in particular, bases its selection of breeding lines on the data processed by the lab. - See also IPZ 5 projects - WG Hop Breeding Research

Development and optimization of aroma analytics, using gas chromatography/ mass spectroscopy

Project lead:	Dr. K. Kammhuber
Project staff:	S. Weihrauch, Dr. K. Kammhuber
Collaboration:	AG Züchtungsforschung Hopfen, Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt (*WG Hop Breeding Research, TUM School of Life Sciences, Weihenstephan*)
Scheduled to run:	April 2014 ─ open end

Since the spring of 2014, WG IPZ 5d has been in possession of a gas chromatography/mass spectrometry system (funded by the Society of Hop Research). To date, 143 substances have been identified. Some substances are important in differentiating between varieties, but are not aroma-active. The objectives of this project are to refine variety identification and determine the aroma-active compounds in order to provide help in breeding and developing new hops with unique flavour.

Development of an NIRS calibration model for the α acids and moisture content

Project lead:	Dr. K. Kammhuber
Project staff:	E. Neuhof-Buckl, B. Wyschkon, C. Petzina, M. Hainzlmaier, Dr. Klaus Kammhuber
Scheduled to run:	September 2000 ─ open end

Starting in 2000, Hüll and the laboratories of the hop processing companies have been developing an NIRS (near infrared spectroscopy) calibration model for α acids content, based on HPLC (high performance liquid chromatography) data and conductometric values, as a fast and cheap method to replace the increasing number of wet chemical tests. The objective was to achieve repeatability and reproducibility that can easily be implemented in practice. The Working Group for Hop Analytics (AHA) considered this model to be practicable and workable as an analytical method useful in the context of hop supply contracts, provided that it is at least as accurate as conductometric titration according to the EBC 7.4 standard.

However, it was decided to discontinue collaboration in developing a joint calibration model in 2008, since no further improvement was possible. Work still continues on developing NIRS calibration in the laboratory at Hüll, as well as on efforts to develop HPLC calibration and determination of moisture content. NIRS is suitable as a screening method in hop breeding and saves a lot of time and money otherwise spent on chemicals. It was also discovered that accuracy of analysis is improving, thanks to continuing expansion every year.

As of 2017, the lab has had new equipment and is at present developing a new calibration for it.

Development of analysis methods for the hop polyphenols

Project lead:	Dr. K. Kammhuber
Collaboration:	Arbeitsgruppe für Hopfenanalytik (AHA) (*WG for Hop Analytics (AHA)*)
Project staff:	E. Neuhof-Buckl, Dr. K. Kammhuber
Scheduled to run:	2007 ─ open end

Thanks mainly to their properties beneficial to health, polyphenols are proving to be of growing interest in the context of alternative applications for hop. Of course, they also play a part in sensory impressions. It is therefore important to have access to suitable methods of analysis. As yet, there are no official standardized models available; all the laboratories involved in poly-phenol analytics are currently using their own methods.

Since 2007, the AHA has been working internally on improving and standardizing analysis models for both total polyphenol content and total flavonoid content.

In the meantime, the method for determining total polyphenol content has been accepted as EBC method 7.14.

Analytics for Working Group IPZ 3d Medicinal and Aromatic Herbs

Project lead:	Dr. K. Kammhuber
Collaboration:	AG Heil-und Gewürzpflanzen **(***WG Medicinal and Aromatic Herbs)*
Project staff:	E. Neuhof-Buckl, Dr. K. Kammhuber
Scheduled to run:	2009 – open end

To ensure more efficient ulilization of the laboratory equipment at Hüll, analyses have been conducted on behalf of WG Medicinal and Aromatic Herbs IPZ 3d, starting in 2009. No analyses were required in 2017.

2 Weather Conditions and Growth Development in 2017 – impact on technical aspects of production in the Hallertau region

LD Johann Portner, Dipl.-Ing. agr.

As regards the weather for hop growing, 2017 was a year of stark contrasts, and this influenced plant growth accordingly. January was very cold, with very little precipitation and measurable ground frost penetration for the first time in three years. This was followed by a warm spring. The warm temperatures and dry soil conditions encouraged growth of the first shoots and were favourable for the necessary pruning and maintenance operations. In mid-April there was a sudden change in the weather, introducing a cold and wet period and several days of frost, which brought growth to a standstill and even caused individual shoots to die off. The appearance of the first shoots in crops which had been pruned late and at a low level was considerably delayed. In contrast, it was possible to begin training work on April 22 in crops which had been pruned higher up somewhat earlier and were growing in soils that were easily warmed through. During the period of cold weather, a minimum temperature below zero was recorded on six days (e.g. -3.6°C on April 21). For this reason, thinning and training were drawn out until mid-May in unfavourable locations.

There then followed a period of hot and dry weather which lasted until July. High temperatures at the end of May led to the first cases of drought stress in newly-planted hops, necessitating irrigation in many cases. The incidence of disease was low, due to the initially cool, and subsequently hot, dry weather. The first warning to deal with secondary downy mildew infection was issued by the warning service after flowering had commenced on July 11. Aphid migration - i.e. winged aphids - began with the start of the warm weather in the second half of May. The control threshold for the two-spotted spider mite had already been exceeded in the first hop yards by the end of May. In the period that followed, the spider mite caused growers quite serious problems in many locations. Since the initial levels of infestation were high even before the first treatment with acaricides, follow-up treatment often became necessary. First symptoms of the dreaded *Verticillium* wilt appeared in the last decade of June. However, on the whole, 2017 was a below-average year for the occurrence of *Verticillium* wilt disease.

With the increasingly dry conditions in the course of July, many crops had shown poor development, particularly those in heavy clay soils or in light soils with an inadequate water supply. The flowering period began about a week early in 2017. In these locations, the hops responded to drought stress with low yields, in spite of the fact that there was enough rain in August. In better locations, the hops were able to benefit from the favourable weather conditions in August and produced above-average yields. Only alpha acids development was below expectations. The start of harvest in 2017 in the last week of August was slightly earlier than in previous years. In spite of isolated cases of damage due to storms and hail, storm damage in general was limited and not widespread. The rain which set in and continued from the end of July was conducive to the development of the downy mildew fungus, and 3 further spray warnings for all hop types were needed in August. In contrast, the occurrence of powdery mildew was less widespread compared to the previous year.

Weather data (monthly means and totals) for 2017, compared with 10-year and 50-year mean values

Month		Temperature at a height of 2 m			Relative humidity	Precipi-tation	Days with precipita-tion	Sunshine
		Mean (°C)	Min.∅ (°C)	Max.∅ (°C)	(%)	(mm)	>0,2 mm	(hrs.)
January	2017	-5.7	-10.3	-1.3	92.5	35.7	13.0	57.8
∅	10-yr.	0.2	-3.1	3.6	89.8	63.8	15.4	50.1
	50-yr.	-2.4	-5.1	1.0	85.7	51.7	13.7	44.5
February	2017	2.4	-0.9	6.8	90.1	32.6	7.0	76.1
∅	10-yr.	0.4	-3.6	5.0	86.0	42.4	12.8	81.2
	50-yr.	-1.2	-5.1	2.9	82.8	48.4	12.8	68.7
March	2017	6.9	1.5	12.6	81.5	38.0	13.0	167.8
∅	10-yr.	4.5	-0.5	10.4	79.6	48.1	12.2	149.8
	50-yr.	2.7	-2.3	8.2	78.8	43.5	11.3	134.4
April	2017	12.9	2.3	12.9	78.8	99.8	11.0	158.5
∅	10-yr.	9.6	3.0	16.4	73.1	45.7	10.0	207.4
	50-yr.	7.4	1.8	13.3	75.9	55.9	12.4	165.0
May	2017	14.2	7.8	20.9	77.0	87.0	12.0	266.2
∅	10-yr.	13.5	7.6	19.5	74.9	111.1	15.9	205.1
	50-yr.	11.9	5.7	17.8	75.1	86.1	14.0	207.4
June	2017	18.7	11.1	25.4	69.9	58.9	12.0	280.6
∅	10-yr.	16.8	10.9	23.0	76.1	111.6	15.1	213.1
	50-yr.	15.3	8.9	21.2	75.6	106.1	14.2	220.0
July	2017	18.8	12.4	25.4	76.5	78.0	15.0	219.7
∅	10-yr.	18.6	12.2	25.5	75.5	111.6	14.0	243.6
	50-yr.	16.9	10.6	23.1	76.3	108.4	13.9	240.3
August	2017	18.6	12.5	25.3	82.2	96.8	13.0	235.6
∅	10-yr.	17.8	11.5	25.1	79.3	101.0	12.6	234.8
	50-yr.	16.0	10.2	22.5	79.4	94.9	13.3	218.4
September	2017	11.8	7.0	17.6	88.9	70.2	14.0	127.5
∅	10-yr.	13.5	8.0	20.1	84.3	65.4	11.1	161.3
	50-yr.	12.8	7.4	19.4	81.5	65.9	11.4	174.5
October	2017	9.8	5.4	15.6	90.4	68.6	16.0	122.4
∅	10-yr.	8.4	4.0	13.9	89.0	50.3	10.5	109.3
	50-yr.	7.5	2.8	13.0	84.8	60.0	10.4	112.9
November	2017	4.0	1.5	7.3	95.1	52.7	16.0	29.2
∅	10-yr.	4.2	0.9	8.2	91.5	61.0	11.2	63.9
	50-yr.	3.2	-0.2	6.4	87.5	58.8	12.6	42.8
December	2017	1.4	-1.1	3.9	94.0	66.6	20.0	28.0
∅	10-yr.	0.8	-2.2	4.1	91.3	59.2	14.5	45.8
	50-yr.	-0.9	-4.4	1.6	88.1	49.1	13.3	34.3
∅ 2017		9.5	4.1	14.4	84.7	784.9	162.0	1769.4
10 – year mean		9.0	4.0	14.6	82.5	871.2	155.3	1765.5
50 – year mean		7.4	2.5	12.5	81.0	828.8	153.3	1663.2

The 50-year mean is based on data from 1927 through 1976,
the 10-year mean is based on data from 2007 through 2016.

3 Statistical Data on Hop Production

LD Johann Portner, Dipl.-Ing. agr.

3.1 Production Data

3.1.1 Pattern of hop farming

Tab. 3.1: Number of hop farms and their hop acreages in Germany

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

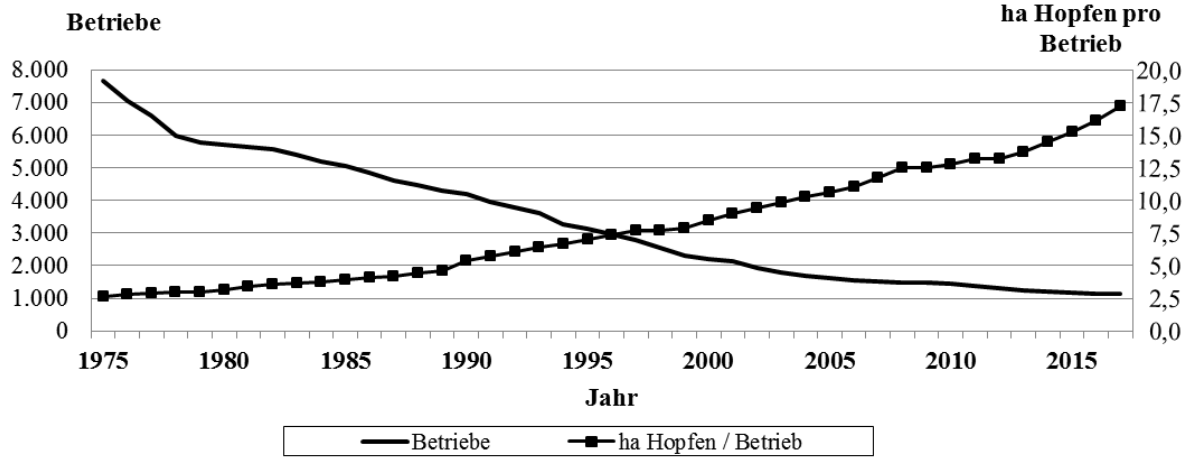


Fig. 3.1: Number of hop farms and their hop acreages in Germany

Tab. 3.2: Acreage, number of hop farms and average hop acreage per farm in the German hop growing regions

Growing region	Hop acreages				Hop farms				Hop acreage per farm in ha	
	in ha		increase + / decrease - 2017 to 2016				increase + / decrease - 2017 to 2016			
	2016	2017	ha	%	2016	2017	farms	%	2016	2017
Hallertau	15 510	16 310	800	5.2	931	912	- 19	- 2.0	16.66	17.88
Spalt	376	391	15	4.0	55	55	± 0	± 0	6.83	7.11
Tettnang	1 282	1 353	72	5.6	135	133	- 2	- 1.5	9.49	10.18
Baden, Bitburg u. Rheinpfalz	22	22	0	± 0	2	2	± 0	± 0	11.00	11.00
Elbe-Saale	1 409	1 466	57	4.0	31	30	- 1	- 3.2	45.44	48.86
Germany	**18 598**	**19 543**	**945**	**5.1**	**1 154**	**1 132**	**- 22**	**- 1.9**	**16.12**	**17.26**

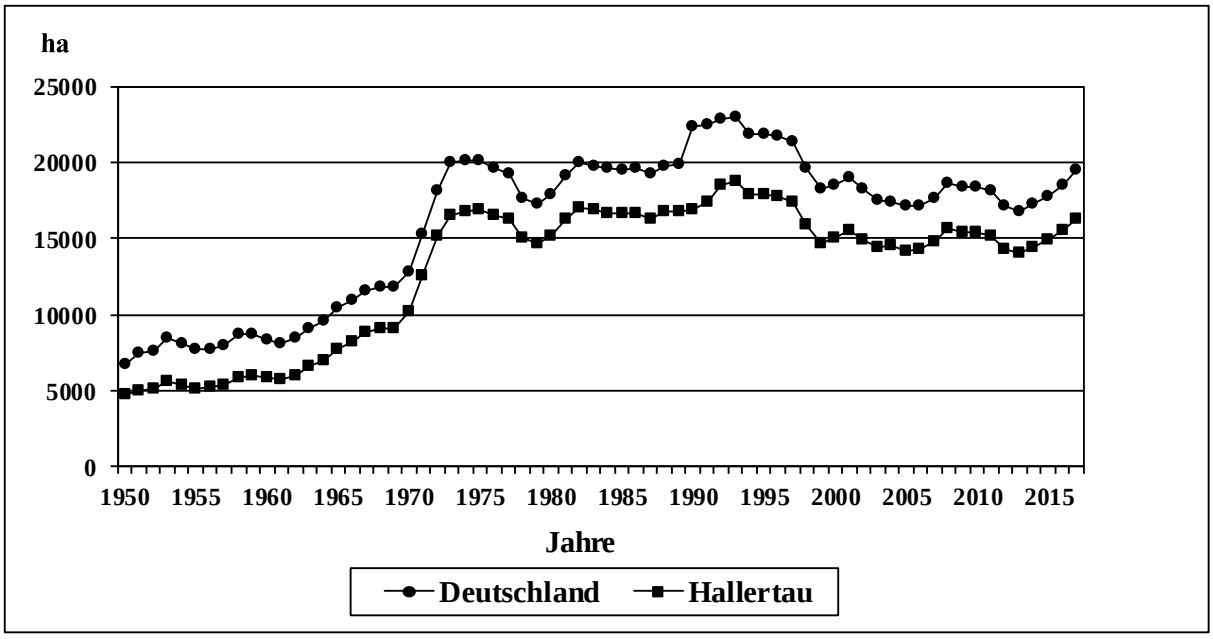


Fig. 3.2: Hop growing acreages in Germany and the Hallertau region

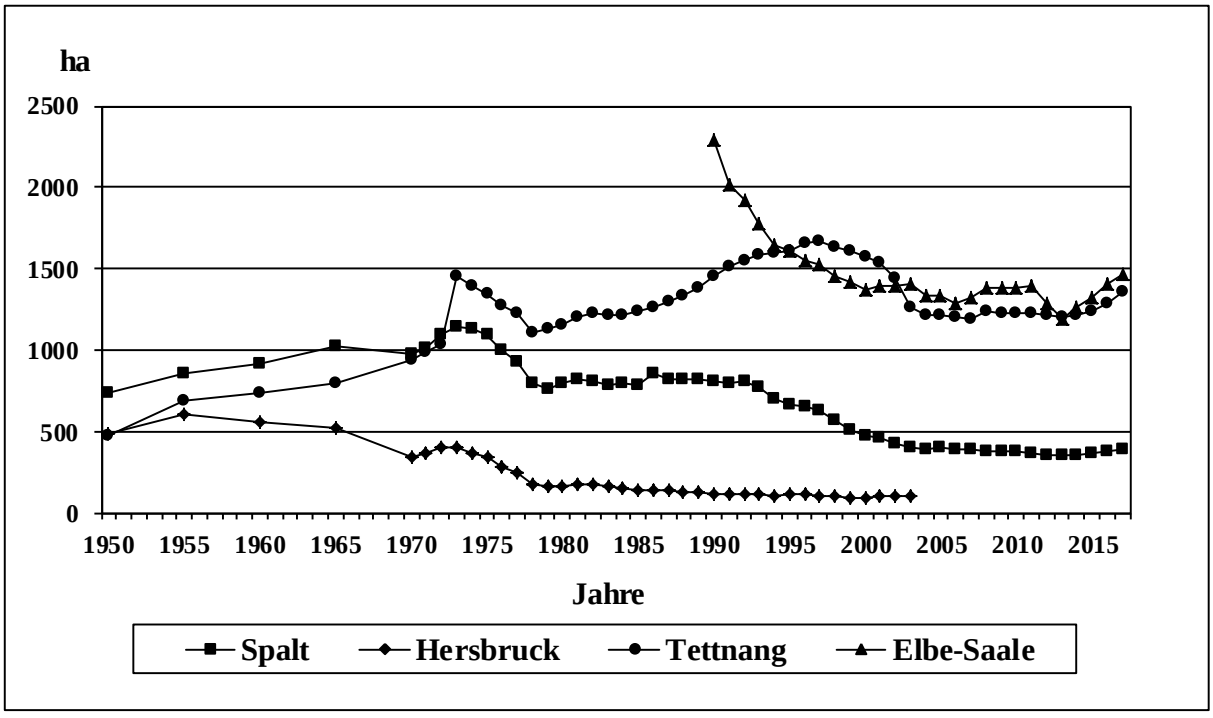


Fig. 3.3: Hop growing acreages in the Spalt, Hersbruck, Tettnang, and Elbe-Saale regions

The Hersbruck region has been part of the Hallertau since 2004.

Hop varieties

In 2017, the acreage under hop once again increased significantly by 945 hectares and now takes up 19 543 ha.

Whereas the acreage under traditional aroma hops such as *Hallertauer Mittelfrüher*, *Hersbrucker Spät*, *Perle* and *Hallertauer Tradition* was on the decline, the area planted to the newer aroma cultivars - *Saphir*, *Opal* and *Smaragd*, and special hops *Saazer*, *Tettnanger* and *Spalter* - grew in size. Likewise, the acreage growing *Northern Brewer*, which is now classified as an aroma variety, also increased. Altogether, the proportion of aroma varieties grown fell by 166 hectares, which equates to 3.5%.

The acreage for bittering hops has increased significantly by 677 ha and now accounts for a share of 43.3%. However, all the older varieties have seen their land area reduced. *Hallertauer Magnum* (-185 ha), in particular, and *Hallertauer Taurus* (-73 ha) have lost out to *Herkules* (+914 ha) and *Polaris* (+68%), and this means that *Herkules* is now the most widely grown hop, making up 29.7% or almost one third of the total acreage under hop in Germany.

The cultivar *Amarillo* (V1) is new to the flavour hops segment and is being cultivated under contract for the American craft beer market on an area covering 280 hectares. The acreage growing other flavour hops has also expanded, with the result that the total acreage for this segment has increased by a third (i.e. by 433 ha) and now accounts for a share of 6.3%.

Tab. 3.3: Aroma varieties by hectare in the German hop growing regions in 2017

Aroma varieties

Hop growing region	Total hop acreage	HA	SP	TE	HE	PE	SE	HT	SR	OL	SD	SA	NB	other	Aroma varieties	
															ha	%
Hallertau	16 310	539			910	2 653	437	2 592	416	138	62	8	162	11	7 929	48.6
Spalt	391	36	121		5	25	81	32	19	1	1			3	325.93	83.3
Tettnang	1 353	147		747	0	56	9	50	37	1	17				1 064	78.6
Baden, Bitburg and Rheinpfalz	22	1				8		4							14	60.8
Elbe-Saale	1 466					222	4	25				129	138		519	35.4
Germany	**19 543**	**723**	**121**	**747**	**916**	**2 966**	**532**	**2 704**	**473**	**141**	**80**	**137**	**300**	**14**	**9 852**	**50.4**
Variety (in **%**)		3.7	0.6	3.8	4.7	15.2	2.7	13.8	2.4	0.7	0.4	0.7	1.5	0.1		

Variety changes in Germany

2016 (in ha)	18 598	733	119	732	940	3 093	534	2 827	450	140	62	113	266	10	**10 018**	**53.9**
2017 (in ha)	19 543	723	121	747	916	2 966	532	2 704	473	141	80	137	300	14	**9 852**	**50.4**
Change (in ha)	945	-10	2	15	-24	-127	-2	-123	23	1	18	24	34	4	**-166**	**-3.5**

Tab. 3.4: Bittering and high alpha varieties by ha in the German hop growing regions in 2017

Bittering and high alpha varieties

Hop growing region	BG	NU	TA	HM	TU	MR	HS	PA	other	Bittering varieties	
										ha	%
Hallertau	16	119		1 387	270	14	5 406	95	33	7 340	45.0
Spalt				3		3	37		2	45	11.5
Tettnang					0		208	5	3	217	16.0
Baden, Bitburg and Rheinpfalz			0	3			5			8	34.7
Elbe-Saale		12		618	14		141	73	1	859	58.6
Germany	**16**	**131**	**0**	**2 011**	**284**	**17**	**5 797**	**174**	**39**	**8 468**	**43.3**
Variety (in **%**)	0.1	0.7	0.0	10.3	1.5	0.1	29.7	0.9	0.2		

Variety changes in Germany

2016 (in ha)	17	152	0	2 196	357	21	4 884	106	59	**7 791**	**41.9**
2017 (in ha)	16	131	0	2 011	284	17	5 797	174	39	**8 468**	**43.3**
Change (in ha)	-2	-21	0	-185	-73	-4	914	68	-20	**677**	**1.4**

Tab. 3.5: Aroma varieties with flavour potential by hectare in the German hop growing regions in 2017

Aroma varieties with flavour potential

Hop growing region	V1	CI	AN	CA	HC	HN	MB	MN	CO	Aroma varieties /flavour potential	
										ha	%
Hallertau	250	58	50	67	143	128	310	28	8	1 042	6.4
Spalt		1	4	5	3	4	3			20	5.2
Tettnang	7	9	7	5	13	13	14	4		72	5.3
Baden, Bitburg and Rheinpfalz				1						1	4.5
Elbe-Saale	24	5		9	11	11	28			87	6.0
Germany	**280**	**73**	**61**	**86**	**170**	**157**	**356**	**31**	**8**	**1 223**	**6.3**
Variety (in **%**)	1.4	0.4	0.3	0.4	0.9	0.8	1.8	0.2	0.0		

Variety changes in Germany

2016 (in ha)	0	31	21	76	154	134	346	20	7	**790**	**4.2**
2017 (in ha)	280	73	61	86	170	157	356	31	8	**1 223**	**6.3**
Change (in ha)	280	41	41	10	16	24	9	11	1	**433**	**2.0**

3.2 2017 Yields

The 2017 hop harvest in Germany produced 41 556 250 kg (= 831 125 cwt) in 2017. In spite of the significant increase (by 945 ha) in the area planted to hop, the crop yielded slightly less than the record volume (42 744 090 kg or 855 322 cwt) of 2016, due to an early summer period that was hot and dry. This meant a drop in volume of 1 209 840 kg (= 24 199 cwt), or 2.8%, compared to last year.

Seen in relation to the total acreage, the per-hectare yield of 2 126 kg/ha is still above average, although this figure is down by 7.5% on last year's crop.

The 2017 alpha acids levels were decidedly lower than the 2016 levels and, for the most part, below the long-term average. Especially for high alpha cultivar Herkules, the yield was disappointing - with an average alpha acids content of 15.5%, i.e. 1.2 percentage points below the long-term mean. In total, the quantity of alpha acids produced in Germany is estimated to be around 4 265 tonnes, a result which is 500 tonnes lower, or a good 10% less, than in the year before.

Tab. 3.6: Crop volumes and per-hectare yields for hop in Germany

	2012	2013	2014	2015	2016	2017
Yield kg/ha or (cwt./ha)	2 013 kg (40.3 cwt.)	1 635 kg (32.7 cwt.) (hail damage)	2 224 kg (44.5 cwt.)	1 587 kg (31.7 cwt.)	2 299 kg (46.0 cwt.)	2 126 kg (42.5 cwt.)
acreage in ha	17 124	16 849	17 308	17 855	18 598	19 543
Total crop in kg or cwt.	34 475 210 kg = 689 504 cwt.	27 554 140 kg = 551 083 cwt.	38 499 770 kg = 769 995 cwt.	28 336 520 kg = 566 730 cwt.	42 766 090 kg = 855 322 cwt.	41 556 250 kg = 831 125 cwt.

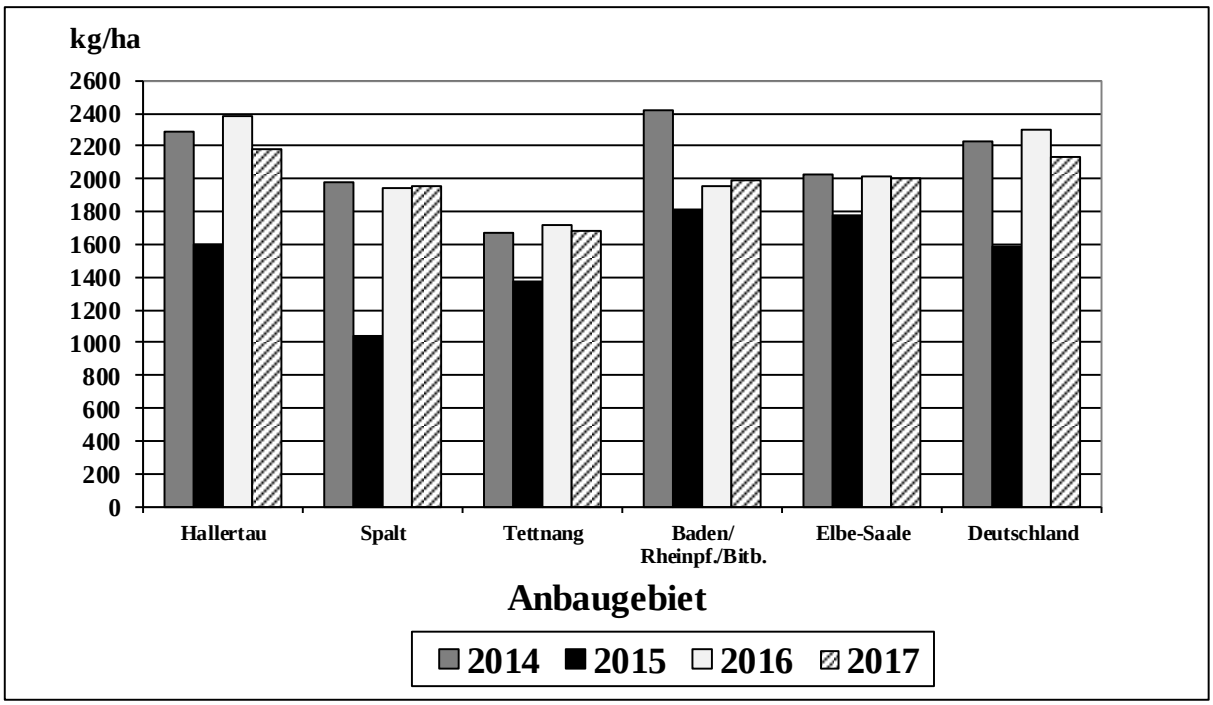


Fig. 3.4: Average yields for the individual growing regions in kg/ha

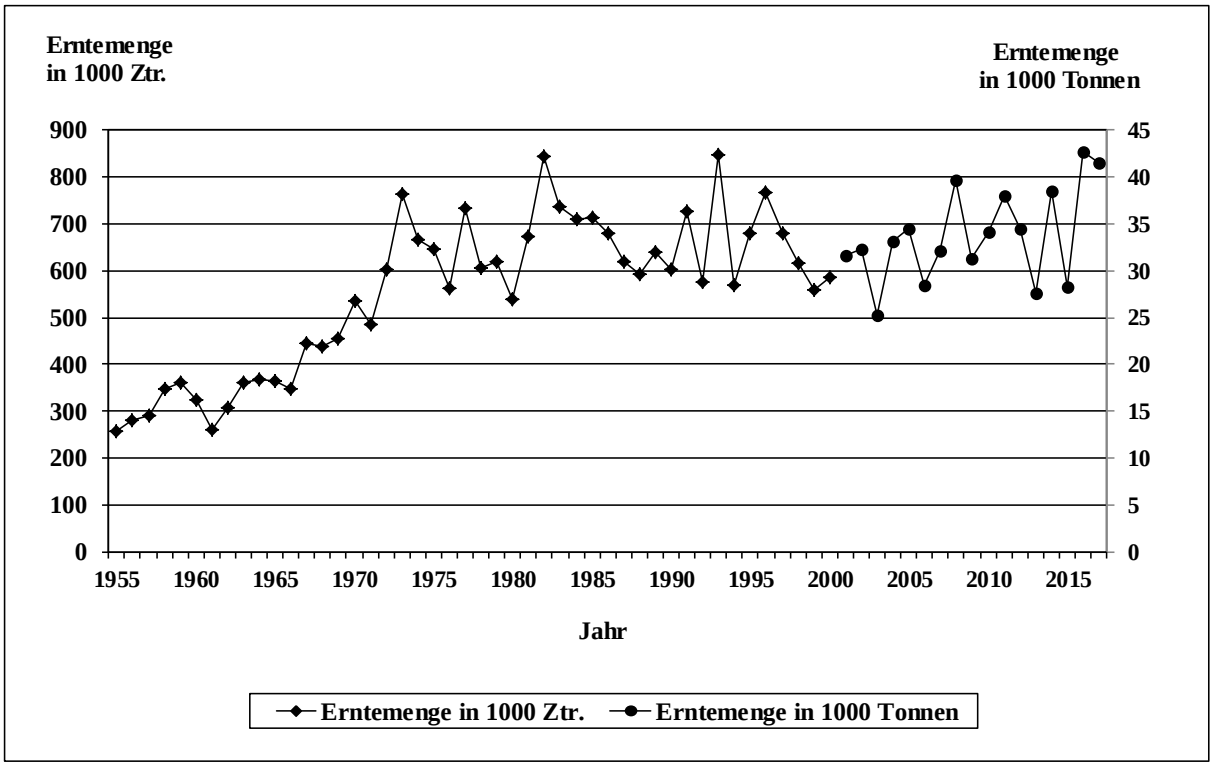


Fig. 3.5: Crop volumes in Germany

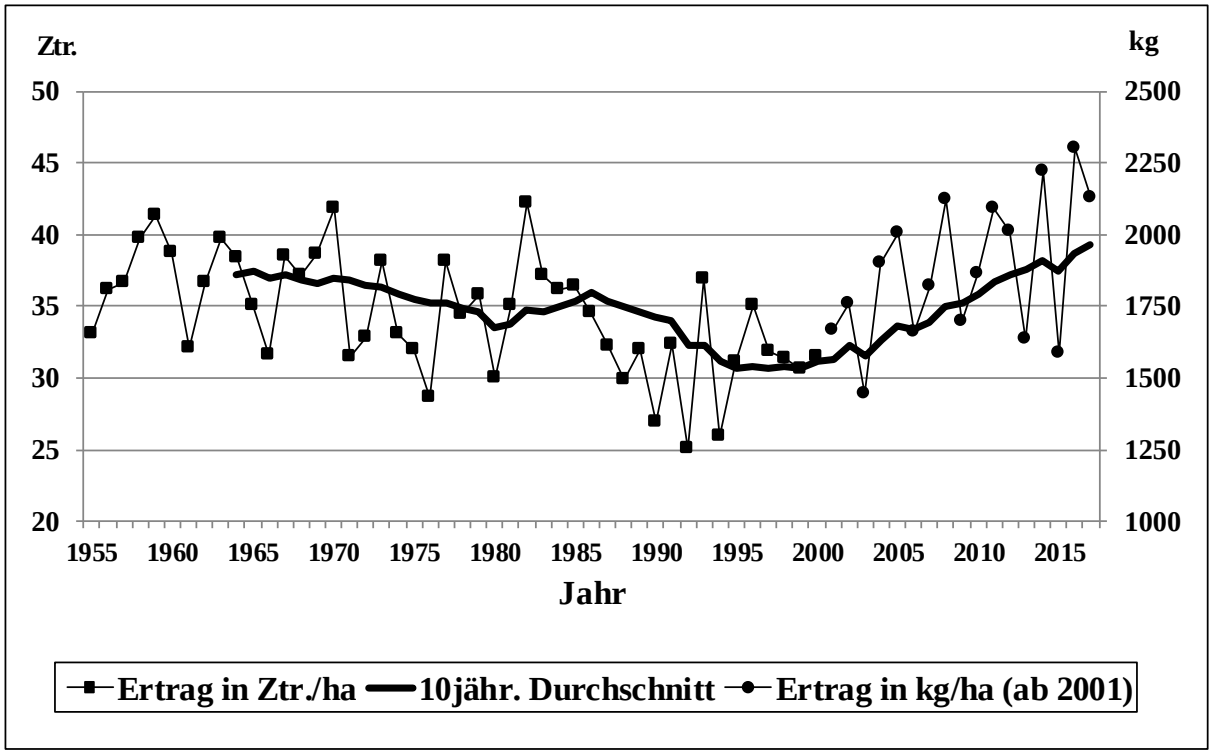


Fig. 3.6: Average yield (cwt. or kg/ha) in Germany

Tab. 3.7: Per-hectare yields in the German hop growing regions

Hop growing region	Yields in kg/ha total acreage								
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Hallertau	1 706	1 893	2 151	2 090	1 638	2 293	1 601	2 383	2 179
Spalt	1 691	1 625	1 759	1 383	1 428	1 980	1 038	1 942	1 949
Tettnang	1 320	1 315	1 460	1 323	1 184	1 673	1 370	1 712	1 677
Bad. Rheinpf./ Bitburg	1 937	1 839	2 202	2 353	1 953	2 421	1 815	1 957	1 990
Elbe-Saale	1 920	1 931	2 071	1 983	2 116	2 030	1 777	2 020	2 005
∅ Yield/ ha **Germany**	**1 697 kg**	**1 862 kg**	**2 091 kg**	**2 013 kg**	**1 635 kg**	**2 224 kg**	**1 587 kg**	**2 299 kg**	**2 126 kg**
Total crop Germany (t or cwt.)	31 344 t 626 873	34 234 t 684 676	38 111 t 762 212	34 475 t 698 504	27 554 t 551 083	38 500 t 769 995	28 337 t 566 730	42 766 t 855 322	41 556 t 831 125
Acreage Germany (ha)	18 473	18 386	18 228	17 124	16 849	17 308	17 855	18 598	19 543

Tab. 3.8: Alpha acids values for the individual hop varieties

Region/variety	2008	2009	2010	2011	2012	2013	2014	2015	2016	**2017**	**Ø 5 years**	**Ø 10 years**
Hallertau Hallertauer	4.4	4.2	3.8	5.0	4.6	3.3	4.0	2.7	4.3	**3.5**	**3.6**	**4.0**
Hallertau Hersbrucker	2.9	3.4	3.5	4.5	3.0	1.9	2.1	2.3	2.8	**2.3**	**2.3**	**2.9**
Hallertau Hall. Saphir	5.1	4.5	4.5	5.3	4.4	2.6	3.9	2.5	4.0	**3.0**	**3.2**	**4.0**
Hallertau Opal	94	9.0	8.6	9.7	9.0	5.7	7.3	5.9	7.8	**7.2**	**6.8**	**8.0**
Hallertau Smaragd	6.7	6.4	7.4	8.0	6.0	4.3	4.7	5.5	6.2	**4.5**	**5.0**	**6.0**
Hallertau Perle	8.5	9.2	7.5	9.6	8.1	5.4	8.0	4.5	8.2	**6.9**	**6.6**	**7.6**
Hallertau Spalter Select	5.4	5.7	5.7	6.4	5.1	3.3	4.7	3.2	5.2	**4.6**	**4.2**	**4.9**
Hallertau Hall. Tradition	7.5	6.8	6.5	7.1	6.7	5.0	5.8	4.7	6.4	**5.7**	**5.5**	**6.2**
Hallertau Mand. Bavaria					8.8	7.4	7.3	7.0	8.7	**7.3**	**7.5**	
Hallertau Hall. Blanc					9.6	7.8	9.0	7.8	9.7	**9.0**	**8.7**	
Hallertau Huell Melon					7.3	5.3	5.4	5.8	6.8	**6.2**	**5.9**	
Hallertau North. Brewer	10.5	10.4	9.7	10.9	9.9	6.6	9.7	5.4	10.5	**7.8**	**8.0**	**9.1**
Hallertau Polaris					20.0	18.6	19.5	17.7	21.3	**19.6**	**19.3**	
Hallertau Hall. Magnum	15.7	14.6	13.3	14.9	14.3	12.6	13.0	12.6	14.3	**12.6**	**13.0**	**13.8**
Hallertau Nugget	12.0	12.8	11.5	13.0	12.2	9.3	9.9	9.2	12.9	**10.8**	**10.4**	**11.4**
Hallertau Hall. Taurus	17.9	17.1	16.3	17.4	17.0	15.9	17.4	12.9	17.6	**15.9**	**15.9**	**16.5**
Hallertau Herkules	17.3	17.3	16.1	17.2	17.1	16.5	17.5	15.1	17.3	**15.5**	**16.4**	**16.7**
Tettnang Tettnanger	4.2	4.2	4.0	5.1	4.3	2.6	4.1	2.1	3.8	**3.6**	**3.2**	**3.8**
Tettnang Hallertauer	4.7	4.5	4.2	5.1	4.7	3.3	4.6	2.9	4.4	**4.4**	**3.9**	**4.3**
Spalt Spalter	4.1	4.4	3.7	4.8	4.1	2.8	3.4	2.2	4.3	**3.2**	**3.2**	**3.7**
Elbe-S. Hall. Magnum	12.2	13.7	13.1	13.7	14.1	12.6	11.6	10.4	13.7	**12.6**	**12.2**	**12.8**

Source: Working Group for Hop Analytics (AHA)

4 Hop Breeding Research

RDin Dr. Elisabeth Seigner, Dipl.-Biol.

Hop breeding work at the Hop Research Center at Hüll is aimed at developing modern, high yielding varieties which meet the needs of the hops and brewing industries. The work pursues the following goals:

- the development of classical aroma varieties with fine aroma profiles typical of hop,
- the creation of robust, high yielding, high alpha hops,
- since 2006, the breeding of aroma varieties with unique, fruity/floral aroma and flavour potential.

For years now, biotechnological and genome-analytical techniques have been employed alongside classical breeding procedures.

4.1 2017 Crosses

A total of 95 crosses were performed in 2017.

4.2 New Breeds from Hüll – less plant protection, less fertilizer - good for the environment, good for the beer

Leads:	A. Lutz, Dr. E. Seigner
Staff:	A. Lutz, J. Kneidl, S. Seefelder, E. Seigner, Team IPZ 5c
Collaboration:	Dr. K. Kammhuber, Team IPZ 5d
	Beratungsgremium der GfH (*Society of Hop Research Advisory Board*)
	Forschungsbrauerei Weihenstephan, Technische Universität München-Weihenstephan, Lehrstuhl für Getränke- und Brautechnologie (*Weihenstephan Research Brewery, Technical University Munich-Weihenstephan, Chair of Brewing and Beverage Technology*) Prof. Becker and Dr. Tippmann
	Bitburger-Braugruppe Versuchsbrauerei, Dr. S. Hanke (*Bitburger Brewery Group experimental brewery*)
	Nationale und internationale Braupartner *National and international brewing partners*)
	Partner aus dem Bereich Hopfenhandel und –verarbeitung (*Partners from the hop trading and hop processing sectors*)
	Verband Deutscher Hopfenpflanzer (*Association of German Hop Growers*)
	Hop growers

With, at present, five aroma cultivars with unique flavour potential and a highly promising breeding line in this range, all developed since 2006, German hop growers have swiftly gained access to the craft beer market.

At the same time, we have continued our efforts to develop classical aroma hops and robust, high yield, high alpha varieties in line with market requirements. Since 2011, we have even been intensifying our breeding activities directed at hops with hoppy-spicy aroma profiles. As part of the breeding project focused on improving *Tettnanger landrace*, breeding lines of promise with a fine Tettnanger aroma profile (see 4.3) are being extensively tested, additionally in collaboration with the Straß experimental station of the LTZ Landwirtschaftliches Technologiezentrum (*Agricultural Technology Center)* in Baden-Württemberg.

Work on developing robust, high yielding, high alpha varieties was stepped up in 2016 with the initiation of our high alpha breeding programme in collaboration with the Elbe-Saale Hop Growers' Association (see 4.4).

The direction taken by the above breeding work reflects the current situation as regards hop growing in Germany (Fig. 4.1). Classical aroma hops are slightly ahead of high alpha varieties. New aroma hops with special flavour potential account for a significant 6.3 % of total hop acreage. US growers are concentrating fully on the craft beer sector, with 78 % of the total hop growing acreage (22 920 ha) now planted to aroma/dual use hops; whereas the acreage under high alpha varieties has decreased in the last seven years, from over 70% to only 22% at present. For details go to the website https://www.usahops.org/img/blog_pdf/104.pdf).

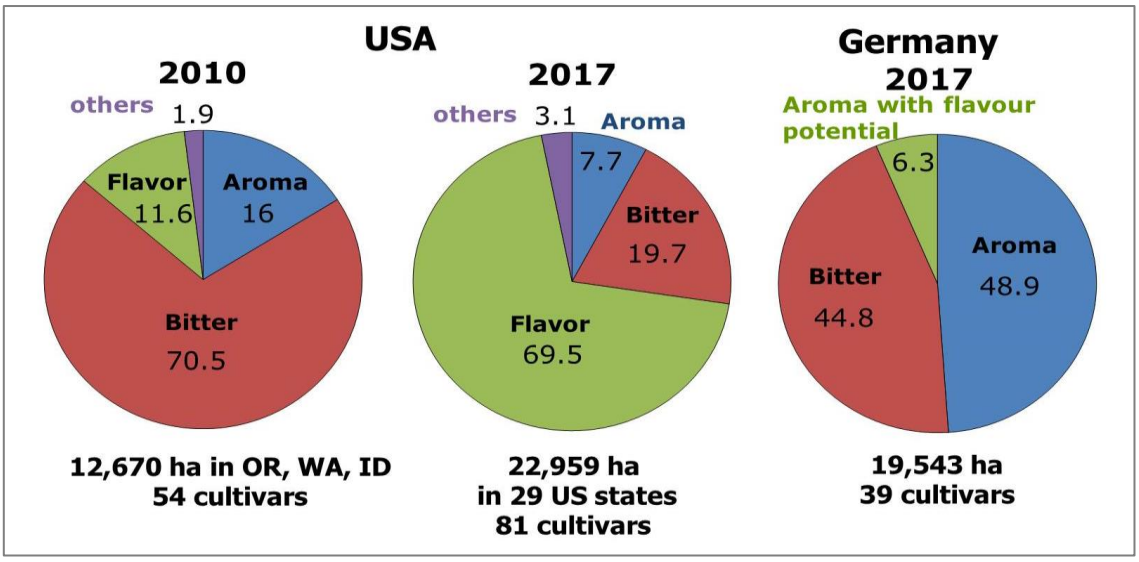


Fig. 4.1: Changes in acreages devoted to growing aroma, bittering and aroma hops with special flavour potential in the USA between 2010 and 2017, and the situation in Germany in 2017. Details given in % of the total acreage; additional information on total acreage, main hop producing states (WA = Washington, OR = Oregon, ID = Idaho) and number of varieties grown acc. to I.H.G.C.list of varieties.

In the new breeds from Hüll great emphasis has been placed not only on the constituent compounds which influence brewing quality, but also on enhanced resistance to the most prevalent pests and diseases. Thanks to broad spectrum resistances and tolerances, these hops require considerably smaller amounts of plant protection products, while still producing healthy cones of the best brewing quality.

Furthermore, work continues on systematically developing new varieties that can produce consistently high yields with less fertilizer application. For decades now, we have been using greatly reduced amounts of nitrogen in the breeding yard, which has allowed us to select breeding lines with optimized nitrogen use efficiency. There are statistics to support this for the cultivar *Herkules* and the new Hüll aroma hops (MBA, HMN, HBC, CAL and ANA).

The low-nitrogen strategy is not only gentle on the environment, it also ensures there are low nitrate levels in the cones, so that there is no problem with using larger quantities of hop, as in dry hopping for example. Issues with wilt disease caused by the *Verticillium* fungus can also be alleviated with smaller nitrogen dosages.

Fig. 4.2: Seedling cultivation starts with screening for PM resistance in the greenhouse at Hüll

Fig. 4.3: Only PM-resistant seedlings without leaf infestation are then pricked out and cultivated as individual plants in preparation for the subsequent test for downy mildew tolerance

Selection in collaboration with the hops and brewing industries

As already frequently reported, the effectiveness of the breeding process has been decisively improved thanks to closer collaboration with the hops and brewing industries. In a four-step selection procedure together with all stakeholders in the value chain - growers, traders, and brewers - the most promising breeding lines were evaluated. The appraisal with respect to a possible variety release placed equal importance on yield, brewing quality, aspects regarding environmental protection, and resource conservation. Cultivars *Ariana* and *Callista*, released by the GfH (*Society of Hop Research*) in 2016, were developed in close collaboration with the hops and brewing industries. The process is described in Fig. 4.4.

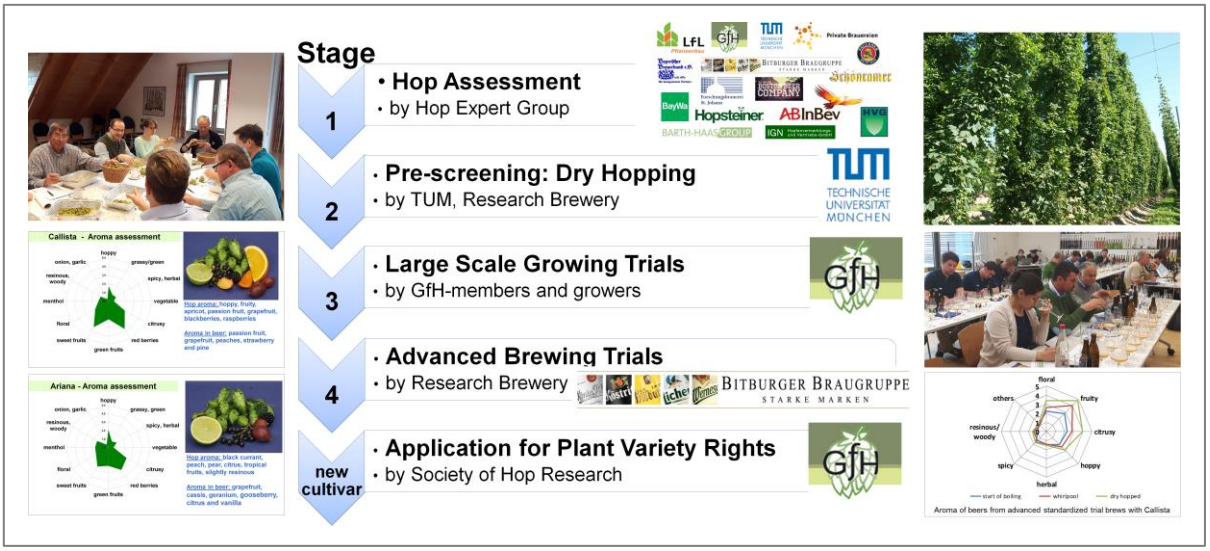


Fig. 4.4: Four-step selection process in close collaboration with the hops and brewing industries

At present, two older hop breeding lines with very fine aroma profiles (noble hops) and one new aroma line with an aroma that has a distinctive hint of grapefruit are under-going large-scale field trials. Additional individual brewing trials confirm their flavour potential in the respective ranges.

Standardized brewing trials

Since 2015, appraisal of the brewing quality of special aroma breeding lines has been conducted in accordance with a standardized procedure. In the autumn of 2017, the GfH panel of experts also drew up a standardized procedure for brewing trials to evaluate bittering quality in high alpha lines.

A standardized procedure for test brewing of aroma varieties with classical aroma profiles will be established shortly.

This means that standardized procedures for conclusive brewing trials for all the above mentioned breeding lines will finally be available. The hops and brewing industries will then have at their disposal practical knowledge as to the brewing quality of the aroma, special aroma, and high alpha lines being tested, as well as, ideally, having access to prior information about the potential brewing suitability of a new cultivar when it is introduced into the market.

4.3 Crossbreeding with Tettnanger Landrace

Objective

The aim of this breeding programme is significantly to improve yield potential and fungal resistance in Tettnanger landrace, while retaining the aroma profile as close to the original as possible. The hop needs to be adapted to suit the present climatic conditions in order to deal with the early flowering problem caused by higher temperatures. Moreover, a modern cultivar is expected to make more efficient use of nutrients, a crucial factor in implementing the new fertilizer ordinance.

Method

This objective cannot, however, be achieved solely through selective breeding within the naturally occurring variability of Tettnanger landrace. Therefore, attempts must be made to obtain the desired result through crossbreeding for traits of interest with preselected male aroma lines which deliver broad spectrum disease resistance and, on account of their relatedness, good agronomic performance.

Thanks to the application of only minimal amounts of plant protection products and reduced quantities of nitrogen during the growing trials (seedling screening and female advanced selections) in our breeding yards, selection has, for many years now, been focused to select the most robust, resistant hops with the most efficient nutrient uptake.

Results

Seedling assessment

Since 2010, 29 specifically created crosses have been performed; over 1 100 female seedlings have been preselected for their resistance and vigour, planted out in the breeding yard at Hüll and trialled over a three-year period.

So far, a total of 11 promising candidates have been chosen for the female advanced selections on the basis of their good agronomic traits, resistances/tolerances and pleasing compounds.

Female advanced selections

In the 2015 season, the first two breeding lines from the Tettnanger breeding programme underwent a growing trial at two locations in the Hallertau, and then, from 2016, at the Straß experimental station in Tettnang. There followed seven more lines in a test of performance potential in different soils and different weather conditions during this four-year trial period. As a result, judgements with respect to vigour, yield, disease resistances, compounds and aroma will be far more reliable. Two new lines reached this crucial trial phase in the 2017 season.

Outlook

The female advanced selections are followed by on-farm field trials. A breeding line must pass further real-world tests on commercial farm plots (field trials in rows and large-scale field trials), a test phase which cannot begin for the first new breeding lines from this crossbreeding programme before 2020, at the earliest.

4.4 Development of Healthy, High Yielding Hops with High Alpha Acids Content, Especially Suited to Cultivation in the Elbe-Saale Region

Objective

The goal of this research project is to produce and test new robust, high yielding hop breeding lines, notable for their alpha acids levels and their broad spectrum resistance/tolerance to fungi and pests, in particular to the pathogens causing crown rot. Furthermore, a modern hop is expected to deliver maximum yields as a result of optimized nutrient use efficiency, in spite of receiving reduced levels of nitrogen.

Eventually, competitive new varieties are to achieve approval with a view to securing the area’s long-term ability to compete as a successful hop producing region in world markets.

Implementation

- **Crosses**

The LfL provides breeding lines and cultivars for the crossbreeding programme from their own breeding material, selected for the desired traits. The crosses, the nursery work and pre-selection for resistance/tolerance to powdery mildew and downy mildew are carried out in the greenhouses and the LfL breeding yard at Hüll. The subsequent 3-year seedling assessment, involving individual plants and female advance selections, will also take place at LfL sites. At the same time, the use of plant protection products and fertilizer will be systematically reduced, and hops will be selected for their robustness, resilience and optimized nutrient uptake.

All further selection stages will take place simultaneously in the Hallertau and the Elbe-Saale region.

Chemical analysis of the cones will be performed by Dr. Kammhuber and his IPZ 5d team at Hüll. Up to the end of the seedling assessment stage, the bitter compounds of the seedlings are to be analysed by NIRS (near infrared spectroscopy) and an organoleptic examination of the aroma quality carried out. Only highly promising seedlings earmarked for advanced female selections are to undergo detailed analyses of their bitter substances using HPLC (High Performance Liquid Chromatography).

- **Row planting trial growing Hüll high alpha lines in the Elbe-Saale region**

New, highly promising breeding lines from the current LfL breeding programmes are being tested in real-world conditions in the Elbe-Saale region, in order to find out which breeding lines are suitable for cultivation in the local conditions and will be able to deliver the required performance traits and resistances to diseases there.

Results

Crosses

37 crosses were performed in 2017 with the above objective in mind. As of May 2017, there were altogether 1 532 seedlings from 40 crosses with the goal ‘high alpha’ in the vegetation hall after pre-screening for resistance.

Promising candidates are currently undergoing the 3-year seedling assessment in the breeding yard at Hüll or the 4-year advanced female selections at Hüll and/or Stadelhof.

Row planting trial in the Elbe-Saale region

In addition, it has been possible to glean more information on the row planting trial underway since 2014 on a hop farm in the Elbe-Saale region.

At present, three Hüll high alpha breeding lines are being trialled at the Berthold farm for comparison with *Hallertauer Magnum, Herkules, Polaris* and *Ariana*. Only high alpha lines noted for their good plant health in the breeding yard at Hüll (see *Tab. 4.1*) were chosen.

After pruning, it soon became obvious that in the case of breeding line 2010/075/764 the stand was becoming more and more heterogeneous over the years. Altogether 12 gaps occurred after pruning. Around 20 April there was a severe ground frost. Here too, this breeding line showed the most sensitive reaction. At this early stage, cultivar *Ariana*, which was newly planted out only in 2016, proved to be highly robust and vigorous.

Tab. 4.1: Results of row planting trial of Hüll high alpha lines (row with 102 plants per breeding line) with an Elbe-Saale grower; Hallertauer Magnum, Herkules and Polaris as reference varieties; [1] α acids content in % by weight air-dry acc. to EBC 7.4

Properties	Hallertauer Magnum	Herkules	Polaris	Ariana	Breeding line 2010/75/764	Breeding line 2010/80/728	Breeding line 2011/71/19
Year planted	1998	2001	2012	2016	March 2014	June 2015	June 2015
assessment of aroma	pleasant	pleasant	pleasant, special aroma	pleasant, fruity, special aroma	pleasant	medium	pleasant
Alpha acids (%)[1]	**12.8** (10.6 – 14.5)	**13.9** (13.5 – 14.5)	**17.1** (16.3 – 18.2)	**8.2 – 9.7**	**12.8** (11.5 - 13.7)	**18.8** (18.5 - 19.0)	**16.4** (15.6 - 17.2)
Yield (kg/ha) **Harvest 2014** **Harvest 2015** **Harvest 2016** **Harvest 2017**	 2.210 1.640 2.830 2.925	 3.230 1.640 2.500 1.950	 2.850 1.900 2.435 2.785	 1.651 (Jungh.) 4.488	 2.615* 3.030 3.010 2.750	 2.210 3.375	 2.230 2.930
kg α-/ha	**314** (174 – 410)	**325** (221-453)	**424** (309 – 507)	(160) **- 368**	**372** (348 – 392)	**522** (420 – 624)	**420** (383 – 457)
Plant health	very good	poor	good – v. good	very good	medium	good	good
Agronomic assessment		yield potential reduced due to crown rot	robust, medium – poor twining ability	weighty, robust, good broad resistences	top-heavy, weighty, α-acids highly variable	full PM resistance, low number of cones, promising yield potential	good PM resistance, good stature, high yield potential

Thanks to the favourable amounts of rainfall - in contrast to conditions in the Hallertau - all breeding lines and reference cultivars continued to developed well over the 2017 growing season. *Hallertauer Magnum* produced its highest yield since the start of the trial, namely more than 2 900 kg/ha. The yield from high alpha breeding line 2011/71/19, planted in 2015, was slightly more than that from *Hallertauer Magnum*, with a roughly 2% higher alpha acids content. Breeding line 2010/080/728 produced the highest alpha acids yield with an output of over 600 kg/ha. *Ariana* was the most homogeneous crop and produced the highest yield, which was just under 4 500 kg/ha.

At the end of March 2017, the new Hüll aroma breeding line 2011/02/04, released in 2016 for large-plot trial plantings, was planted out in order to test whether the hitherto good plant health rating can be maintained in the difficult Elbe-Saale conditions.

Outlook

Before any reliable observations can be made about the breeding lines involved in the row planting trials, each of the breeding lines will have to undergo these growing trials over a period of five years.

The first findings concerning the promising new breeding lines from the crossbreeding programme are not expected until after the 3-year seedling assessment in the Hüll breeding yard, i.e. in 2020/2021 at the earliest.

4.5 Research Into and Work On the Problem of *Verticillium* on Hop

Managing *Verticillium* wilt disease in the German hop growing regions is a long-term undertaking. The research conducted and the guidance provided by the LfL and the implementation by hop growers of preventive plant cultivation measures play a crucial role in the concerted efforts to control *Verticillium* in hop growing.

Molecular detection direct from the hop bine via Real-Time PCR

Objective

Apart from the implementation of phytosanitary and horticultural measures, (see *Green Pamphlet*) the use of *Verticillium*-free planting material plays a decisive part in preventing the further spread of the *Verticillium* wilt fungus in the hop growing regions.

In order to secure *Verticillium*-free planting material for the LfL's own growing trials, for the propagators under contract to the Society of Hop Research (GfH) and, consequently, for hop growers, hops are examined for evidence of the fungus before propagation. To this purpose, a highly sensitive molecular detection technique was devised and established in our laboratory (Maurer et al., 2013), by means of which it is possible relyably to say whether or not a plant is infested with *Verticillium* (Seigner et al., 2017).

Method

Molecular detection direct from the hop bine via Real-Time PCR (Polymerase Chain Reaction) based on Maurer, Radišek, Berg und Seefelder (2013).

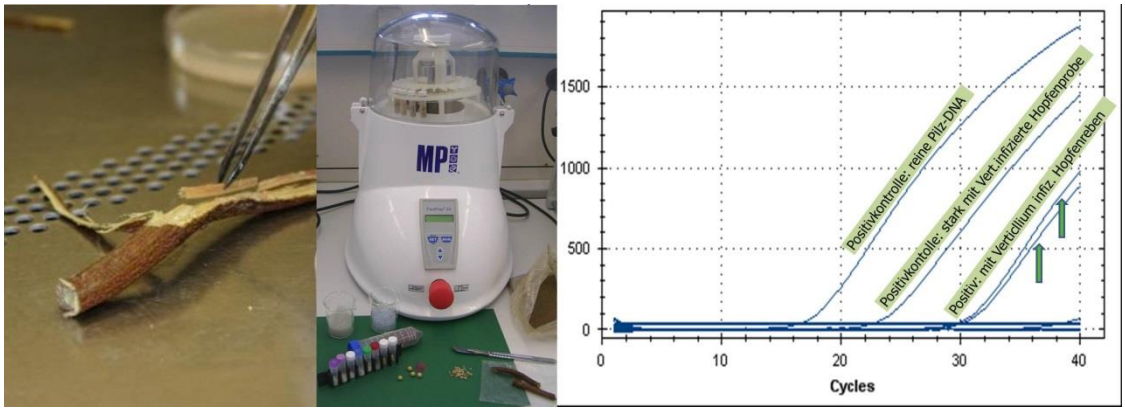


Fig. 4.5: Stages of Verticillium detection procedure, from sample taking, to homogenization of the bine material, to molecular detection via Real-Time PCR

A segment of inner core of a hop bine, containing water-conducting vascular tissue and, thus, potentially also *Verticillium* spores or mycelium, is dissected out of the hop bine for examination. This bine segment is then shredded in a homogenizer, after which DNA is isolated; hop DNA as well as DNA from possible fungal contamination in the vascular tissue is also isolated. Through Real-Time PCR, using primers and probes specific to *Verticillium,* any fungal infestation eventually shows up as an increase in the intensity of the fluorescent signal between amplification cycle numbers 18 to around 35.

Advantages of the Real-Time PCR detection technique

- highly specific
- no likelihood of confusion with other fungal infections
- even tiny amounts of fungus are captured
- simultaneous detection of *Verticillium nonalfalfae* and *Verticillium dahliae* in what is known as a multiplex PCR cycle. A so-called internal control always makes sure that the PCR reaction functions correctly, in order to rule out any 'false negatives'.
- result 2 days later

A disadvantage of the Real-Time PCR detection technique

- Detection is based on the available DNA, which can still be detected during the process of decay. Real-Time PCR does not, therefore, clearly show whether the *Verticillium* fungus is still contagious or is already dead.

Conventional PCR with *Verticillium*-specific primers

Alongside Real-Time PCR, conventional PCR is also employed with specific primers, in accordance with the EPPO guidelines (Down et al., 2007), to support and supplement any issues in diagnosing *Verticillium*. Up to mid-2017, this was the only method, using the primers developed by Seefelder und Oberhollenzer (unpublished), of distinguishing between mild and lethal strains. Conventional PCR was also used to verify the results from Real-Time PCR, in spite of the fact that the sensitivity is lower than that of Real-Time PCR.

Results

In 2017, approximately 3 330 hop samples were examined for *Verticillium*, using Real-Time PCR. Conventional PCR was used with 1 980 samples. The goals pursued were as follows:

- examining the Hüll breeding material for *Verticillium nonalfalfae* and *V. dahliae* and distinguishing infection caused by mild strains from those caused by lethal strains of *V. nonalfalfae*
- molecular verification of wilt disease symptoms in the Hüll breeding yard, in the two wilt selection yards and on commercial farm plots, in collaboration with S. Euringer, IPZ 5b
- examining regenerated meristem plants after 'hoped for' elimination of *Verticillium* through heat therapy and meristem culture
- improving technique (optimization of primers, temperature) and testing of different reference genes as an internal control (DRH1, CAC, COX); testing of primers published by Guček et al. (2016) for detecting and distinguishing mild and lethal strains of *V. nonalfalfae,* in collaboration with Dr. B. Büttner, IPZ 1b, and Dr. L. Seigner, IPS 2c.
- Comparing the sensitivity of different detection methods (fungal growth, Real-Time PCR, conventional PCR with specific primers), in collaboration with S. Euringer, IPZ 5b, and Dr. P. Büttner, IPS 2a

Internal control with Real-Time PCR

Since 2016 work on optimizing Real-Time PCR has been underway (Multiplex-TaqMan®-Realtime-PCR). A recent change is the now standard use of a so-called internal control in a multiplex assay for detecting *Verticillium nonalfalfae* and *V. dahliae* run alongside the specific primers and gene probe for plant-specific DNA (COX for cytochromoxidase; Weller et al., 2000). This means that 'false negative' results from the Real-Time PCR cycle, caused by interference factors as well as errors in extraction of the DNA, can be ruled out.

Distinguishing mild and lethal strains of *Verticillium nonalfalfae* via Real-Time PCR

Another objective was differentiating between mild and lethal strains of *Verticillium nonalfalfae,* not only via conventional PCR, but also using the more sensitive Real-Time PCR. We tested primer pairs from Guček et al. (2016) and the above mentioned primers from Seefelder und Oberhollenzer (unpublished), whereby the corresponding gene probes were designed and tried out by means of a software package (CLC Genomics Workbench, Qiagen). As far as is currently known, the Real-Time system based on the primers from Seefelder and Oberhollenzer delivers reasonably reliable information with regard to infestation of hop with lethal and mild strains of *V. nonalfalfae*, which corresponds to the symptom assessments.

Creation of a reference collection for *Verticillium*

At the beginning of 2017, once more work was done on building up a *Verticillium* reference collection, based on single-spore isolates.This involved isolating both mild and lethal strains of *Verticillium* (from the Hüll breeding yard, *Verticillium* selection plots, and from individual commercial farm plots); these were characterized by means of Real-Time PCR and conventional PCR and finally preserved as glycerine stock solutions, in order to maintain their virulence properties over a long period. They are needed as positive control samples in all PCR tests. This strain collection should be available for future strategies for research into issues associated with *Verticillium.*

Outlook

Work on optimizing the Real-Time PCR system is ongoing. A constant check is kept on whether the primers used in the PCR reaction for detecting *Verticillium nonalfalfae* still cover all the mild and aggressive species occurring in the Hallertau region.

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4.6 Meristem Culture to Obtain Healthy Planting Material

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

Objective

Verticillium as well as viruses on hop can cause devastating yield losses and harm to quality, but these diseases cannot be kept down by means of plant protection agents. For this reason, a biotechnological method - the meristem culture - has now taken on greater importance. It involves regenerating healthy, virus- and *Verticillium*-free plants from shoot tips taken from infected hop plants, following heat treatment. Based on the assumption that the meristem is not connected to the functioning vascular system and also on the conclusion that even inadvertently introduced viruses or fungal structures have been deactivated after heat treatment, it should be possible successfully to regenerate pathogen-free hop plants from heat-treated meristems.

Method

For the purpose of producing *Verticillium*- and virus-free hop plants, the uppermost tip of a shoot (= meristem), is excised following heat treatment and cultured on a tissue culture medium. Thanks to special nutrients in the tissue culture medium, leaf structures emerge from a meristem after about 3 weeks, which then go on to develop into a complete plant.

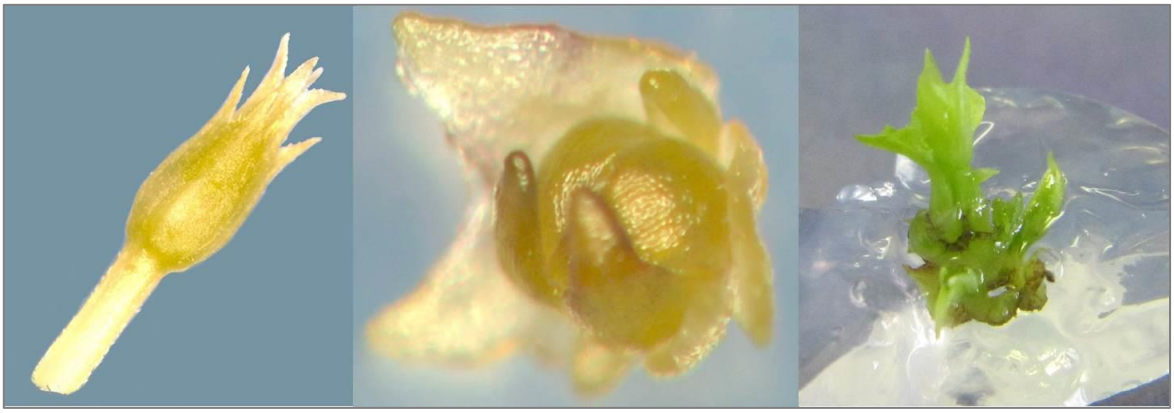

Fig. 4.6: The meristem is excised from the heat-treated shoot tip; on a culture medium it goes on to develop into a hop plantlet

In order to make sure that the meristem-derived hops are virus-free, the leaves are examined for the various viruses typical in hop. This is done by Working Group IPS 2c, using the DAS-ELISA (Double Antibody Sandwich Enzyme Linked Immunosorbent Assay) technique or RT-PCR (Reverse Transcriptase Polymerase Chain Reaction).

For verification of the successful elimination of the *Verticillium* fungus through the meristem culture technique, the plantlets generated in vitro are examined for *Verticillium* via Real-Time PCR, using specific TaqMan probes and primers (Seigner et al., 2017).

Results of optimization of the meristem culture technique

The first step in the development of the excised meristem - the formation of small leaves - happens relatively fast, but continuing growth and the regeneration of a complete shoot is a highly time-consuming process and can take up to 10 months. This is mainly because the regenerated plantlets eventually have to be cloned in order to produce enough starting material for the subsequent analyses to verify their *Verticillium*- and virus-free status.

With a view to accelerating the whole process quite significantly, different culture process parameters were investigated and optimized. Above all, thanks to the use of RITA®-fluid culture systems, the time required for regeneration of the plantlets was considerably shortened, as opposed to the timeframe for the process using only an agar-solidified culture medium. The plants derived from meristem culture were healthier, while, at the same time, the influence of genotype on the capacity to regenerate was greatly reduced.

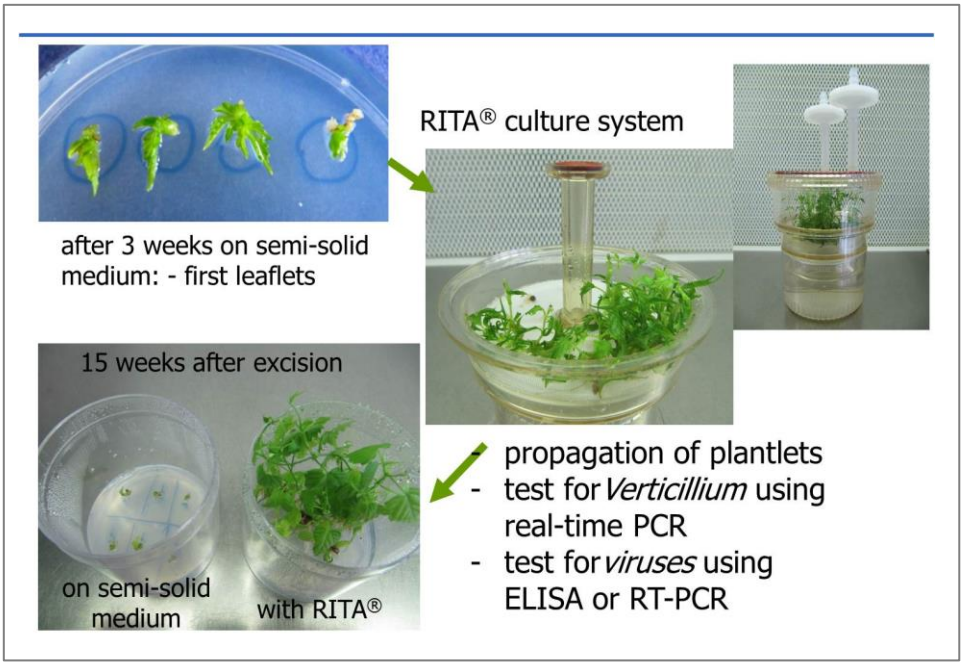

Fig. 4.7: Regeneration of a meristem to become complete hop plantlets cultured in fluid and on a solid medium. Markedly faster development of vigorous, healthy hops using the fluid culture process.

As growth of the small leaves emerging from the meristems continues, either exclusively on a solid medium or using the RITA fluid culture, it becomes clear, 15 weeks after the meristem excision, that there are obvious differences between the culture systems. The fluid culture process facilitates faster regeneration of more vigorous plantlets. The meristem-derived hop plantlets are propagated (cloned) and subsequently examined for viruses and *Verticillium*. Only pathogen-free plantlets are planted in soil and made available as healthy planting material.

Since 2015, this meristem culture procedure has been used in successfully eliminating *Verticillium* infections in 20 breeding lines; 7 additional lines were free of viruses after the procedure.

Outlook

Work on further optimizing the regeneration of meristems continues and is currently focused on improving the effectiveness of meristem culture in eliminating pathogens. The main challenge now is the elimination of viroids.

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4.7 Establishing a Detached Leaf Assay to Assess the Level of Tolerance in Hop to Downy Mildew (*Pseudoperonospora humuli*)

Leads: Dr. E. Seigner, A. Lutz
Staff: B. Forster

Again and again. when hops become infected with downy mildew, a condition caused by the fungus *Pseudoperonospora humuli*, hop growers are confronted with enormous problems. In the wet summer of 2016, in particular, the incidence of downy mildew became increasingly frequent in commercial farms. For decades now, the well-established downy mildew warning service has been helping growers in their struggle to combat this fungal disease effectively. One of the most important contributions towards dealing with the problem is through breeding efforts, focused on developing hops with markedly improved tolerance to the fungus. Every year, thousands of new seedlings undergo greenhouse spraying with a fungal spore suspension in order to screen for downy mildew tolerance at an early stage. This is then followed by an assessment of their reaction to the fungus. During this mass screening process, it is not possible to establish the level of tolerance in the individual hops with any precision.

Objective

To enable fact-based judgements to be made regarding the tolerance of individual seedlings or cultivars, a standardized testing system based on detached leaves (detached leaf assay) is to be established in the laboratory, by means of which tolerance or susceptibility to downy mildew can be accurately and reliably assessed. Only tolerance to so-called secondary infection is examined in this context, i.e. how susceptible or resistant the hop is to the sporangia of the fungus, which land on the leaves from the outside. When humidity is very high, the zoospores are released from the sporangia, penetrate the interior of the leaves through the leaf stomata and develop into a fungal mycelium. The leaves of susceptible hops then exhibit the typical symptoms of fungal infection - yellowish (chlorotic) spots which later turn brown (necrosis).

Method

The undersides of the leaves of hops with very different tolerances to downy mildew are sprayed with the downy mildew sporangia suspension. Five to fourteen days after inoculation, the reaction of the leaves is visually assessed, in part using a microscope. The following infection scenario unfolds: when humidity is very high (> 90%), i.e. in practice when it rains, the zoospores (mobile spores) are released from the sporangia and find their way into the interior of the leaves via the leaf stomata. Within only a few days, a fungal mycelium develops, which then spreads out in the interior of the leaf (intercellular space) and, in turn, can grow out of the stomata again. This is followed by a grey-black coating of spores visible on the leaf underside (zoosporangia on carriers = sporulation). The symptoms (chlorosis, necrosis, sporulation) are monitored and evaluated 5 to 14 days after inoculation (dpi).

The leaves are rated on a scale from 0 to 5, focusing on sporulation: 0 (highly tolerant) = no symptoms; 1 (tolerant) = 1-10%; 2 (medium) = 11-30%; 3 (susceptible) = 31-60%; 4 (highly susceptible) = 61-80%; 5 (extremely susceptible) = 81-100% of the leaf's surface is affected.

Results

Work on establishing and optimizing a leaf assay has been in progress since 2012. Building on research done in the USA, the UK and the Czech Republic, and studies carried out by Dr. Kremheller at Hüll in the 1970s and 80s, the various test parameters were reviewed. First findings in this context were collated in 2013 in a bachelor thesis (Jawad-Fleischer, 2014). After further improvements in reproducibility and in maintaining the vitality of the zoospores, it became possible, depending on the tolerance to downy mildew, reliably to produce chlorosis, necrosis and, in the case of susceptible hops, sporulation, on the leaves being tested. In 2016, some of the individual parameters of the leaf test system were further modified *(Fig. 4.8)*. The main focus was on optimizing the temperature regime. By maintaining temperatures at a constant 20-22°C during the dark/light phase, it was possible to accelerate the development of the necrosis signifying the death of the host cells to such an extent that sporulation on the dead leaf cells was no longer possible. Only after the temperature had been lowered to 13°C during the 12-hour dark phase was sporulation of the downy mildew fungus already detected on the leaves of susceptible hops in the first days immediately after inoculation, before, in the course of the infection, the host cells later died as a consequence of infestation by downy mildew (distinct patches of necrosis). This made it possible to differentiate clearly between the two reactions.

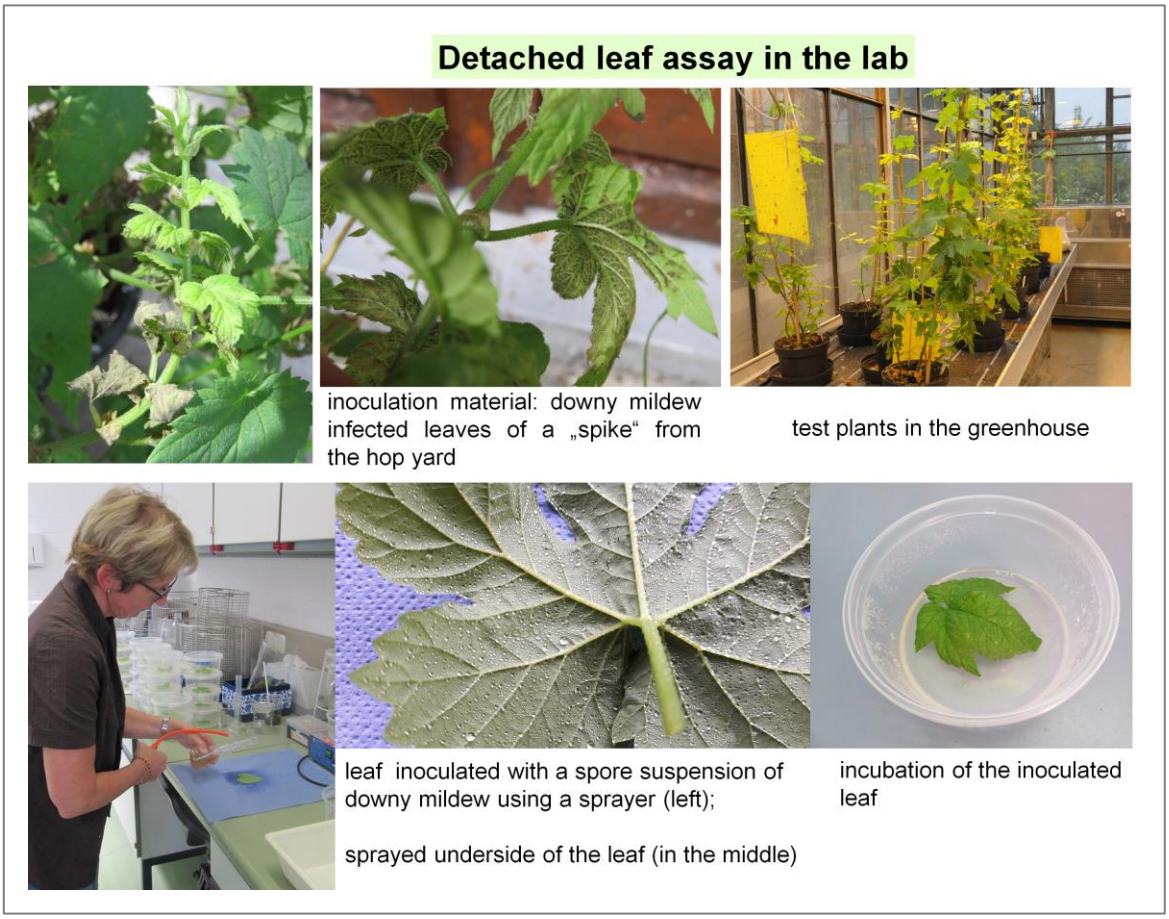

Fig. 4.8: Leaf testing procedure, starting with preparation of the fungal spore solution and the hop plants ready for testing in the greenhouse, spraying of the test leaves with downy mildew suspension and incubation of the sprayed leaves in containers in the incubator

Optimized parameters for the detached leaf assay:

- **age of the leaf:** leaves of the 3rd node of greenhouse plants
- whole leaves rather than leaf discs
- **inoculation material:** fresh, stunted, yellowish shoots known as 'Bubiköpfe'
- rinsing the sporangia off the leaf with deionized water at a temperature of 4 °C
- **inoculation density:** $2 \times 10^4 - 5 \times 10^4$ sporangia/ml
- **inoculation:** leaf underside sprayed with sporangia suspension using an atomizer
- **incubation** of the leaves in 0.7 % water-agar in steam-saturated containers at 22 °C with a 12-hour light phase and a 12-hour dark phase at 13 °C
- **visual assessment:** tolerant/susceptible according to evaluation of infection (chlorosis, **sporulation** and necrosis) on the underside of the leaf 5-14 days after inoculation (dpi)

In more tolerant types of hop, either sporulation was suppressed altogether, or, above all in the early stages of infection, minor necrosis spots appeared on the leaves as a defensive reaction (hypersensitive reaction of host cells). In more susceptible/less tolerant hops, chlorotic marks soon appeared on the leaves a few days after inoculation, with distinct sporulation on the leaf undersides. At a later stage, these develop into dark brown necrosis spots. The reactions vary, depending on the age of the leaf. Leaves at an earlier stage of growth display more distinct symptoms than older leaves.

In assessing the levels of tolerance of a hop plant to the downy mildew fungus, it was found that the early onset of intense sporulation was an indicator of a high degree of susceptibility.

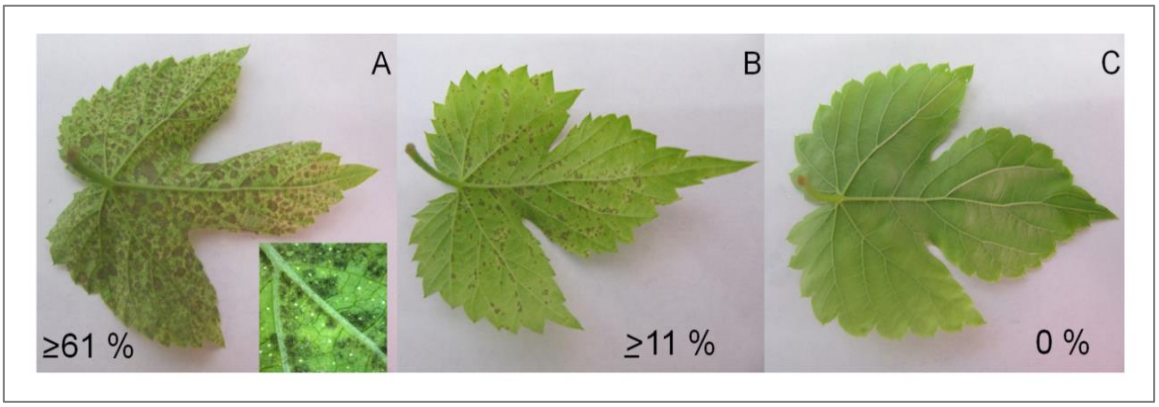

Fig. 4.9: Different reactions of hop leaves 6 days after inoculation with downy mildew: susceptible (A), moderately tolerant (B) and highly tolerant (C) to the fungus; % of infected leaf surface =sporulation; additionally, in photo A, a close-up of downy mildew infection with black spore areas

Tab. 4.2: Comparison of tolerance to downy mildew in different hop cultivars – assessment in the field and during the detached leaf assay

Bewertung im	Hallertauer Mittelfrüher	Hallertauer Tradition	Saphir	Hüller Bitterer	Herkules	Polaris
Feldversuch	- - -	+ + +	- -	+ +	-	-
Blatt-Test	- -	+ + +	- -	+	- -	- -

Bewertung im	Ariana	Callista	Mandarina Bavaria	Huell Melon	Hallertau Blanc
Feldversuch	+	+	+ / -	+	+
Blatt-Test	+ / -	-	-	+ / -	+

Rating: - - - extremely susceptible; - - highly susceptible; - susceptible; +/- moderately tolerant; + tolerant; ++ highly tolerant; +++ very highly tolerant

Outlook

We view the detached leaf assay for assessing tolerance to downy mildew as the ideal complement to field assessment. It has a definite advantage in that it permits judgements to be made as to tolerance to disease of a hop cultivar or breeding line, under standardized conditions, i.e. independently of influence by weather or location.

In the coming season, cultivars and breeding lines will again be examined with the help of this downy mildew leaf assay. At the end of the day, the decisive factor will be whether the tolerance/susceptibility of a hop to secondary downy mildew infections as determined by means of the leaf assay in the laboratory can be correlated to the tolerance/susceptibility it exhibits in the field. Only then will the screening system be practicable and fit for purpose in breeding and selection for tolerance to downy mildew.

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

Seigner, E. und Forster, B. (2014): Verbesserung des Sämlingstestsystems zur Beurteilung der Toleranz von Hopfen gegenüber Falschem Mehltau (Pseudoperonospora humuli) im Gewächshaus Jahresbericht 2013 – Sonderkultur Hopfen, LfL-Information: 48-49.

Seigner, E., Forster, B. & Lutz, A. (2017): Improved selection system to test for downy mildew tolerance of hops. Proceeding of the Scientific-Technical Commission of the International Hop Growers´Convention, Austria, 100.

4.8 Precision Breeding for Hop

Precision breeding is an innovative tool to be made available to German hop breeding research as an addition to the traditional selection process. By combining the traditional process with the new genome-based technique, it is possible to produce new robust, high yielding varieties for the hops and brewing industries, in a faster and more efficient way.

Objective

The project is directed at carrying out the necessary ground work before employing genome-based selection when choosing parent plants for cross-breeding and evaluating the offspring of a cross. This selection, based on molecular markers, means that it will be possible to estimate the breeding value of not only female but also male hops - a decisive step forward. Until now, it has not been possible to assess male hops specifically with respect to yield and brewing quality because there are no cones, therefore their value as a cross partner has hitherto always remained unclear.

Procedure

Inherent disease resistances, agronomic traits and cone compounds (phenotype) are identified within a diverse reference collection. Then all hops are genotyped, i.e. their genetic material is sequenced and the order of letters in their DNA is determined. A biostatic technique - association mapping - correlates the sections of DNA (molecular markers) to the various phenotypic traits, thus identifying marker-trait relationships. Thanks to the associaton of genetic markers with traits of interest in the reference collection, it is possible to develop a prediction model, whereby the phenotypic characteristics of new selection candidates can be deduced solely on the basis of their genetic data (= genotype).

The goal is genome-based selection of new high alpha varieties in collaboration with the hops and brewing industries.

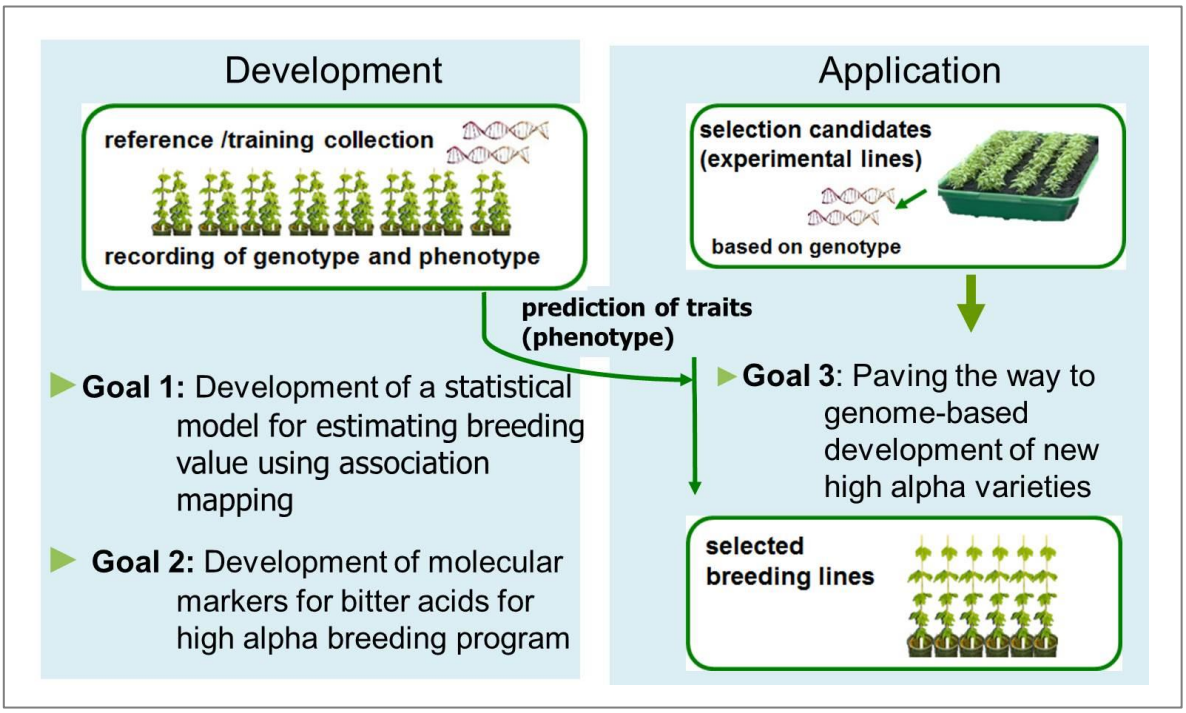

Fig. 4.10: Development of a model for estimating breeding value via association mapping and development of molecular markers for bitter acids, with the objective of breeding new high alpha varieties based on genome analysis.

Stage 1: July 2015 - March 2017
Optimization of hop breeding process using genome and metabolite analysis

The initial work was done in a collaborative partnership between the LfL, the University of Hohenheim (UHOH) and the Max-Planck-Institut für Entwicklungsbiologie (MPI) (*Max Planck Institute for Developmental Biology*) to facilitate marker-assisted breeding for hop in the future:

- Establishment of a mapping population
- High-throughput genotyping of the hop reference collection and the mapping population, and processing of the molecular data via bioinformatics
- Development of a genetic map with genome-wide markers (completion mid-2018)
- Phenotyping of the reference collection: gathering of data on inherent disease resistances, agronomic traits, and cone compounds, from different locations and crop years; provision of historic data, in some cases dating back to the 1990s.

Fig. 4.11: Pollination of the female flowers for crosses for the initial population was carried out inside a pollination bag in order to prevent cross-pollination.

Stage 2: August 2017 - July 2020
Genome-based precision breeding for the quality hops of the future

The project, which is directed at developing and establishing marker-assisted breeding for hop, will be continued by the LfL in collaboration with Hohenheim University (UHOH), the GfH Gesellschaft für Hopfenforschung (*Society of Hop Research*), the HVG Hopfenverwertungsgenossenschaft (*Hop Sales Cooperative*), and other partners and will focus on the following:

- continued phenotyping of the reference collection
- molecular studies of bitter acids synthesis and its regulation
- association mapping: biostatistic correlation of phenotypic data (inherent resistances, agronomic traits, cone compounds) to the genotypic data of the reference collection to identify simple and complex marker-trait relationships.
- development of a prediction model to assess breeding value (genomic selection)

Stage 3: from 2019 on
Genome-based selection of new high alpha varieties in collaboration with the hops and brewing industries

Abb. 4.12: Selection of new high alpha varieties in collaboration with the hops and brewing industries

Candidates assessed as having a high breeding value are tested for bittering quality in brewing trials conducted by the GfH and HVG. They are then released by the GfH for large-scale field trials. After completion of growing trials over several years, a decision regarding potential variety release is made.

rentenbank

Funding is from the Federal Government's ringfenced funds at the Landwirtschaftliche Rentenbank.

5 Hop Farming, Technical Aspects of Production

LD Johann Portner, Dipl.-Ing. agr.

5.1 N_{min} Audit in 2017

The use of nitrogen fertilizers in compliance with DSN (N_{min}) is now an established part of fertilization management on commercially run hop farms and will become increasingly important in the future with the implementation of the new fertilizer ordinance. In 2017, about half of the total number of hop farms in the Bavarian hop growing regions Hallertau und Spalt took part in the DSN audit, in the course of which 3 067 hopf yards (2 797 samples in 2016) were tested for N_{min} levels, and a fertilization recommendation drawn up.

The graph below is a compilation showing the history of the number of samples taken for the purposes of the N_{min} audit. The average N_{min} concentration of 102 kg N/ha in the Bavarian hop yards in 2017 was significantly higher than the previous year's figure (80 kg N_{min}/ha). This is probably due to the dry winter with only slight leaching losses and to the ground frost with accumulation of nitrate nitrogen in the top layer of soil. As a consequence, the average fertilization recommendation of 138 kg N/ha (152 kg N/ha in 2016) for the Bavarian hop yards, which was calculated on the basis of the N_{min} value, was lower than in the year before.

As every year, there were again considerable fluctuations from farm to farm and, within the farms, from yard to yard and variety to variety. It is, therefore, imperative that individual checks are carried out to determine the optimal application rates for each farm.

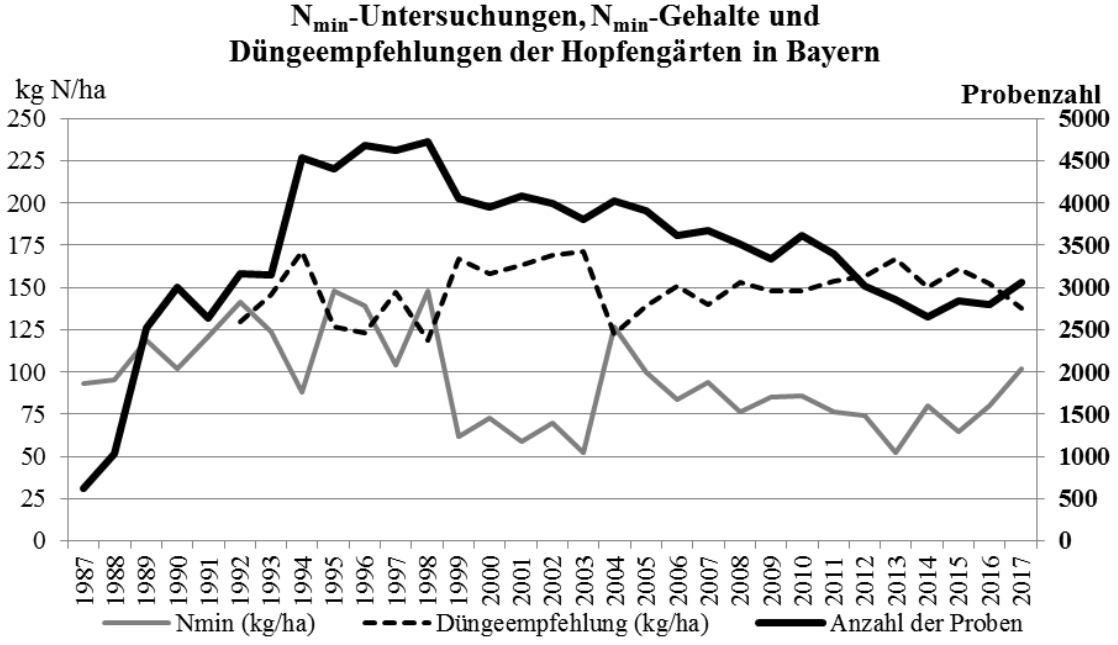

Fig. 5.1: N_{min} audits, N_{min} levels and fertilizer application rate recommendations in the Bavarian hop yards over the years.

The next chart shows the number of hop yards audited in the Bavarian hop producing regions, by rural administrative district, along with the average N_{min} values and the average recommendation for nitrogen fertilization calculated accordingly.

Conditions in the different districts and regions in Bavaria show a clear north-south divide. The highest N_{min} levels are to be found in the Spalt region. Considerably lower N_{min} values were measured in hop growing soils in the rural district of Eichstätt (Jura). This is followed by the Hallertau region, where there were hardly any differences in average values from rural district to rural district; only the N_{min} values for the rural district of Freising were slightly lower.

Tab. 5.1: Number of samples, average N_{min} levels and fertilizer recommendations in hop yards by rural district/region in Bavaria, in 2017

Rural district/growing region	Number of samples	Nmin kg N/ha	Fertilizer recommendation kg N/ha
Spalt (without Kinding)	96	154	85
Eichstätt (without Kinding)	239	109	135
Pfaffenhofen	1043	104	138
Neuburg-Schrobenhausen	3	104	157
Kelheim	1106	101	139
Landshut	195	98	133
Eichstätt (Kinding)	31	90	138
Freising	307	87	150
Hersbruck	47	85	145
Bavaria	**3067**	**102**	**138**

The following table lists values arranged by cultivar and fertilizer recommendation.

Tab. 5.2: Number of samples, average N_{min} levels, and fertilizer recommendation for different hop cultivars in Bavaria, in 2017.

Cultivar	Number of samples	Nmin kg N/ha	Fertilizer recommendation kg N/ha
Herkules	835	94	156
Polaris	10	74	156
Mandarina Bavaria	58	92	149
Hallertau Blanc	34	91	147
Huell Melon	26	95	145
Smaragd	12	85	143
Hall. Magnum	258	97	142
Nugget	19	113	141
Hall. Taurus	65	101	140
Opal	27	92	140
Cascade	17	112	132
Perle	523	106	130
Hall. Tradition	527	109	129
Saphir	86	107	128
Hallertauer Mfr.	137	96	127
Spalter Select	119	109	124
Northern Brewer	30	106	124
Hersbrucker Spät	185	115	123
Spalter	48	143	82
Other	51	89	142
Bavaria	**3067**	**102**	**138**

5.2 Increasing Drying Rate and Improving Hop Quality in a Belt Dryer (ID 5382)

Project lead: LD Johann Portner

Project staff: LA Jakob Münsterer

Duration: 2014 - 2017

Situation at the outset and objective

In numerous small-scale drying trials, it has been shown that the drying rate can be significantly increased and the appearance (colour) of the hop best be preserved by selectively controlling air velocity and drying temperature to coincide with the highest level of moisture release. Such results are easily transferable to the hop drying process in a belt dryer. Drying rate and quality are affected most by the air velocity in the first third of the top belt. An attempt shall therefore be made to increase air velocities and, as a result, the quantities of air passing through, by carrying out technical refits and optimizing the air flow systems in an existing belt dryer.

In order to learn more about flow conditions in the typical Czech-built belt dryers, an actual-state analysis was to be carried out with the help of an air flow simulation. A belt dryer of the type most commonly used in the industry, with three belts and a base area of 54 square metres, was chosen as a model, which meant that the findings would help as many farmers as possible to optimize quality and drying rates and reduce energy consumption. The technical requirements of staging a simulation are complex and it can only be done by air flow specialists or physicists who are experts in the field; HTCO GmbH, a specialist company from Freiburg, was therefore commissioned to do the job.

Using the findings from the air flow simulation, modules were then to be developed or measures to be devised which would ensure that air flow was improved and the air more evenly distributed over all drying areas. Thanks to the additional development of suitable air flow systems (modules) for the drying zone, with higher air velocities timed for the period of the greatest moisture release in the first third of the top belt, it was anticipated that there would be a significant improvement in drying rates and in preserving the external appearance of the hop.

Method

With the help of technical drawings and original plans as well as typical configurations used in the industry, the flow physicists from HTCO employed what is known as 3D modelling to simulate the air flow conditions during drying. First they established the flow behaviour of the drying air on all three dryer belts. Since there is an interplay between the air flows of the individual belts, it makes sense to consider them together as a whole. As a result, the velocity distribution on the longitudinal plane (X plane), the transverse plane (Y plane) and the speeds of the air passing through the hops (Z plane) were modulated for all three belts.

Findings from the simulation

Because feed-in of the air supply is from the side, localized high air velocities, known as jets, can arise in the inflowing drying air. As these jets hit the opposite wall, turbulences are created in the drying air, and, as a result, drying is uneven with ‘nests’ and ‘holes’ forming. The greater the localized air velocities, the more pronounced this phenomenon. In an effort to slow the jets down and distribute the drying air more uniformly, it was suggested that two perforated metal plates should be installed in the spaces between the top and middle dryer belts, in the same direction as the belt is travelling. This modification would then be tried out in a further simulation. In the retrofitted simulation belt dryer, the drying air entering from the side hits these diffusor plates head-on and is thus slowed down and swirled around; as a result, the air distribution is both more even and more efficient over the entire width of the belt.

Another focus of attention was the possibility of increasing the air flow rate, and, at the same time, raising the air velocity, in the first third of the top belt ─ something which is absolutely essential if the drying rate is to be increased further. One suggested way of doing this cheaply and effectively is to include an additional air intake on the opposite side. With the resulting double volume flow, it might then be possible in future to achieve air velocities of at least 0.5-0.6 metres per second on the top belt.

In this case, the diffusor plates would be designed in such a way as to prevent the air supplies from opposite sides from meeting too violently and would thus contribute to a homogenizing of the two air currents.

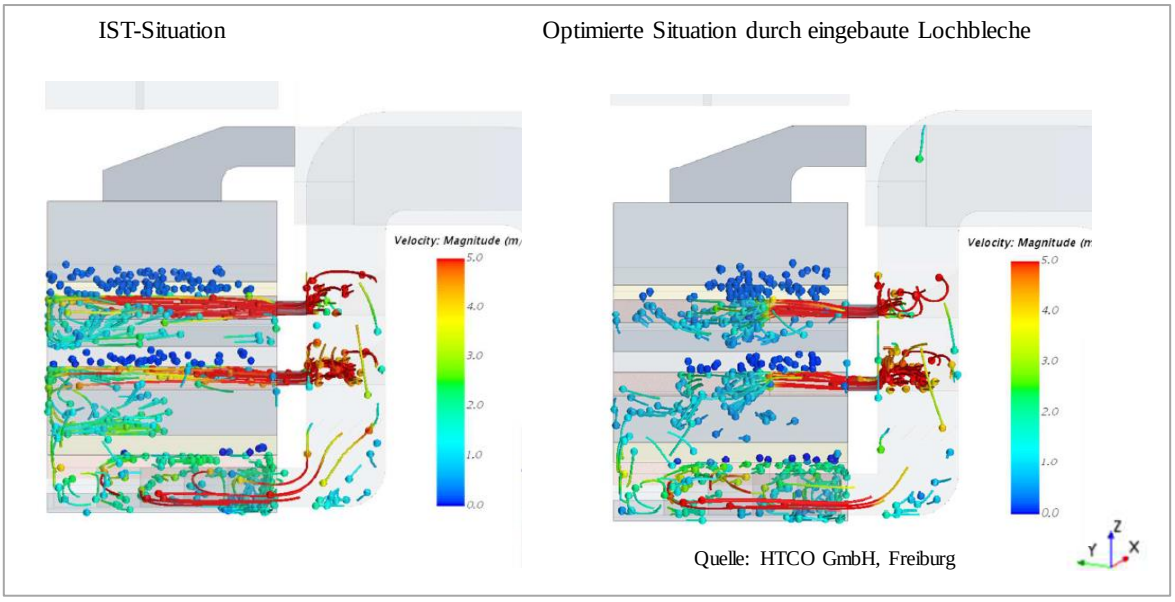

Fig. 5.2: Flow lines on the transverse plane (Y plane) illustrate the flow of drying air in the belt dryer

Putting the findings into practice

In 2017, on advice resulting from the simulation, perforated plates were installed in the direction of travel in the spaces between the top and middle belts. Fig. 5.2 clearly shows the air intakes for the drying air at the side. The perforated plates are intended to slow down the jets created in the drying air by the air intakes and facilitate a more even distribution.

Fig. 5.3: Drying belt with diffusor plates installed and air intakes on the right hand side

During the 2017 hop harvest, measurements done with a thermal imaging camera at the cone surface and records from data loggers were able to verify the findings of the flow simulation. The data loggers can record over a specified period both the temperature in degrees Celsius and the relative humidity of the air. They were placed on the drying hop cones about 50 cms from the outer wall in both the left and right halves of the dryer, so that temperature and relative humidity were recorded directly above the cones during their sojourn on the top belt. The graph Fig. 5.4, charting temperature and humidity shows that there are only slight differences between the right and left halves of the belt, thus verifying the evenness of the drying process.

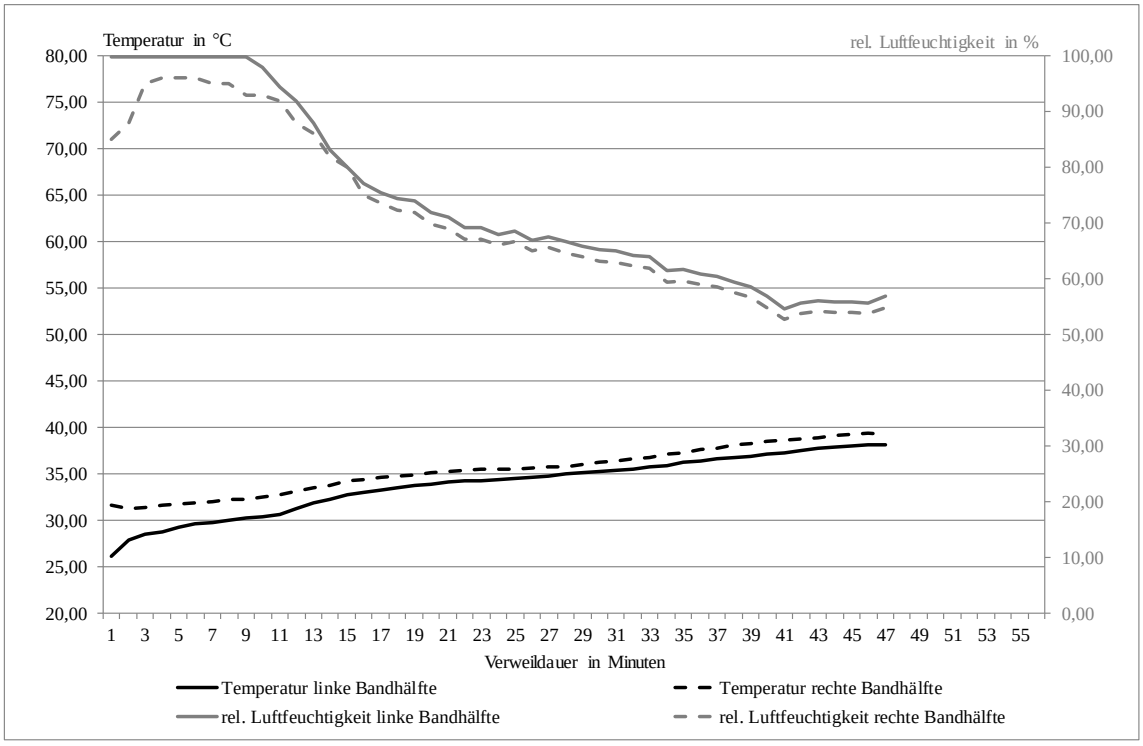

Fig. 5.4: Change in temperature and relative humidity in the outgoing air on the top drying belt

5.3 LfL Projects as Part of the Production and Quality Campaign

As part of an agricultural production and quality drive in Bavaria, the Bayerische Landesanstalt für Landwirtschaft (*Bavarian State Research Center for Agriculture*) has once more arranged for representative data on yields and quality of selected agricultural crops to be collected, recorded and analysed in the period 2014 to 2018. The work was done on behalf of the IPZ Hops Department by their joint advisory service partners Hopfenring e.V (*Hop Growers' Syndicate*). There follows a brief outline of the objectives of the individual projects concerning hop, with a short resumé of the results for 2017.

5.3.1 Annual survey, study and analysis of data on hop quality post-harvest

Dry matter and alpha acids monitoring

In the period 16.08. – 26.09.2017 – spaced out across the Hallertau region – a trained bine from each of 4 aroma varieties and 2 bittering varieties, taken each time from 10 different commercially run hop yards, were harvested at weekly intervals and then dried separately. This was done on 5 (for aroma varieties) and 7 (for bittering varieties) different dates. By determining the extent of moisture loss, and analysing dry matter content and alpha acids levels in an accredited laboratory, it was possible, the following day, to establish the dry matter content of the green hop and the alpha acids content at 10% moisture content. The information was subsequently sent on to the LfL Hop Advisory Service for evaluation.The results were averaged, presented in the form of graphs, tables and charts and then up-loaded to the internet, together with accompanying comments. Farmers were thus able to refer to the data when they need information as to the optimum harvest maturity of the most important hop varieties.

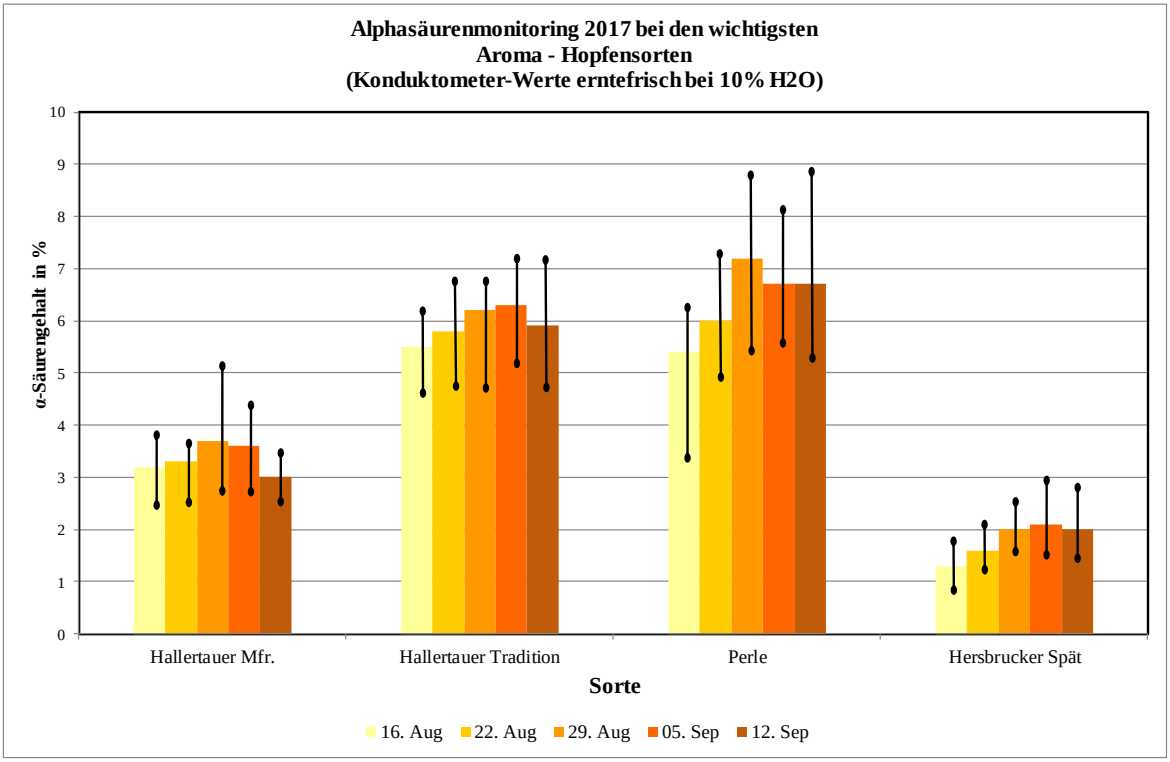

Fig. 5.5: Alpha acids monitoring in the major aroma varieties in 2017

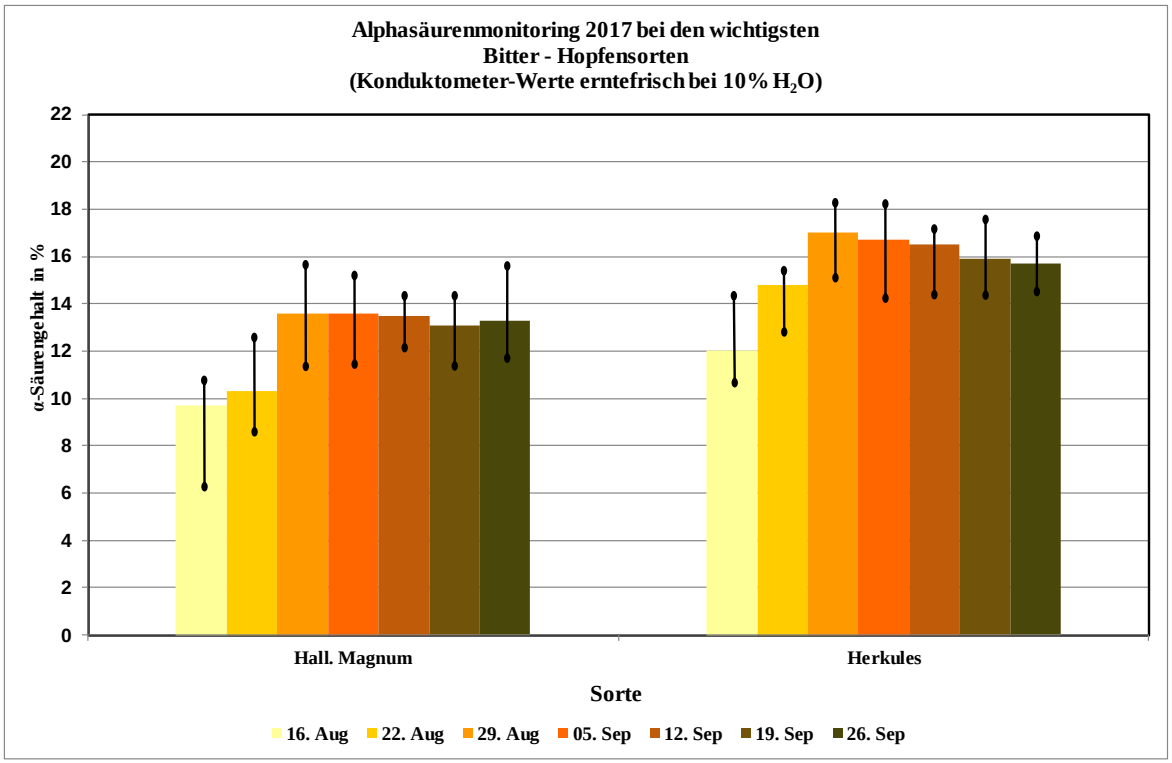

Fig. 5.6: Alpha acids monitoring in the high alpha varieties in 2017

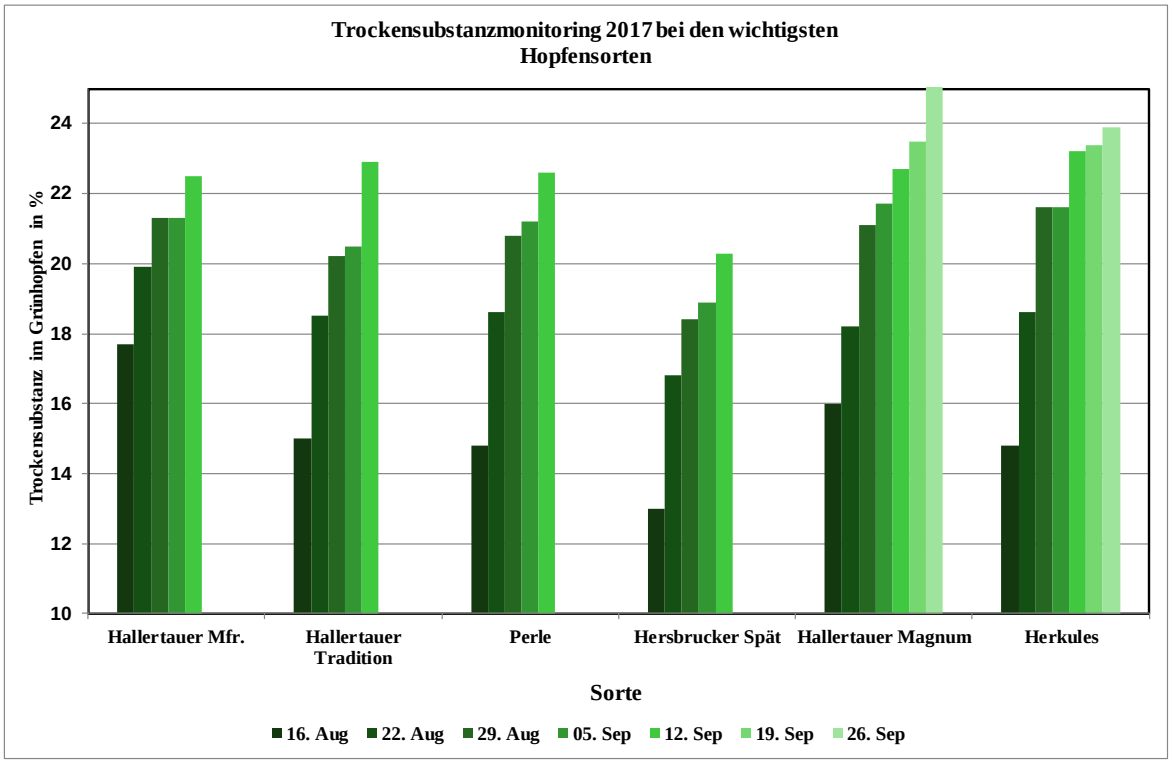

Fig. 5.7: Dry matter monitoring in the major hop varieties in 2017

Impact of location and technical aspects of production on hop quality

The data on quality gathered as part of the NQF (Neutrale Qualitätsfeststellung) quality assessment provide valuable information about hop quality for the different harvest years, as well as on diseases and pest infestation, technical production failings, or inappropriate treatment of the harvested hops.

While the project continues, the NQF data from 150 batches each of cultivars HT, PE, HM, and HS are to be expanded to include the corresponding alpha acids content and selected data concerning location and production techniques. It is hoped that the evaluation of location-specific parameters and details of production techniques alongside the quality data will deliver valuable information for the advisory service. However, since only 103 of the anticipated 600 data sets were submitted in 2016, this meant that stratification and an evaluation were once again not possible.

5.3.2 Annual survey and investigation of pest infestation in representative hop yards in Bavaria

Surveys and accurate assessments of levels of infestation in commercially run hop yards are necessary to provide a basis for the advice dispensed and the strategies devised to keep aphids and spider mites in check.

To this end, in the period May 29 to July 31, 2017, assessments were carried out at weekly intervals on 10 different dates in 30 representative hop yards (different varieties) in the regions Hallertau (22), Spalt (5), and Hersbruck (3) to scout for infestation by the hop aphid and the two-spotted spider mite, and thus to determine the average level of infestation by aphids (counts) and spider mites (infestation index).

The results obtained found their way into advisory recommendations and control strategies.

5.3.3 Multiple-laboratory ring analysis for quality assurance in determining alpha acids content for hop supply contracts

For years, hop supply contracts have included a rider linking payment to the alpha acids content of the consignments of hops delivered. Apha acids content is determined in state-run laboratories, production labs, and private laboratory facilities, depending on the testing capacity available. The procedure (sample division, storage) is explicitly laid down in the specification of the Arbeitsgruppe für Hopfenanalytik (*Working Group for Hop Analysis)*, which also specifies which labs conduct the analysis reliability checks, and gives the tolerance ranges permitted in the analysis results. With the aim of guaranteeing the quality of alpha acids analytics in the interests of hop growers, the multiple-lab analyses are organized, conducted and evaluated by the Bayerische Landesanstalt für Landwirtschaft in its capacity as a neutral body.

The role of the Hopfenring (*Hop Growers' Syndicate*) within the project is to take samples from a total of 60 randomly chosen batches of hop on 9 or 10 different dates in the Hallertau region and hand them over to the LfL laboratory at Hüll.

5.4 Advisory Service and Training Activities

Apart from conducting applied research into the technical aspects of production in hop growing, the remit of AG Hopfenbau/ Produktionstechnik (IPZ 5a) (*WG Hop Farming/Production Techniques)* also includes processing test findings for practical implementation and providing support for hop farmers by dispensing specialist advice, running instruction sessions, study groups, training courses and seminars, giving lectures and talks, and making available press publications, both direct and via the internet. Organizing and running the downy mildew warning service and keeping warning service information updated is also part of their remit, as is collaborating with the various hops organizations, or offering training and expertise in support of their joint advisory service partners at Hopfenring (*Hop Growers'Syndicate*).

The training and advisory activities carried out last year are outlined below:

5.4.1 Written information

- The *Green Pamphlet* Hop (das *Grüne Heft* Hopfen) for 2017 – hop growing, varieties, fertilization and plant protection management, harvest – was brought up to date in cooperation with AG Pflanzenschutz (*WG Plant Protection)*, and in coordination with the information centres of the Federal States of Baden-Württemberg and Thuringia. A total of 2 360 copies were distributed to ÄELF and research facilities by the LfL, and to hop growers by Hopfenring Hallertau.
- Current information on hop growing and the warning service alerts were sent out to hop growers in 27 faxes via the Hopfenring multiple recipient fax (2017: 50 faxes in the Hallertau region + 1 additional fax for Spalt, with 1 010 subscribers).
- In the context of the N_{min} soil audit, 3 067 results were checked for plausibility and cleared for dispatch to hop growers.
- Advisory service information and specialist articles for hop growers were published in 2 ER Hopfenring circulars and also in 7 monthly issues of the *Hopfen Rundschau.*

5.4.2 Internet and intranet

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

5.4.3 Telephone advisory and information services

- The downy mildew warning service was set up for the period 09.05. - 05.09.2017 by Arbeitsgruppe Hopfenbau, Produktionstechnik (*WG Hop Farming/Production Techniques*) in Wolnzach, in collaboration with the Arbeitsgruppe Pflanzenschutz (*WG Plant Protection*) in Hüll and updated 81 times, for access on request, either via answerphone (Tel. 08442/9257-60 u. -61) or via the internet.
- The specialists from *WG Hop Farming/Production Techniques* supplied answers over the phone to highly specialized questions regarding hop production techniques in approx. 1 700 cases, or delivered advice in individual consultations and on site.

5.4.4 Lectures and talks, conferences, guided tours, training courses, and meetings

- Weekly exchange of information during the growing season with the Hopfenring specialist advisors
- 9 hop cultivation meetings in conjunction with the ÄELF
- 22 specialist lectures
- 3 guided tours of trial sites for hop growers and the hops industry
- 5 conferences, trade events or seminars

5.4.5 Basic and continuing training courses

- Setting assignments for 4, and examining 7, work projects as part of a Master's Certificate (vocational)
- 8 instruction sessions at the Landwirtschaftsschule (*Agricultural College*) Pfaffenhofen for students studying hop cultivation
- 1-day course in the summer term at Pfaffenhofen Agricultural College
- 1 informational event for vocational school students from Pfaffenhofen
- Hosting a BiLa seminars *Hop Farming* - 4 evenings
- 5 meetings of the study group *Hop Management*

6 Plant Protection Management in Hop

Silvana Wolf, M.Sc. Biologie

6.1 Pests and Diseases Affecting Hop

6.1.1 The two-spotted spider mite

Tab. 6.1: Monitoring infestation by the two-spotted spider mite in 30 locations in the Bavarian hop growing regions

Date	Eggs	Spiders	Spider mite index per leaf		
	Ø	Ø	Ø	min.	max.
29.05.	0.27	0.25	0.07	0.00	0.80
05.06.	0.29	0.27	0.07	0.00	0.60
12.06.	0.38	0.47	0.10	0.00	0.45
19.06.	0.81	1.52	0.15	0.00	0.85
26.06.	1.40	0.25	0.25	0.00	0.85
03.07.	2.37	0.25	0.28	0.00	1.40
10.07.	0.92	1.77	0.22	0.00	0.80
17.07.	0.52	3.07	0.17	0.00	0.90
24.07.	0.28	2.29	0.09	0.00	0.90
31.07.	0.88	0.78	0.12	0.00	1.50
	Main treatment dates 30.06. - 17.07. 7 locations treated twice				

In 2017, infestation by the two-spotted spider mite was observed throughout all locations, but levels were relatively low to moderate. A selective spraying operation at the beginning of July was able to keep infestation in check in two thirds of the hop yards under observation. Only a small number of growers treated their stands with an acaricide at the beginning of June when infestation was first detected. Some of these farms had to spray a second time in order to keep their hops free of mites up until harvesting time.

6.1.2 Aphids

Aphid migration at the Hüll site started at the end of May, but at very low levels (2.5 animals/leaf) compared to 2011 (44 animals/leaf). Depending on the location, aphid populations varied considerably, e.g. evidenced by the maximum count of 73 animals per leaf, recorded on 03.07., in contrast to the average of 3.8 aphids per leaf. High temperatures at the beginning of July curbed further aphid population growth in the crops, with the result that no treatment at all was necessary in 11 locations throughout the entire 2017 pest monitoring period (*Tab.* 6.2).

However, a comparison of treatments in the monitored yards over the last five years shows that the treatment index has risen. Whereas 75 % of the plots were able to do without aphid control treatment in the period 2012 to 2015, this applied to only 35 % in 2017.

Methods of controlling hop aphids are extremely limited. At present only 3 approved active substances are available, which makes it difficult to practise resistance management. On top of that, the active substance Imidacloprid is an IRAC class 4A substance (one of the Neonicotinoids) and is consequently under public discussion, owing to the risk it poses for bees (B1). Another active substance, Pymetrozine, has been in use for over 15 years and is beginning to show seasonal gaps in its effectiveness. If this situation continues, it is to be expected that the third approved active substance, Flonicamid, will lose its biological effectiveness in the near future, due to its frequent application over large areas. First indications that this will happen have been provided by the spray tower trials to test hop aphid sensitivity to active agents in the laboratory.

We must expressly draw attention to the fact that, in the event of an unexpectedly high concentration of hop aphids in the next few years, things could become very difficult as far as the implementation of practicable and effective control strategies is concerned.

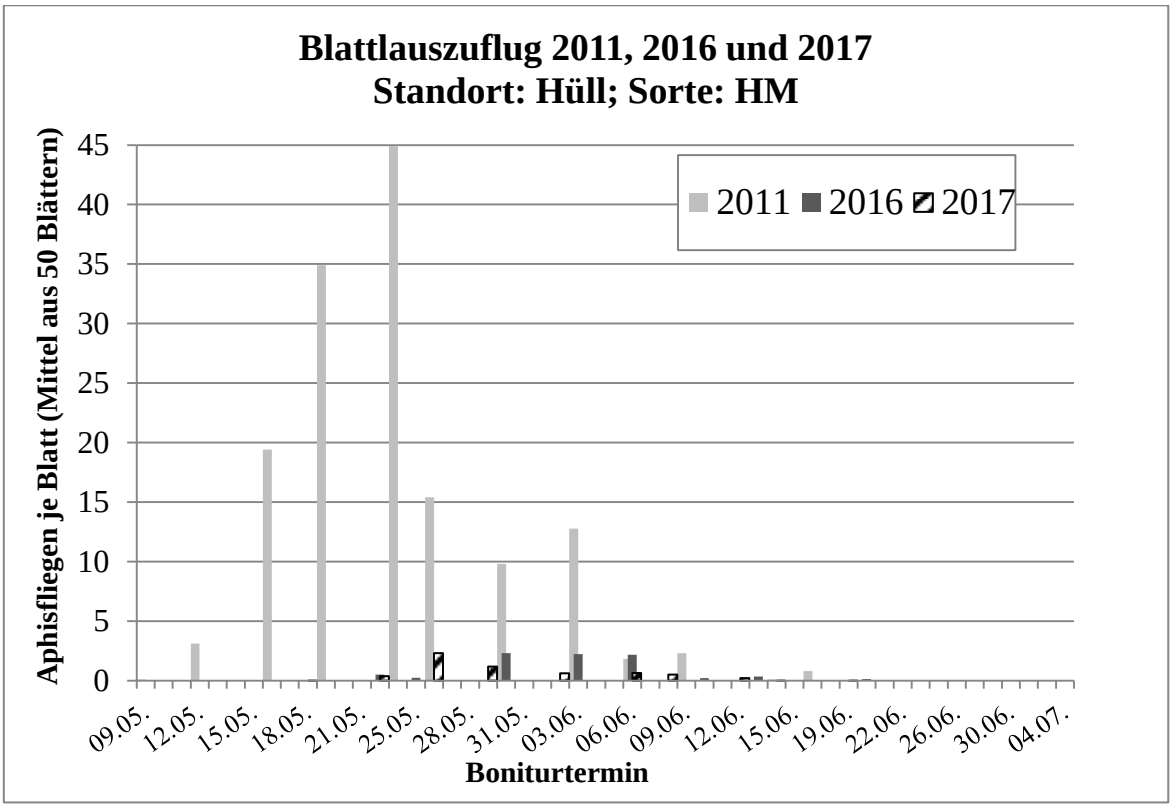

Fig. 6.1: Aphid migration in 2017 at the Hüll site

Tab. 6.2: Monitoring aphid migration and infestation in 30 locations in the Bavarian hop growing regions

Date	Aphid migration	Aphids per leaf		
	Ø	Ø	min.	max.
29.05.	1.60	2.90	0.00	16.00
05.06.	1.00	3.10	0.00	16.80
12.06.	0.20	3.50	0,02	19.90
19.06.	0.00	2.90	0.00	26.80
26.06.	0.00	2.40	0.00	17.40
03.07.	-	3.80	0.00	73.20
10.07.	-	0.70	0.00	1.40
17.07.	-	0.20	0.00	0.50
24.07.	-	0.00	0.00	0.20
31.07.	-	0.00	0.00	0.30
	Main treatment period 10.07. – 24.07., 11 locations left untreated			

6.1.3 Downy mildew

Downy mildew infection pressure was very low in 2017. It is likely that primary infection was significantly curbed by the late frosts which occurred at the end of April, at the time when training of the bines was being carried out. The potential for secondary infections therefore remained minimal right up to August, on account of the low levels of rainfall. It was not until mid-August that there was more rainfall while temperatures remained moderate, with the result that zoosporangia numbers exceeded threshold levels, making treatment necessary. On 14.08. a spray alert was first issued for all susceptible varieties, but this soon had to be expanded to cover all varieties because spore counts had risen and the weather was conducive to infection. Altogether, the warning service issued a spray alert only 4 times throughout the entire growing season.

Tab. 6.3: Downy mildew warning service in 2017

Fax No.	Date	Primary downy mildew alert	Spray alerts		
			suscept-ible varieties	all varieties	late maturing varieties
42	11.07.			x	
58	02.08.			x	
66/68	14.08/17.08		(x)	x	
74	25.08			x	
Number of spray alerts				4	

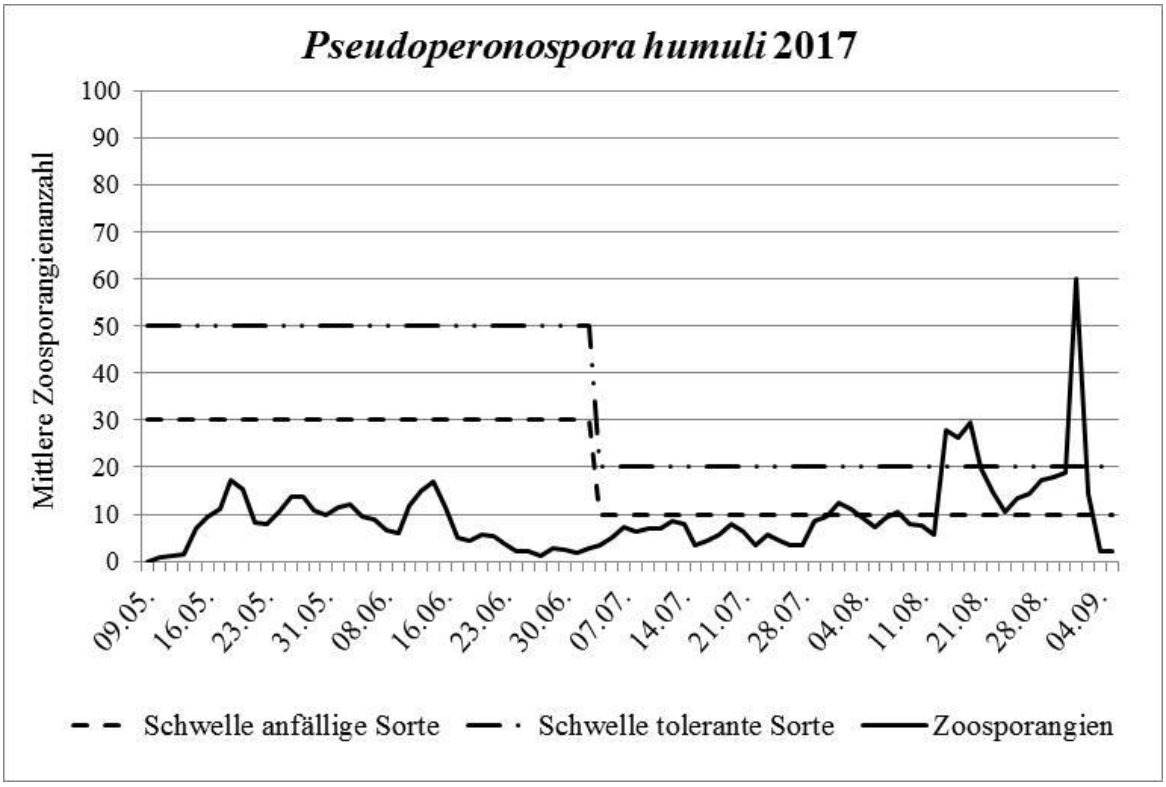

Fig. 6.2: Downy mildew warning service in 2017 – average zoosporangia migration at 5 locations in the Hallertau.

6.2 Research Into and Work On the Problem of *Verticillium* on Hop

Managing *Verticillium* wilt disease in the German hop growing regions is a long-term undertaking. The research conducted and the guidance provided by the LfL play a crucial role in aiding hop growers in their struggle to control *Verticillium.*

Sanitation of soils infected with *Verticillium* and selection of breeding material tolerant to *Verticillium*

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Objective

Since the first outbreak in the Hallertau of lethal strains of *Verticillium nonalfalfae*, the pathogen causing the aggressive form of hop wilt disease, the infected area has been seen to be growing steadily. This pathogen is a soil-borne fungus with a broad host range, which can survive underground as a sclerotium for 4 to 5 years. There is no direct means of controlling it. An integrated approach is needed to manage the infection, and this involves the implementation of hygiene procedures, breeding efforts, appropriate cultural practices, and a sanitation strategy. It is important to ensure that the knowledge already gleaned is soon translated into support for the hop growers in the affected areas as they implement management measures; it is also essential to see that efficient sanitation is carried out as quickly as possible.

Method

During surveys at commercial hop farms in the Hallertau, both with and without wilt problems, data are to be collected which can inform viable and effective cultural measures to prevent and reduce this fungal infection. In support of the work focused on breeding resistant cultivars, the hitherto well-established field selection system for wilt tolerance screening of breeding lines is to be supervised, evaluated, and further developed. The necessary sanitation work to be carried out on infected land is to receive scientific supervision, parallel to the development of new strategies for optimizing soil sanitation. In addition, existing techniques for diagnosing and analysing *Verticillium* are to be optimized and refined. A method of testing the soil with the help of a system of indicator plants highly susceptible to wilt, in order to check whether sanitation measures are having the desired effect, is to be trialled to ascertain whether this is a useful approach.

Results

Verticillium in 2017

Compared to 2016, 2017 was not a *Verticillium* year. This subjective assessment is correct for the greater part of the Hallertau producing region, but it does not apply in general in every wilt-infected area. In less favourable locations, there was nevertheless an increase in the incidence of *Verticillium* in 2017. A comparison of aerial photographs taken in 2016 with the infection assessment of 2017 confirms this observation.

Collaboration with commercial farms

For the wilt-affected areas strategies were devised in collaboration with farmers to stop *Verticillium* spreading and, as far as possible, to reduce the intensity of the *Verticillium* infestation. In these areas, after assessment of individual plants, the source infection was defined as a primary infection and the hop yard characterized according to the topography and assessment of the soil. The level of success of these control strategies will be judged in the coming crop years by how far the infection has spread and how the symptoms are expressed.

In 2017, parallel to the assessment of symptoms, 500 hop samples, from the breeding yard at Hüll, the selection yards in Niederlauterbach and Engelbrechtsmünster, and from 22 commercial plots were analysed for *Verticillium* using Real-Time PCR (see 4.5). In 220 of these cases, an additional specific PCR was also carried out. The results confirmed the assessments from the individual plots and helped determine *Verticillium* distribution and the aggressive nature of the individual *Verticillium* species. In 20 of the 22 commercial farm samples a combination of both mild and lethal strains was found. The high proportion of aggressive *Verticillium* strains is not representative of the Hallertau; it is due to the fact that these areas were specially chosen for wilt trials.

Development of an explanatory model to show seasonal fluctuations in *Verticillium* wilt

As far as we know at present, the *Verticillium nonalfalfae* fungus is not prevalent in all soils in the Hallertau. The expression of optical symptoms in infected hop yards cannot be reduced to one single characteristic. A system-oriented explanatory model has been devised to illustrate the complex relationships between the factors involved in *Verticillium* wilt disease on hop.

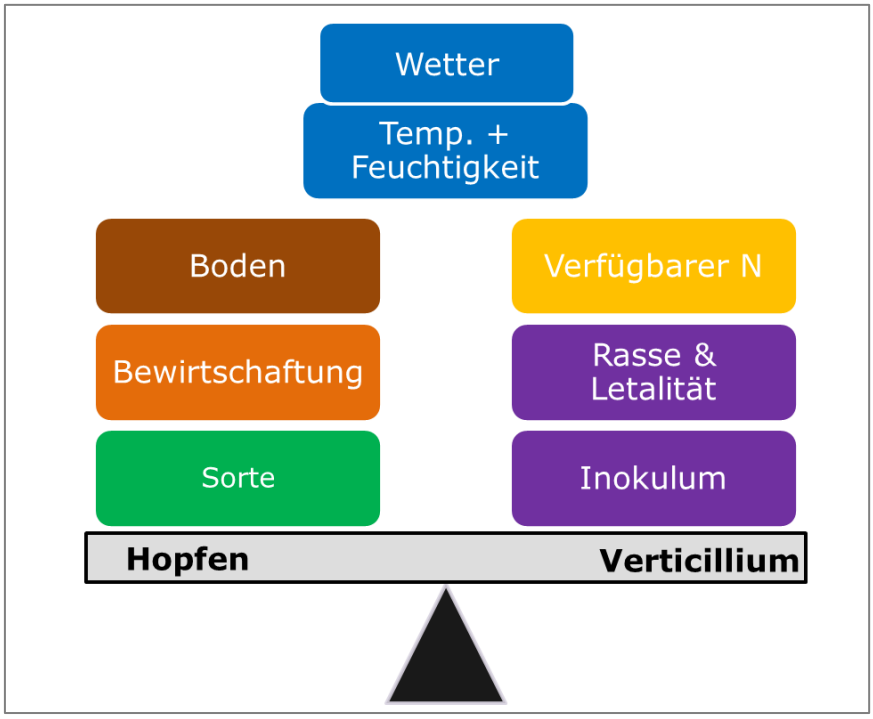


Fig. 6.3: Explanatory model for Verticillium wilt disease on hop - seasonal fluctuations

The model shows the most important factors to have an impact on *Verticillium*, depicted as if stacked on scales. These factors impact the hop, as well as having a direct influence on the pathogen, but they can also affect each other, and their complex interactions result in the way the wilt symptoms are exhibited. The factors can be split roughly into three groups:

- cannot be influenced: weather, *Verticillium* species, and lethality rate
- can be influenced to a limited extend: soil, available N (nitrogen)
- can be influenced: system of farming, cultivar, inoculum

The aim of integrated disease management is to adjust all the factors that can be influenced, in order to provide the best possible support for the health of the hop and to reduce the incidence of infection. Until now, it has not been possible to control *Verticillium* direct, and, for this reason, preventive measures and early detection are absolutely crucial. Potential phytosanitary and plant cultivation measures available to the hop grower are listed in the Green Pamphlet (*Grünes Heft*). In cases where the incidence of infection is very high or the *Verticillium* strains are highly aggressive, it may be necessary to dig up the whole crop or at least part of it, and follow the measure with sanitation, in order to achieve a reduction in *Verticillium* inoculum density (pathogen mass). The spreading of *Verticillium* in general, and of lethal species in particular, within and between crops, must be avoided at all costs.

Sanitation of soils infected with Verticillium

The *Verticillium* wilt research project envisages trialling and refining viable methods of sanitizing hop yards infected with *Verticillium*.

Objectives of the project:

- to evaluate different methods of sanitation
- to adapt these methods to suit hop farming

Procedure:

- using symptoms to establish the source of infection
- digging up the infected crop
- implementation of sanitation options:
    - pulling the land out of production (fallow)
    - arable farming (crop rotation with a high proportion of grasses)
    - growing non-host plants (grasses)
    - biological soil decontamination: (incorporating biomass/exclusion of air through ground cover)
- Zero control:
    - continuing with the crop as a zero control until all sanitation measures have been completed on the affected land
    - digging up the infected crop
- growing a tolerant variety
- assessment horizon: at least 2 years

Fig. 6.4: Hop yard with extensive wilt damage

7 Ecological Issues in Hop Cultivation

Dr. Florian Weihrauch, Dipl.-Biol.

The job of the Working Group is basically to collate the knowledge gathered so far and to carry out applied research into the ecological and environmentally compatible production of hops. This includes diagnosing, observing and monitoring the infestation of hops by pests and their biological antagonists, in the context of progressive climate change and the consequent impact on biocenoses. At the same time, the work involves the development and evaluation of biological and other environmentally sound means of plant protection. The Working Group relies primarily on attracting the funding for its research into ecological issues in hop cultivation.

7.1 *Metarhizium* Trial - Hop Flea Beetle Management, Laipersdorf 2017

As part of the research project *Developing Methods of Controlling the Hop Flea Beetle, Psylliodes attenuatus, in Ecological Hop Cultivation*, funded by StMELF (*Bavarian State Ministry for Nutrition, Agriculture and Forestry)*, a scientific test concerned with controlling hop flea beetle larvae was set up as a sub-project. The trial site was a hop yard planted to the cultivar *Saphir* in Laipersdorf near Schnaittach in Franconia. The trial was managed in three trial blocks (each in 4 replications) with 12 plots and 63 hop plants (3 hills and 3 spaces between poles) per plot. To control hop flea beetle larvae in the soil, two different formulations of the entomopathogenic fungus *Metarhizium anisopliae* (strain Na43) were used, which had been produced by our collaborative partner Julius Kühn-Institut(JKI), Institut für Biologischen Pflanzenschutz (*Institute for Biological Plant Protection*), in Darmstadt (Dr. Dietrich Stephan). Application was either in granulate form, i.e. grains of millet coated with the fungus, analogous to Met52 granulate, or as a suspension. The granulate was spread by hand on 24 May (application rate: 50 kg per ha, banded, onto the hilled row), immediately after manual stripping in the trial yard. It was then covered with compost, following which the hilled rows were abutted. This ensured that the fungus did not dry out and created ideal conditions for multiplication. The suspension was applied by pouring, also by hand, on 23 June (application rate: 3.2×10^{11} of fungal conidia in 60 litres of water per plot). The third trial block was the untreated control.

In order to gauge the success of the treatments, a photo eclector with a 1 m^2 footprint was set up on 14 July in the middle of each plot on the hilled row, enabling a quantitative assessment of the hatching beetles. The eclectors remained in place until 31 August, with the eclector head boxes, in which the insects were caught, being emptied at weekly intervals, seven times in all.

The number of beetles caught in a photo eclector trap varied between 10 individuals (plots 1a, control, 02.08., and 3c, suspension, 31.08.) and a maximum of 2 073 individuals (plot 3d, suspension, 10.08.). However, on none of the days when the traps were emptied was it possible to discern that the entomopathogenic fungi deployed had had any effect on the hatching process of the beetles, nor was there was any significant difference between the variants. On the contrary, the analysis of the total catch was surprising: an average catch of, at a conservative estimate, 2,000 beetles per square metre of hilled row, i.e. in only one third of the total area, would produce an annual number of 6 million hop flea beetles per hectare, or 3 000 individuals per hop plant. In fact, this number exceeds by a factor of five the figure of 1.2 million beetles per hectare recorded in another organically managed hop yard (Haushausen near Wolnzach) in 2016. This demonstrates the great pressure that hop growers could face if *P. attenuatus* multiplies unchecked.

Fig. 7.1: Application of metarhizium anisopliae granulate by hand in the trial yard.

Fig. 7.2: Metarhizium anisopliae granulate on the hilled row.

Fig. 7.3: Granulate covered with compost, and abutting of the hilled rows.

Fig. 7.4: Installation of the photo eclectors in the middle of each plot in the trial yard.

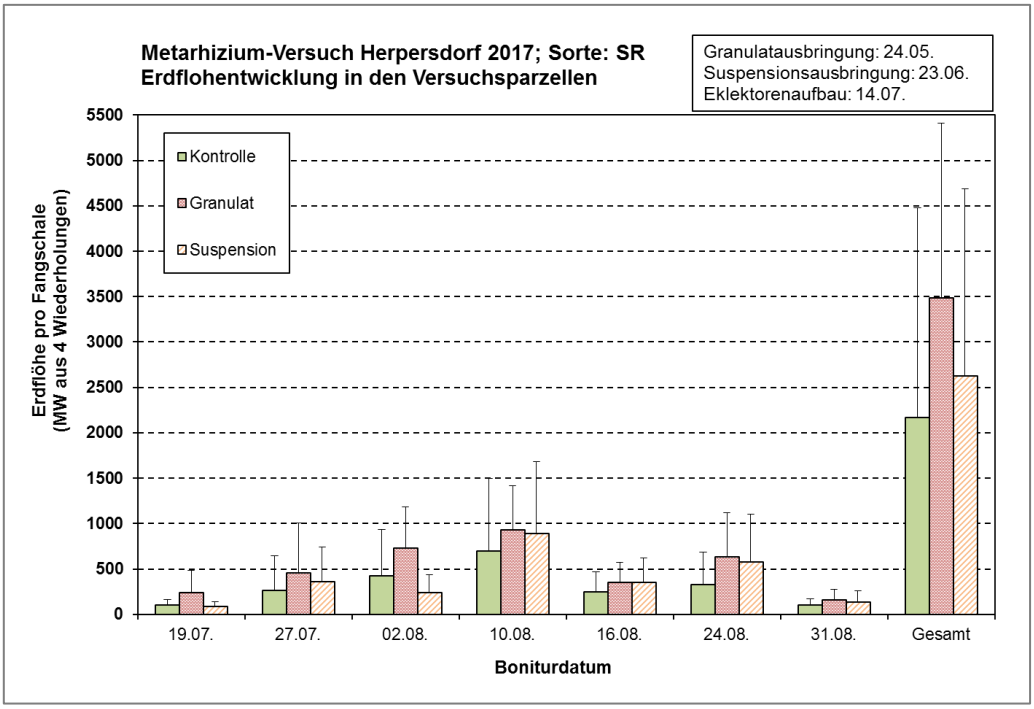


Fig. 7.5: Hop flea beetles newly hatched from the larvae caught in the ecological trial yard at Laipersdorf, summer 2017. At a conservative estimate, an average catch of 2 000 beetles per square metre of hilled row, i.e. in only a third of the total area, means that annual production would amount to 6 million hop flea beetles, or 3 000 individuals per plant.

7.2 Minimizing the Use of Copper-based Plant Protection Products in Ecological and Integrated Hop Cultivation Systems

There has been a call across the EU in future to forgo the use of copper-based plant protection products. However, copper is considered safe in agriculture provided it is applied correctly, and organic hop farms still depend heavily on this active ingredient, as does all sustainable agriculture, since it is the only option in the treatment of fungal diseases such as downy mildew on hop.

Following a 4-year project (2010-2014) sponsored by BÖLN (*Federal Organic Farming Program*), aimed at reducing by 25% the use of copper in hop growing, i.e. bringing it down from a permitted application rate of 4 kg per hectare per year, the testing of other minimizing strategies has been underway since 2014 ─ currently at a Naturland farm in Schweinbach. By employing modern copper hydroxides and a novel encapsulating technique (*CuCaps*), it has been possible with an application rate of 3 kg/ha, in virtually every case, to achieve the same success in controlling the disease as had been possible earlier using 4kg/ha copper oxychloride. Combinations with synergists almost always produced improvements in efficacy. At present, the most promising combination partners are: encapsulated extract of hop and bioflavonoids.

Another strategy is copper monitoring in organic hop cultivation, which has meanwhile been conducted annually since 2010 in all the important crops grown in Germany (besides hop: in viticulture, fruit growing, arable farming, and vegetable and potato cultivation), in line with the 'Strategiepapier zu Kupfer als Pflanzenschutzmittel unter besonderer Berücksichtigung des Ökologischen Landbaus' (*Strategy Paper on Copper as a Plant Protection Agent, Focusing Special Attention on Organic Farming*).

The highly heterogeneous nature of the monitoring results illustrates just how widely levels of infestation with downy mildew can fluctuate every year (Fig. 7.6). Average use of copper in organic hop farming in Germany has nevertheless definitely declined, reaching less than 3 kg of pure copper per hectare in the last five years, mainly thanks to the efforts of organic hop farmers to minimize deployment of copper-based fungicides. In the meantime, a 25% reduction in copper use has also become a reality, albeit confined to tolerant breeding varieties from Hüll. It is well nigh impossible to grow susceptible landrace hops in organic systems while, at the same time, reducing the amount of copper deployed.

It is hugely important, in terms of successfully implementing the copper reduction strategy, to establish a farm record of copper use in each case. Every farm is allowed to decide how to space out application of the permitted quantities over a five-year period and keeps an account (known as a *Hoftor-Bilanz*) of the copper quantities used, whereby farmers can react more flexibly to weather-induced infestation levels. The next concrete goal is to achieve a further reduction, down to quantities in the region of 2 kg/ha, by combining the next generation of copper-based products with other environment-friendly agents and by devising new strategies, with a view to establishing sustainable copper management.

Unfortunately, there is no indication, as yet, that organic hop farming will be able to dispense altogether with copper products any time soon.

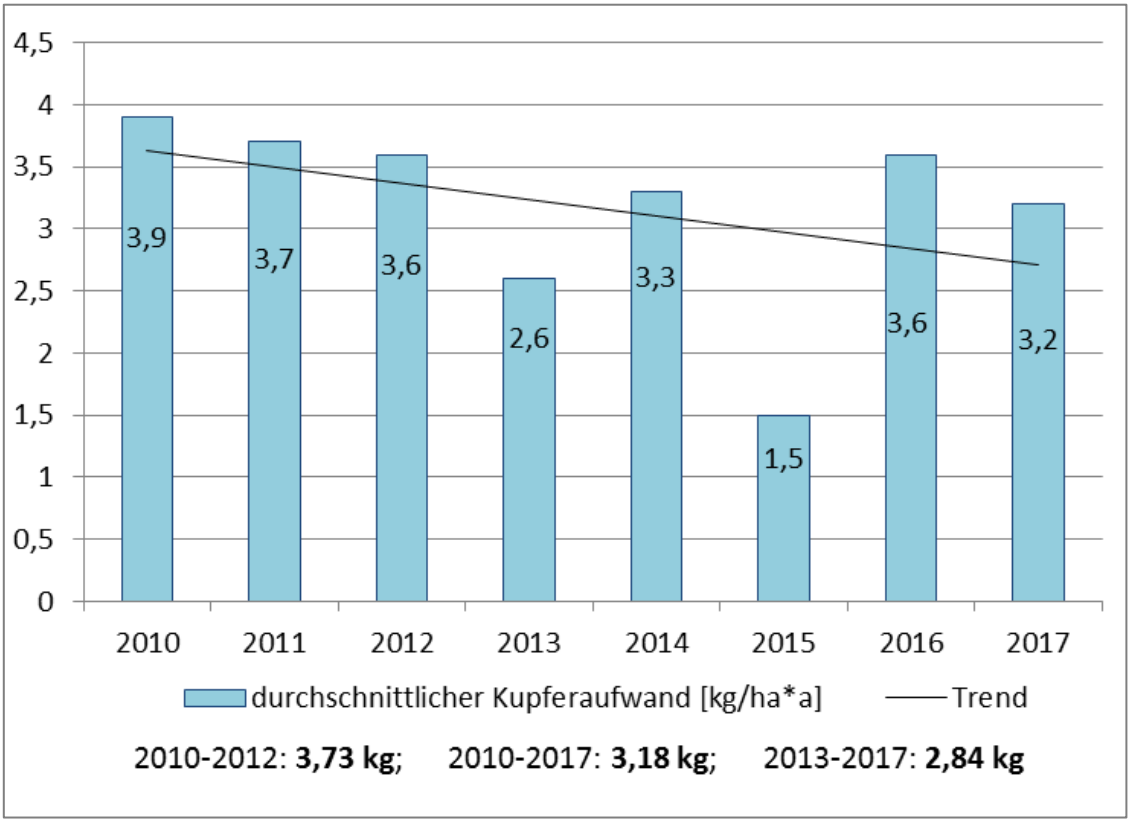


Fig. 7.6: Average quantities of pure copper in kg/ha applied between 2010 and 2017 in German hop production to combat downy mildew on hop.

8 Hop Quality and Analytics

ORR Dr. Klaus Kammhuber, Dipl.-Chemiker

8.1 General Information

Working Group IPZ 5d carries out all analytical testing needed in the IPZ Hops Department to support issues arising from testing by the other Working Groups, especially WG Hop Breeding Research. Ultimately, hop is cultivated for its compounds, making hop analytics a key precondition for effective hop research.

Present in hop are three groups of important substances; ranked in order of importance, these are the bitter compounds, the essential oils, and the polyphenols (*Fig. 8.1*).

Fig. 8.1: The important substances in hop

Until now, the alpha acids have been considered to be the key element contributing to hop quality because they are a determinant for the bittering potential; hop is added to beer on the basis of its alpha acids content (internationally, approx. 4.3 g alpha acids to 100 l beer, at present). Alpha acids also play an increasingly important role in the way hops are paid for. Payment is made either by weight of the alpha acids (in kg), or based on a system specified in supplements to the supply contracts, whereby the price goes up or down according to whether alpha acids levels are above or below a specified neutral range.

Hop affects beer in multiple ways, most important, however, are its bittering contribution and the fine and agreeable flavour that hop imparts to the beer. (*Fig. 8.2*).

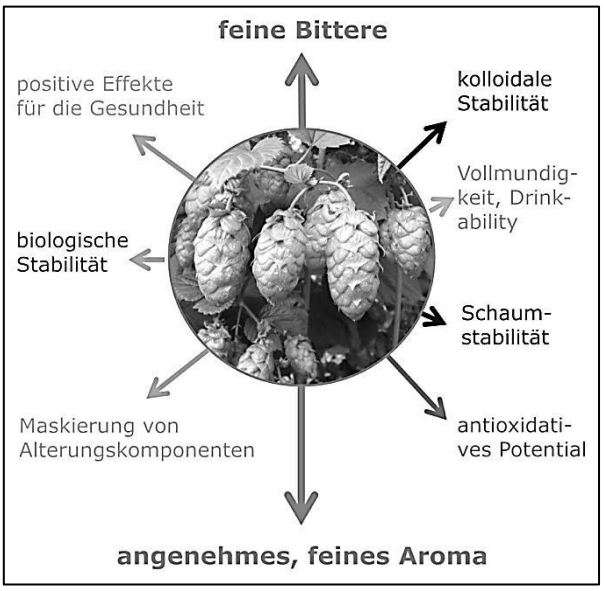


Fig. 8.2: The effect of hops in beer

8.2 The Craft Brewer Movement – new opportunities

A new beer-brewing ideology has evolved in the USA as a counter movement to the industrialization of beer production. The trend, known as the craft beer movement, eventually spread to Belgium, Scandinavia, and Italy and has now reached Germany. Craft brewers want to return to producing strong-tasting beers brewed with skill and artistry. The movement has gained momentum, one positive effect being that beer and hops are now subjects that are much more talked about. The craft brewers are looking for hops with special aroma and flavour, sometimes not even typical of hop. As a result, a more discerning appreciation of the different hop varieties and hop growing regions has developed.

Craft brewers have rediscovered the technique of dry hopping, which goes back to the nineteenth century and is now enjoying a renaissance. The method involves adding hops again to the finished beer in the storage tanks, usually on the basis of their oil content. Beer contains 92% water and 5% ethanol, so that primarily substances with a similar polarity are dissolved out of the hops. According to an age-old saying in chemistry '*Like dissolves like'*.

„Similia similibus solvuntur" = „Ähnliches wird mit ähnlichem gelöst"

Alpha acids dissolve only in trace amounts because they are not isomerized. Chiefly low molecular esters and the terpene alcohols are transferred to the beer – the reason why dry hopped beers acquire fruity and flowery flavours. Non-polar substances, like myrcene, are also dissolved in trace amounts. Polyphenols as a group, too, are polar, and easily soluble. One constraining factor in dry hopping is nitrate content. On average, hop contains 0.9% nitrate, all of which is transferred to the beer. However, the limit value of 50 mg/ltr for drinking water does not apply to beer. Plant protection agents generally tend to be non-polar and are therefore not readily soluble in water. No accumulation is noticeable in dry hopped beers, as opposed to conventionally brewed beers.

On the whole, the craft brewing movement represents a huge opportunity for hop production and is set to bring about a fundamental change in the hops industry. 20% of global hop output is used for 2% of world beer production. In the United States, the acreage devoted to hop growing again increased, from 12 670 hectares in 2010 to 23 096 hectares in 2017. It will be very interesting to see how this development affects the German hop growing regions.

8.2.1 The aroma-active substances are gaining in importance

Eating and drinking can be said to be a holistic experience of sensual pleasure, during which smell, taste, physical stimulation and other impressions, such as 'that certain something', are all processed side by side in the brain *(*Fig. 8.3*).* The perception of smell is the most important of these because olfactory impressions go straight to the unconscious where they can trigger emotions. But also 'that certain something', in which social elements, atmosphere, mood, and conviviality all play a role, is not to be underestimated.

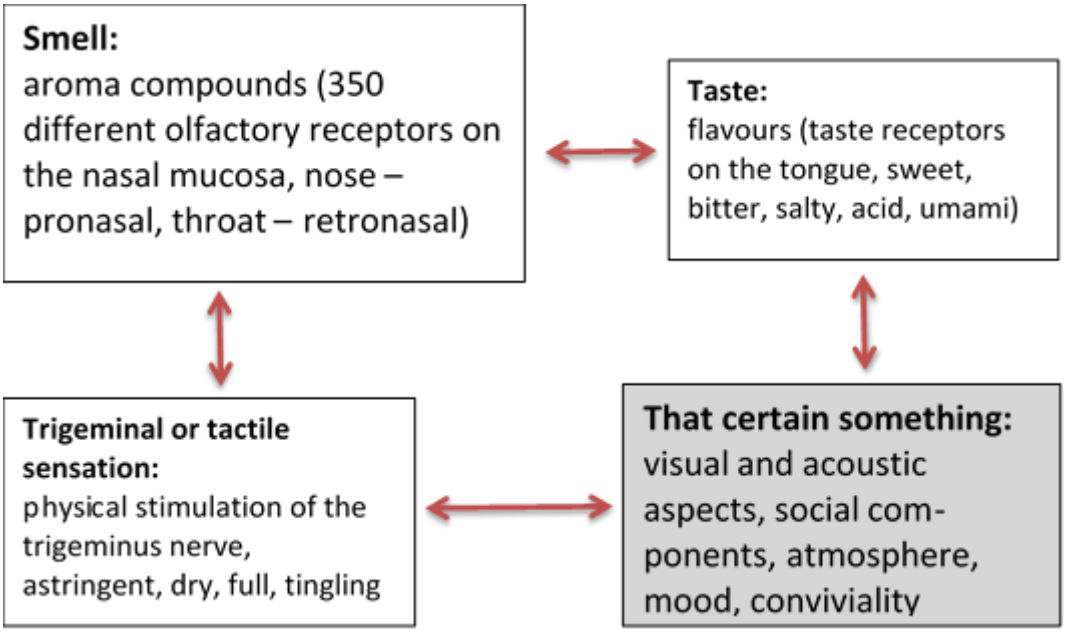


Fig. 8.3: Eating and drinking is a holistic experience of sensual pleasure

Craft brewers are more interested in the aroma-active substances in hop, and this poses a challenge for analytical testing. The hop essential oils are composed of approx. 300 - 400 single different substances. There are many synergies. Some substances are perceived as being intensified, others cancel each other out. Smell is a subjective perception, in contrast to chemical analysis, which delivers objective data. However, key substances need to be defined so that the quality of their aroma can be characterized analytically. Substances such as linalool, geraniol, myrcene, low molecular esters, and sulphur compounds are of relevance to hop aroma. Craft brewers want hops with 'exotic aromas', like mandarin orange, melon, mango or blackcurrant.

8.3 Optimization of Constituent Compounds as a Breeding Goal

8.3.1 Requirements of the brewing industry

The brewing industry still accounts for 95% of hop output, making it the biggest consumer of hops at present and set to remain so in the future. (Fig. 8.4).

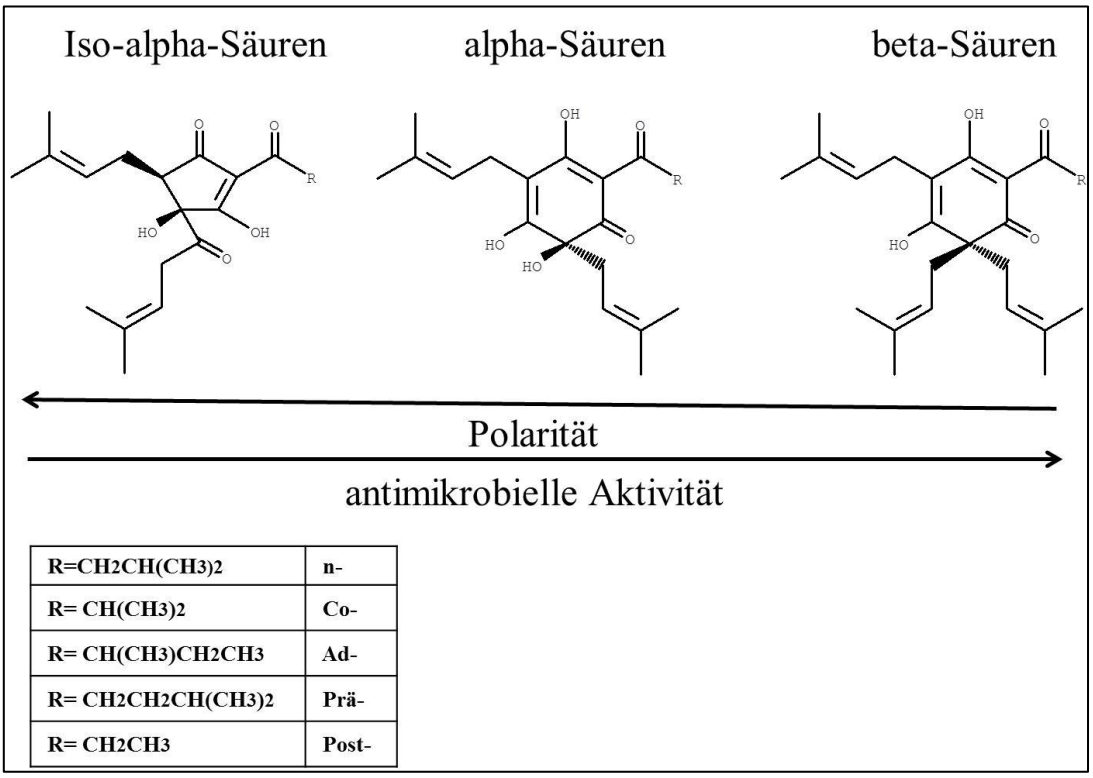
Fig. 8.4: Uses of hop

The requirements of the brewing industry and the hops trade with regard to the compounds in hop are changing continually. However, the consensus is that breeding programmes need to produce hops with the highest possible alpha acids levels which are simultaneously capable of remaining as stable as possible in spite of the fluctuations in the crops from year to year. A low concentration of cohumulone is no longer deemed so important as a quality criterion. In fact, for downstream and Beyond Brewing products there is even a demand for high alpha varieties with high cohumulone levels. However, a low concentration of cohumulone has a positive influence on foaming stability.

8.3.2 Alternative applications

To date, only 5% of the hop harvested is used in alternative applications, but there is scope for expansion in this area. The usefulness of the hop plant is not only confined to the cones; the other parts of the hop plant can also be put to good use. The woody inner parts of the hop bine, known as shives, make good material for safety insulation purposes and in composite insulation mats, thanks to their good insulating properties and excellent mechanical strength. The fibres can also be processed for use in moulded parts, for example as door panelling for cars. As yet, no large-scale technical applications have presented themselves. AUDI have been interested in exploring the possibility of using the tannins from hop leaves for tanning leather. However, the tests were not very successful.

Where the cones are concerned, it is primarily the antimicrobial properties of their bitter compounds that lend themselves best to alternative uses. The bitter compounds already have antimicrobial and preservative properties in catalytic amounts (0.001 – 0.1 % by weight), in the following ascending order: iso-α acids, α acids, and ß acids (Fig. 8.5).



R=CH2CH(CH3)2	n-
R= CH(CH3)2	Co-
R= CH(CH3)CH2CH3	Ad-
R= CH2CH2CH(CH3)2	Prä-
R= CH2CH3	Post-

Fig. 8.5: Order of antimicrobial activity: iso-α acids, α-acids and ß-acids

The more non-polar a molecule, the higher the level of antimicrobial activity. The bitter compounds destroy the pH gradients at the cell membranes of bacteria, rendering them unable to absorb nutrients, with the result that they die. (*Fig. 8.6*).

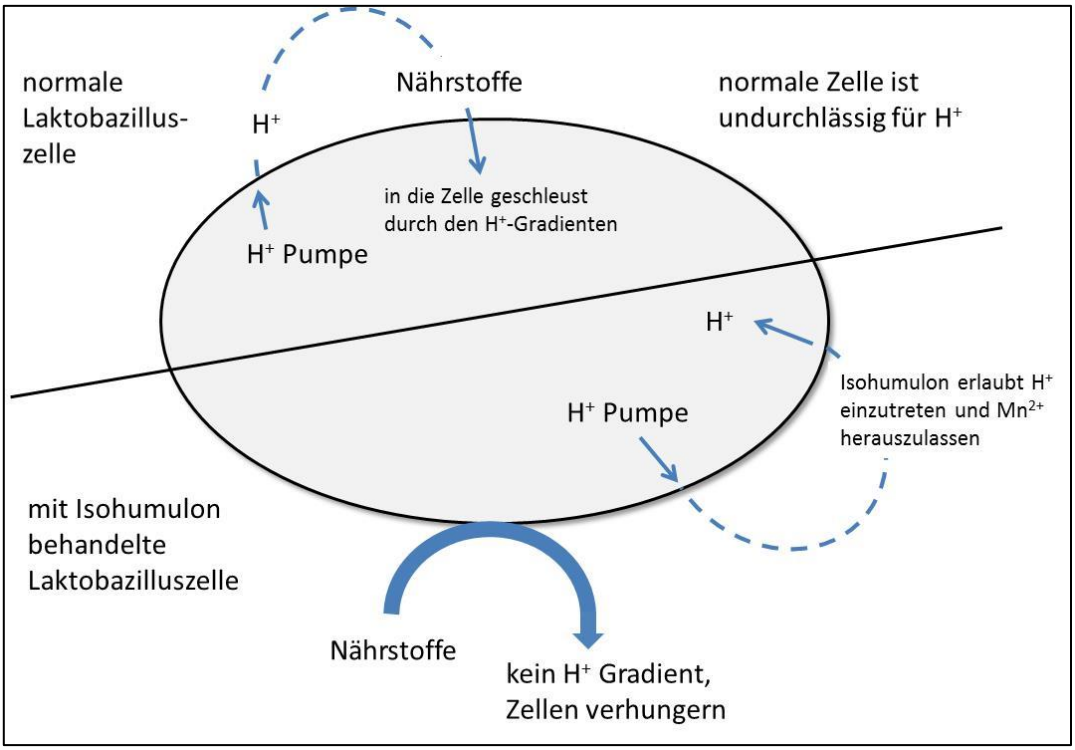


Fig. 8.6: Destruction of the pH gradient shown in a lactobacillus cell, using the method Buggey, L., Price, A., Stapely, S., J.

In fact, the iso-α acids in beer protect against *helicobacter pylori*, a bacterium which can trigger stomach cancer. The β acids are especially effective against gram-positive bacteria such as listeriae and chlostridiae and in inhibiting growth in *mycobacterium tuberculosis*, the tuberculosis pathogen. The hop bitter compounds can thus be employed as natural biocides wherever bacteria need to be kept at bay. In the sugar refining and ethanol industries, formalin is already successfully being replaced by β-acids. Thanks to their antimicrobial function, further possible applications are: use as a preservative in the food industry (for fish, meat and dairy products), in sanitization of biogenic waste (sewage sludge, compost), removing mould, improving hygiene and odours in animal litter, controlling allergens, and as an antibiotic in animal feed. In the future, it is likely that hop will be in greater demand for these applications. With a view to meeting this demand, Hüll is breeding for higher β-acids content. The present record is a content of approx. 20%. There is actually a breeding line that produces only β acids and no α acids. This variety is used in making teas.

Hop is also of considerable interest to the health, spa, food additive, and functional food sectors, because it contains a large number of polyphenolic substances. With a polyphenol content of as much as 8%, hop is a highly polyphenol-rich plant. Polyphenols are generally thought to have a highly positive influence on health because of their antioxidant effect and because they can scavenge free radicals. Substances with a very high antioxidative potential are oligomeric proanthocyanidins (up to 1.3%), glycosidically bound quercetin (up to 0.2%) and kaempferol (up to 0.2%). Multifidols, at up to 0.5%, are also a principal component of hop.

The name is derived from the tropical plant *jatropha multifida* because these compounds are found in its sap. These substances have anti-inflammatory properties. Traces of prenylated flavonoids, e.g. 8-prenylnaringenin (one of the most potent phytoestrogens), are also present, so that hop has a slight oestrogen-like effect.

Of all the hop polyphenols, xanthohumol is the one that grabs the attention of the public, and scientific studies on the subject have now sprung up everywhere. In the meantime, scientific evidence has been found to support the health claims for xanthohumol, and this means that it can be marketed for use in food supplements and functional foods. Xanthohumol can be used in treatments for more or less everything *(*Fig. 8.7*)*, the most promising discovery being that it works in treating cancer.

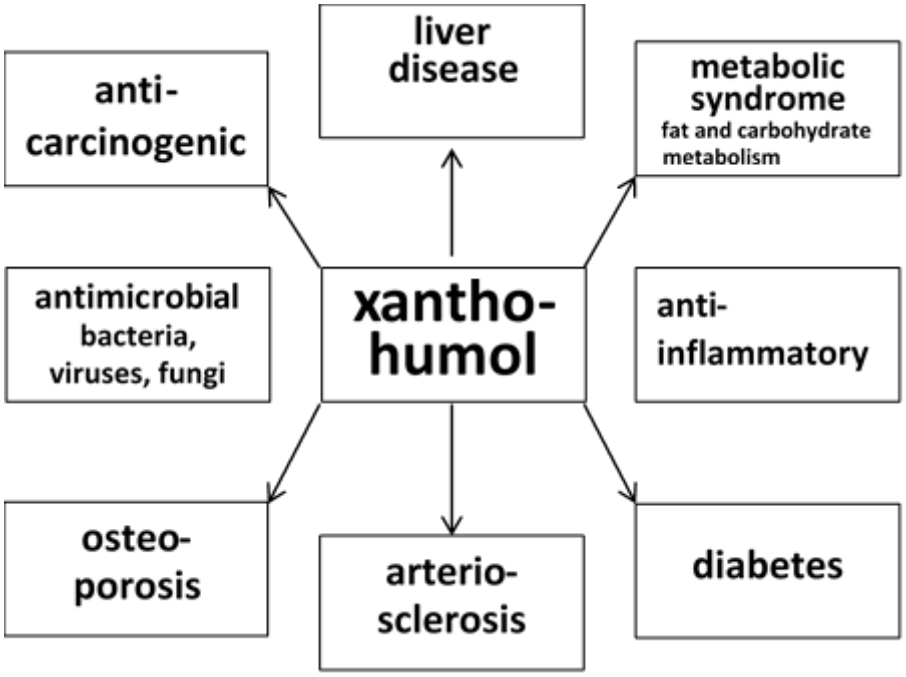


Fig. 8.7: Xanthohumol can help treat almost anything

In general, aroma hops have a higher polyphenol content than bittering hops. If specific components are called for, Hüll can respond at all times by breeding for the substances of interest in collaboration with the analytics team.

8.4 World Hop Collection (2016 Crop)

The essential oils from the world hop range are analysed every year, using headspace gas chromatography; the bitter compounds are analysed with the help of HPLC. *Tab. 8.1* gives the results for the 2016 crop. It can be used as an aid to identifying what variety an unknown hop cultivar belongs to.

Tab. 8.1: World Hop Collection (2016 Crop)

Cultivar	Myr-cene	2-M.-iso-butyrate	Sub. 14 b	Sub. 15	Lina-lool	Aroma-dendrene	Unde-canone	Hu-mulene	Farne-sene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß,γ-Ca-dinene	Seli-nadien	Gera-niol	α acids	ß acids	ß/a	Cohu-mulone	Colu-pulone
Admiral	4539	1416	0	112	79	0	13	694	6	24	4	6	54	0	0	15.0	6.2	0.41	43.9	64.7
Agnus	1022	139	0	7	20	0	5	247	0	25	6	9	49	0	3	8.9	5.8	0.65	36.9	58.8
Ahil	3716	849	102	5	32	0	20	472	31	23	8	16	48	3	13	8.6	4.4	0.51	32.7	54.0
Alliance	2127	246	1	3	35	0	16	663	4	27	4	5	58	0	0	4.7	2.6	0.54	31.9	52.9
Apolon	5135	159	116	13	45	0	4	515	50	24	6	11	48	0	10	7.5	4.3	0.58	27.5	48.3
Aquila	3662	97	4	108	39	54	33	45	0	30	55	113	32	206	13	7.3	5.2	0.71	47.5	71.0
Ariana	3304	722	323	75	39	0	48	718	0	28	21	38	62	2	2	11.6	5.8	0.50	40.8	58.7
Aromat	6748	21	3	25	114	0	50	777	49	27	3	5	54	0	3	2.6	4.4	1.70	24.6	41.3
Atlas	4488	1568	70	7	36	0	3	455	31	20	8	16	42	0	23	6.5	3.7	0.57	39.6	61.3
Aurora	3977	366	6	199	68	0	68	611	50	20	3	4	49	0	3	9.9	4.5	0.46	21.6	46.6
Backa	4111	1526	0	25	54	0	17	667	12	30	3	5	59	0	0	7.6	5.4	0.71	41.4	63.4
Belgisch Spalter	3345	460	2	42	47	9	24	394	3	30	23	51	48	88	1	4.5	3.1	0.68	24.5	47.9
Blisk	3018	806	105	3	54	0	7	566	21	28	7	13	53	0	14	8.8	3.7	0.42	31.9	54.6
Bobek	4899	282	37	287	92	0	47	646	49	23	4	6	53	0	6	7.2	6.1	0.84	24.6	45.4
Bor	3889	181	0	241	16	0	18	679	0	19	3	4	46	0	2	9.5	4.6	0.49	22.4	45.6
Bramling Cross	6491	811	37	15	93	5	43	634	0	50	14	26	92	31	2	4,4	3.5	0.8	33.4	59.4
Braustern	2892	426	3	119	20	0	16	561	0	26	3	4	55	0	1	8.4	5.2	0.62	25.9	47.5
Brewers Gold	1326	443	46	16	23	0	2	368	0	24	8	14	54	0	12	7.7	5.3	0.69	41.5	65.3
Brewers Stand	9113	2970	226	33	122	36	68	109	0	253	83	166	416	263	19	8.2	4.9	0.60	28.1	47.8
Buket	3090	616	3	120	51	0	45	626	16	29	3	5	59	0	2	8.8	4.5	0.51	22.2	52.3
Bullion	2104	459	58	17	28	0	5	404	0	25	10	20	51	2	2	6.7	5.4	0.81	40.4	64.0
Callista	4756	472	173	16	119	0	24	720	0	34	40	82	68	0	0	4.3	10.1	2.36	18.5	36.5
Cascade	4540	744	128	31	46	0	12	562	24	26	12	22	56	0	4	9.5	6.8	0.71	33.8	52.9
Chang bei 1	4951	422	9	7	72	0	43	587	21	33	21	42	62	47	1	4.4	4.7	1.07	24.9	45.6

Cultivar	Myr-cene	2-M.-iso-butyrate	Sub. 14 b	Sub. 15	Lina-lool	Aroma-dendrene	Unde-canone	Hu-mulene	Farne-sene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß,γ-Ca-dinene	Seli-nadien	Gera-niol	α acids	ß acids	ß/a	Cohu-mulone	Colu-pulone
Chang bei 2	4634	16	10	5	78	0	47	576	22	28	17	33	52	53	1	3.9	4.4	1.13	19.5	40.5
Columbus	1726	296	55	14	24	0	3	332	0	56	11	18	109	27	2	17.4	5.8	0.34	32.9	56.4
Comet	2174	155	24	69	21	0	6	12	0	6	36	79	11	30	2	8.9	4.0	0.45	39.2	61.0
Crystal	3082	69	6	18	67	46	21	532	0	45	40	80	56	106	2	1.7	5.7	3.36	16.8	33.4
Density	5491	430	0	10	87	0	38	670	0	25	3	6	51	0	0	4.4	3.7	0.84	34.5	60.6
Early Choice	5163	402	0	111	26	0	16	618	6	19	40	88	43	0	1	2.4	2.0	0.85	33.4	49.2
Eastwell Golding	2882	192	0	35	31	0	15	675	0	23	4	5	53	0	1	6.1	3.8	0.62	24.4	46.1
Emerald	2426	137	16	49	11	0	16	673	0	21	3	5	50	0	1	5.9	5.1	0.87	26.2	44.5
Eroica	3991	1264	176	178	11	0	13	445	0	22	9	17	44	0	1	10.4	8.4	0.81	38.2	61.0
Estera	3616	419	0	16	55	0	15	663	20	23	3	4	53	0	1	3.3	2.7	0.82	30.5	48.9
First Gold	3099	839	0	48	47	0	23	567	14	22	84	171	51	0	1	8.8	4.5	0.51	30.5	55.3
Fuggle	2127	387	4	38	46	0	13	464	20	23	4	5	51	0	1	5.1	3.5	0,68	29.5	48.6
Galena	2856	757	130	304	9	0	10	433	0	21	14	26	47	1	1	10.5	8.5	0,81	39.7	60.2
Ging Dao Do Hua	6434	1838	0	8	53	0	23	567	2	49	35	72	99	3	5	5.5	5.0	0,9	45.4	66.5
Glacier	5381	35	5	17	67	0	20	685	0	23	4	5	54	0	2	5.9	8.7	1.47	10.1	34.2
Golden Star	8134	2047	0	10	58	0	24	593	0	50	36	74	102	1	5	5.0	4.7	0.93	47.2	69.3
Granit	2421	184	20	20	13	0	49	494	0	19	8	16	42	0	1	7.9	4.5	0.57	22.8	44.7
Green Bullet	9313	525	29	47	49	0	22	707	0	20	4	6	46	0	0	7.4	4.0	0.54	40.6	63.9
Hallertau Blanc	1653	2528	507	64	125	0	38	168	0	46	515	1056	107	5	4	11.2	5.9	0.53	23.6	39.0
Hallertauer Gold	3519	281	97	10	59	0	21	719	0	27	4	5	56	1	1	6.5	5.7	0.87	18.6	39.5
Hall. Magnum	3919	243	130	57	14	0	9	681	0	23	3	5	48	0	1	14.2	7.3	0.51	25.8	43.9
Hallertauer Merkur	1522	441	51	11	39	0	12	444	0	26	4	5	54	0	1	11.8	6.2	0.52	19.3	41.6
Hallertauer Mfr.	1008	308	7	1	62	0	23	518	0	38	5	7	75	0	1	4.1	5.1	1.25	19.5	37.4
Hallertauer Taurus	3195	152	64	29	69	0	22	554	0	24	55	110	52	0	2	18.8	6.2	0.33	18.2	39.9
Hall. Tradition	1916	392	31	4	63	0	19	641	0	28	3	5	57	0	1	6.8	5.8	0.86	22.8	43.5

Cultivar	Myr-cene	2-M.-iso-butyrate	Sub. 14 b	Sub. 15	Lina-lool	Aroma-dendrene	Unde-canone	Hu-mulene	Farne-sene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß,γ-Ca-dinene	Seli-nadien	Gera-niol	α acids	ß acids	ß/a	Cohu-mulone	Colu-pulone
Harmony	4584	103	9	42	60	0	36	642	0	27	65	147	58	3	1	8.6	7.4	0.86	18.8	37.5
Herald	3101	624	2	396	25	0	68	391	0	17	19	38	40	0	8	12.4	5.2	0.42	35.9	57.4
Herkules	4046	726	266	322	24	0	21	605	0	17	4	5	44	1	5	19.0	6.3	0.33	32.7	50.7
Hersbrucker Pure	2861	227	0	40	54	14	35	512	0	29	26	52	48	100	1	4.7	2.7	0.57	23.3	43.6
Hersbrucker Spät	3860	137	9	11	102	64	17	500	0	53	55	101	59	145	2	1.7	5.2	3.00	18.2	33.2
Huell Melon	7669	3147	9	95	50	0	51	193	72	67	254	500	137	155	9	8.9	9.7	1.09	28.4	48.3
Hüller Anfang	1466	451	24	1	59	0	23	723	0	44	5	7	80	0	0	2.2	4.6	2.05	22.0	37.4
Hüller Aroma	2593	335	11	2	74	0	23	751	0	36	4	6	70	0	0	2.8	4.2	1.49	22.9	43.4
Hüller Bitter	3881	310	105	7	51	14	21	424	0	125	44	80	208	174	3	6.4	4.8	0.76	26.3	45.2
Hüller Fortschritt	2979	259	28	2	82	0	26	767	0	33	4	6	63	0	0	2.5	5.2	2.11	23.0	39.4
Hüller Start	1888	237	4	4	32	0	39	771	0	38	4	6	68	0	0	2.4	4.1	1.71	22.3	40.3
Kazbek	1805	373	52	19	21	0	4	370	0	24	10	19	49	3	2	6.9	5.9	0.85	39.4	63.6
Kirin 2	6933	1829	0	9	54	0	22	519	0	59	40	83	119	0	5	5.8	5.3	0.91	46.1	68.5
Kumir	3889	263	3	86	47	0	25	641	12	21	4	6	47	0	2	10.9	5.2	0.48	19.3	42.6
Late Cluster	5596	1705	226	67	101	31	56	109	0	198	79	143	347	207	11	8.8	5.1	0.58	27.4	48.4
Lubelski	5509	15	6	10	70	0	40	757	56	28	3	5	57	0	2	4.2	6.0	1.44	21.5	37.8
Mandarina Bavaria	4944	1334	57	41	50	0	36	716	7	37	81	167	85	4	15	11.5	7.6	0.66	32.0	52.3
Marynka	3340	720	1	77	21	0	21	351	83	19	6	12	41	0	6	8.7	4.0	0.45	21.0	47.6
Mt. Hood	826	173	58	4	24	0	9	425	0	39	4	8	73	0	2	5.1	6.0	1.17	24.7	44.7
Neoplanta	2403	444	0	43	19	0	20	555	10	30	4	5	61	0	1	8.0	4.0	0.5	35.5	61.0
Neptun	1891	467	136	12	35	0	6	432	0	27	3	4	55	0	0	14.1	5.6	0.4	21.3	41.3
Northern Brewer	1597	287	1	98	16	0	14	398	0	24	3	4	50	0	1	10.8	6.0	0.55	24.4	46.2
Nugget	2035	248	3	87	35	0	11	342	0	14	7	14	32	0	0	13.9	4.5	0.32	25.7	49.7
NZ Hallertauer	4618	262	4	41	48	3	13	463	10	28	16	35	45	56	1	4.0	6.2	1.55	31.3	56.1
Opal	2265	132	48	53	61	0	20	482	1	27	1	4	56	0	3	8.8	6.5	0.73	13.2	30.2

Cultivar	Myr-cene	2-M.-iso-butyrate	Sub. 14 b	Sub. 15	Lina-lool	Aroma-dendrene	Unde-canone	Hu-mulene	Farne-sene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß,γ-Ca-dinene	Seli-nadien	Gera-niol	α acids	ß acids	ß/a	Cohu-mulone	Colu-pulone
Orion	1757	274	20	9	33	0	16	499	0	29	3	4	59	0	1	8.4	5.7	0.68	25.8	50.9
PCU 280	3109	228	0	55	9	0	11	631	0	19	3	5	48	0	1	9.3	3.8	0.41	26.7	47.5
Perle	1415	185	0	76	9	0	9	439	0	21	3	4	49	0	1	8.0	5.0	0.63	28.3	51.2
Phoenix	3077	749	6	54	17	0	17	605	8	22	40	91	51	0	1	11.3	5.2	0.45	26.3	47.7
Pilgrim	4958	1037	1	571	34	0	46	608	0	17	54	118	42	0	6	7.8	4.2	0.54	37.5	60.0
Pilot	8936	1407	2	569	128	0	92	145	1	27	273	579	68	1	3	8.5	4.5	0.53	35.6	59.9
Pioneer	3128	783	12	580	21	0	60	421	0	19	20	42	43	0	6	11.0	4.5	0.41	32.3	56.6
Polaris	2251	298	60	240	10	0	11	386	0	21	3	4	47	0	1	21.5	5.8	0.27	23.5	42.4
Premiant	2489	287	4	36	55	0	22	484	7	20	3	4	44	0	2	9.1	5.5	0.60	21.1	43.3
Pride of Ringwood	3712	135	0	1	20	0	28	40	0	18	53	116	38	0	2	9.8	5.1	0.52	31.2	50.8
Progress	1093	2958	282	64	122	36	71	84	0	255	84	170	428	279	20	8.5	5.2	0.61	26.7	47.1
Relax	2260	128	46	4	16	0	28	696	0	37	4	6	63	0	8	0.4	10.1	23.6	29.3	26.1
Rottenburger	3760	119	4	7	60	0	28	715	6	28	11	23	58	0	1	3.4	6.2	1.82	25.1	40.0
Rubin	1998	322	116	28	24	0	10	494	0	29	59	116	60	0	8	1.,8	4.7	0.34	32.0	51.2
Saazer	3346	1	4	8	83	0	55	790	25	33	4	6	63	0	7	3.7	5.6	1.5	23.2	40.0
Saphir	2987	89	9	64	61	10	71	502	0	28	18	35	50	55	2	3.6	6.8	1,89	11.4	39.5
Serebrianker	2768	286	0	13	58	0	15	473	2	38	35	70	68	0	3	1.9	4.1	2.17	21.5	37.9
Sladek	3670	241	7	61	47	0	24	672	6	23	3	5	49	0	1	9.8	5.1	0.52	18.6	42.2
Smaragd	3346	64	47	74	58	0	14	622	3	21	1	5	50	0	2	7.5	5.7	0.76	13.8	29.1
Spalter	3408	3	4	10	89	0	48	764	29	32	4	6	61	0	7	3.4	5.6	1.69	23.7	40.8
Spalter Select	5867	250	90	17	175	22	53	523	71	30	29	61	47	92	1	5.4	4.9	0.91	21.2	40.4
Sterling	3413	198	1	117	32	0	12	415	0	14	7	14	34	0	0	12.8	4.0	0.31	24.4	48.8
Strisselspalter	2678	86	26	10	63	43	19	493	0	45	44	92	56	137	1	3.0	6.6	2.2	17.5	32.6
Südafrika	2316	65	0	5	5	0	12	546	0	32	53	113	63	1	2	6.3	4.2	0.67	30.6	47.9
Talisman	2667	338	17	115	17	0	12	539	0	24	3	5	50	0	1	9.8	5.6	0.57	25.4	47.7

Cultivar	Myr-cene	2-M.-iso-butyrate	Sub. 14 b	Sub. 15	Lina-lool	Aroma-dendrene	Unde-canone	Hu-mulene	Farne-sene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	ß,γ-Ca-dinene	Seli-nadien	Gera-niol	α acids	ß acids	ß/a	Cohu-mulone	Colu-pulone
Tettnanger	3603	18	5	11	109	0	55	777	29	33	4	6	63	0	9	3.7	6.0	1.6	22.6	40.4
Vojvodina	5413	368	1	96	19	0	21	602	4	21	3	4	47	0	2	5.5	3.4	0.61	28.4	57.2
WFG	5487	108	21	7	85	0	47	752	27	33	4	7	63	2	3	4.1	4.9	1.20	22.5	39.6
Willamette	1790	225	1	19	31	0	6	470	18	24	4	7	53	0	1	3.5	3.4	0.96	33.3	52.5
Wye Challenger	3877	869	6	127	59	0	28	610	7	25	48	97	54	1	1	5.2	5.0	0.96	25.9	45.2
Wye Northdown	3197	369	3	104	20	0	13	569	0	24	4	6	52	1	1	7.7	4.6	0.6	26.5	49.3
Wye Target	2618	640	2	54	53	0	28	401	0	46	9	14	93	16	1	12.3	5.9	0.48	32.3	54.8
Wye Viking	5313	786	19	150	45	0	60	571	57	26	39	84	56	0	3	6.6	5.0	0.75	23.2	41.5
Yeoman	3339	756	55	55	19	0	12	541	0	19	35	75	47	0	2	12.3	5.7	0.46	25.5	44.9
Zatecki	3208	317	1	31	52	0	12	617	22	23	3	5	52	0	1	2.9	2.9	1.03	29.0	47.0
Zenith	3795	230	0	86	43	0	22	652	1	23	60	143	53	0	1	9.0	3.7	0.41	24.9	45.9
Zeus	1540	267	50	15	17	0	2	312	0	56	11	17	112	29	2	17.2	5.6	0.33	33.3	56.5
Zitic	3508	0	0	6	19	0	24	690	7	22	3	5	50	0	7	6.1	5.5	0.92	17.5	37.7

Essential oils = relative values, ß caryophyllene = 100, α- and β-acids in % ltr., analogues in % of the α- or β-acids
Sub. 14b = Methyl iso heptanoate, Sub. 15 = trans-(β)-ocimene

8.5 Improving Aroma Analytics with the New Gas Chromatography/ Mass Spectrometry System

8.5.1 Identification of essential oil components

For four years now, Hüll has had a new gas chromatography/mass spectrometry system; it is one of the most cutting edge pieces of analytical equipment in the State Research Center for Agriculture. With the help of this equipment, it has so far been possible to identify 143 substances, by comparing the mass spectra and using the available standards.

Fig. 8.8 shows the classification system of essential oils in hop; *Tab. 8.2* gives the number of identified substances, arranged in chemical categories.

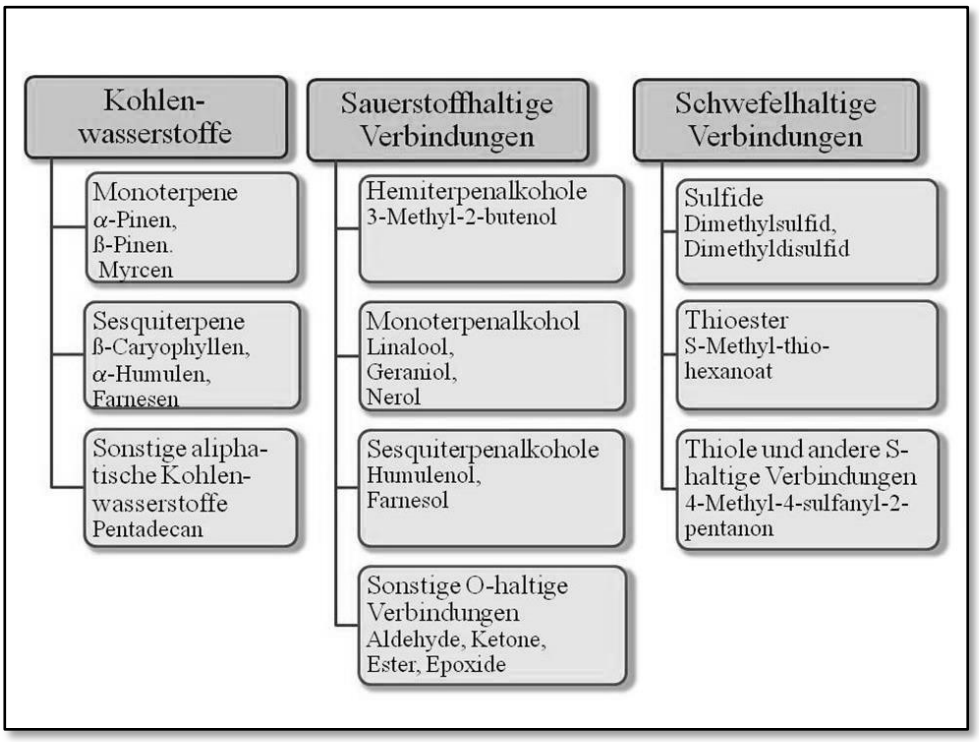


Fig. 8.8: Classification system of the hop essential oils

Tab. 8.2: Identified aroma substances in chemical categories

Category	Number	Category	Number
Hemiterpenes	3	Ketones	14
Monoterpenes	26	Aldehydes	3
Sesquiterpenes	37	Carbonic acids	2
Esters	32	Sulphur compounds	10
Alcohols	10	Other	4

With the new analytics system it is now possible to characterize hop cultivars in greater depth and more detail. New substances hitherto not mentioned in the relevant literature have also been discovered, e.g. perrilene, bergamotene, santalol etc. ...

The purpose of aroma analytics is to objectify sensory impressions and understand the science behind them. In this context, it is very important to evaluate and interpret the data so that correlations between chemical analysis and sensory impressions can be established. Hop is one of a number of foodstuffs whose aromas cannot be satisfactorily characterized even with the help of a variety of substances, but it is precisely this fact that makes it so interesting. Aroma is the result of diverse and complex interactions between many different aroma-active compounds (*Fig. 8.9*); nevertheless, it makes sense to use a reductionism approach so that key substances can be defined. These can then serve as marker substances for a fine hop aroma, thus helping us to understand which substances are transferred to the beer.

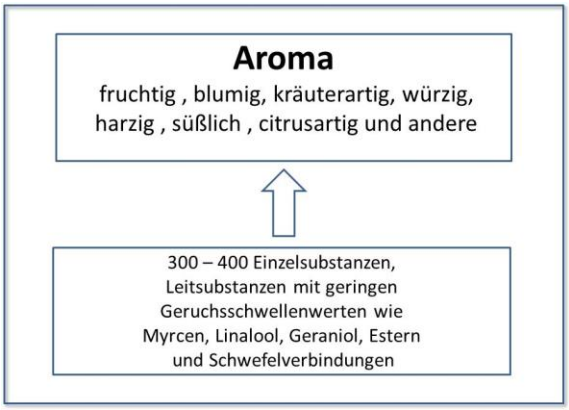


Fig. 8.9: Aroma is the result of many different complex interactions between many aroma-active substances

Important key aroma-active substances in hop and their olfactory impressions are shown in Tab. 8.3 .

Tab. 8.3: Important key aroma-active substances in hop

Aroma substance	**Concentration in hop [mg/100 g]**	**Odour threshold value in water [µg/l]**	**Olfactory impression**
Myrcene	20 – 2300	10 – 125	piney, metallic
α-Terpinol	1- 10	200	lilac
Linalool	4 -10	6	flowery, citrussy
Citronellol	0,4 - 4	40	citrussy
Geraniol	1 - 10	20	flowery, rose-like
Ester (Isobutylisobutyrate, 2-Methylbutyl-isobutyrate)	3 - 35 14 - 47	30 -60	fruity
4-Mercapto-4-methyl-2-pentanone (4-MMP)	0 – 0,008	0,0001	blackcurrant
3-Mercaptohexanol (3-MH)	0 – 0,003	0,2	blackcurrant, passion fruit
3-Mercaptohexylacetate (3-MHA)	0 – 0,003	0,017	grapefruit, passion fruit

8.6 Quality Assurance in Alpha Acids Analytics for Hop Supply Contracts

8.6.1 Multi-laboratory ring analysis of the 2017 crop

Since 2000, hop supply contracts have included a supplementary agreement concerning α acids content. The price agreed in the contract applies when the α acids content is within what is termed a 'neutral range'. If the content is above or below this range, the price paid is raised or lowered. The specification of the Working Group for Hop Analytics prescribes exactly how sampling should be carried out (sample division, storage), which labs can conduct analysis reliability checks and what tolerance ranges are permitted in the analysis results. In 2017, WG IPZ 5d was again tasked with organizing and evaluating the multi-laboratory ring analysis in order to guarantee the quality of α acids analytics.

In 2017, the following labs participated in the ring analysis:

- Hallertauer Hopfenveredelungsgesellschaft (*Hallertau Hop Processing Society*) (HHV), Au/Hallertau plant
- Hopfenveredelung (*Hop Processing*) St. Johann GmbH, Wolnzach
- Hopfenveredelung (*Hop Processing*) St. Johann GmbH & Co. KG, St. Johann
- Hallertauer Hopfenveredelungsgesellschaft (*Hallertau Hop Processing Society)* (HHV), Mainburg plant
- Hallertauer Hopfenverwertungsgenossenschaft (*Hallertau 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 Departmen*t), at Hüll

The ring analysis began in 2017 on September 12 and finished on November 10, with most of the hop batches having been analysed in the labs during this time. Altogether, ring analyses were performed nine times (9 weeks). The sample material was very kindly provided by Mr. Hörmannsperger (Hopfenring Hallertau). Each sample was only ever taken from a single bale to ensure homogeneity as far as possible. For each analysis, the samples were ground on the Monday in a hammer mill at Hüll, then divided using a sample divider, vacuum packed and delivered to the various labs. On the following days of the week, one sample per day was analysed. The results were then sent back to Hüll a week later for evaluation. In 2017, a total of 33 samples were analysed.

The evaluation findings were passed on to the individual labs as soon as possible. Fig. 8.10 is an example of what an ideal evaluation of a ring analysis should look like. The numbers beside the labs (1-7) in the following list do not correspond to the order in which the labs appear in the above list. The outlier tests were calculated in accordance with DIN ISO 5725. Cochran's test was applied for within-lab assessment; Grubbs' test was used for inter-lab assessment.

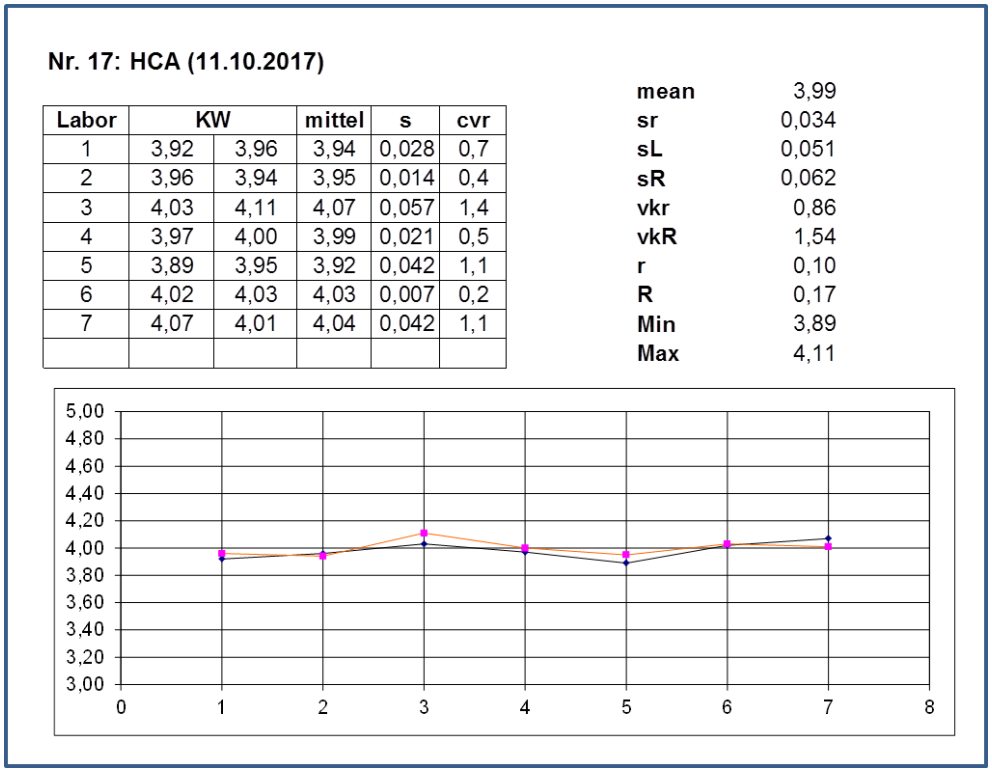


Fig. 8.10: Evaluation of a ring analysis

The outliers in 2017 are shown in *Tab. 8.4*

Tab. 8.4: 2017 outliers

	Cochran		Grubbs	
Sample	α = 0.01	α = 0.05	α = 0.01	α = 0.05
5	5			
5		5		
27				3
32		5		
Total:	**1**	**2**	**0**	**1**

As of 2013, there are now 5 alpha classes and new tolerance limits. *Tab. 8.5* shows the new classes and the outliers in 2017.

Tab. 8.5: Updated alpha acids classes and tolerance limits; outliers in 2017

	< 5.0 %	5.0 % - 8.0 %	8.1 % - 11.0 %	11.1 % - 14 %	> 14.0 %
Critical difference range	+/-0.3 0.6	+/-0.4 0.8	+/-0.5 1.0	+/-0.6 1.2	+/- 0.7 1.4
Outliers in 2017	0	0	0	0	0

In 2017 there were no cases where the permitted tolerance limits were overrun.

Fig. 8.11 shows all analysis results for each lab as deviations relative to the mean (= 100 %) differentiated by α acids levels <5 %, >=5 % and <10 % and >=10 %. The charts show clearly whether the analysis results of a particular lab tend to be too low or too high.

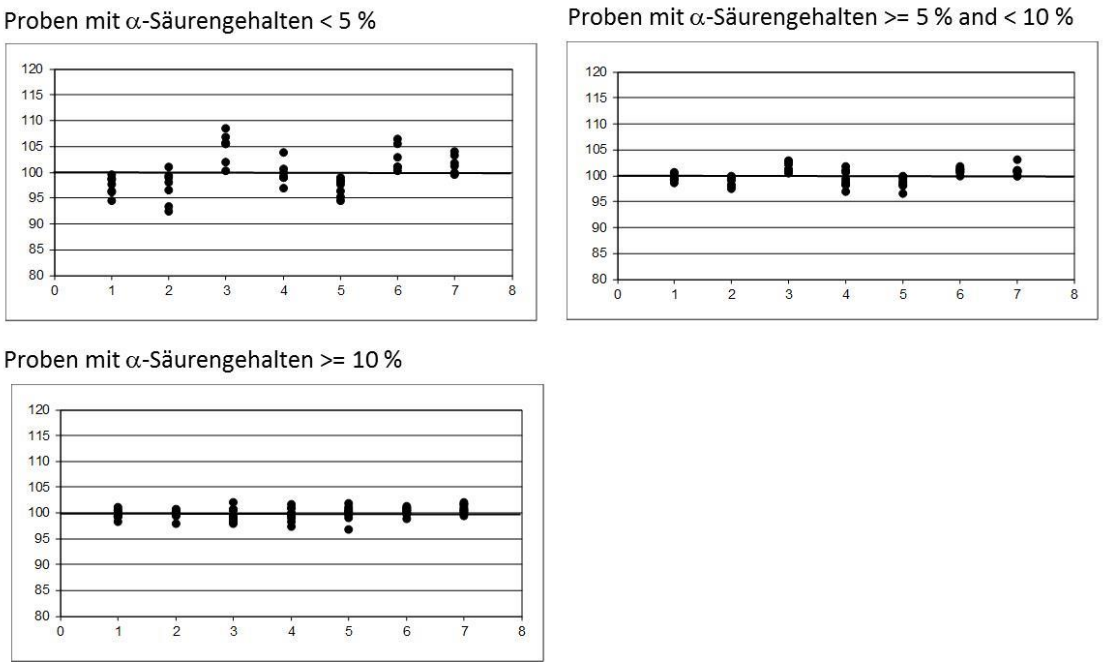


Fig. 8.11: Analysis results of the laboratories in relation to the mean

The Hüll lab is number 5.

8.6.2 Evaluation of analysis reliability checks

Since 2005, analysis reliability checks have been carried out in addition to the multi-lab ring analysis. These are evaluated by WG IPZ 5d and the findings sent back to the labs involved and to the Hop Growers' Association and Hop Trade Association. A lab which does the initial analy-sis selects three samples per week, which are then analysed by three different labs, in accordance with the AHA specification. The result of the initial analysis is validated when the mean value of the reliability check and the result of the initial analysis are within the tolerance limits (Tab. 8.5). Tab. 8.6 gives the results for 2017.

Tab. 8.6: Analysis reliability checks in 2017

Sample designation	Initial test laboratory	Initial test	Reliability check			Mean value	Result validated
			1	2	3		
3993 HT	Agrolab	5.4	5.1	5.3	5.3	5.23	yes
4099 TE	Agrolab	3.4	3.1	3.1	3.3	3.17	yes
4181 PE	Agrolab	6.5	6.2	6.3	6.3	6.27	yes
KW 38 HPE	HHV AU	7.5	7.5	7.5	7.7	7.57	yes
KW 38 HNB	HHV AU	6.3	6.3	6.3	6.5	6.37	yes
KW 38 HHM	HHV AU	12.8	12.7	13.0	13.0	12.90	yes
QK 17/002224 HHM	HV Wolnzach	11.3	11.0	11.2	11.4	11.20	yes
QK 17/002240 HTU	HV Wolnzach	14.4	14.1	14.2	14.5	14.27	yes
QK 17/002243 HHS	HV Wolnzach	14.4	14.4	14.4	14.6	14.47	yes
KW 40-3074 HNB	HVG Mainburg	7.7	7.7	7.7	7.8	7.73	yes
KW 40-3319 HHT	HVG Mainburg	6.1	6.1	6.1	6.1	6.10	yes
KW 40-4047 HPE	HVG Mainburg	6.9	6.7	6.8	6.9	6.80	yes
14049	Agrolab	4.0	3.8	3.9	3.9	3.87	yes
14080	Agrolab	8.2	8.0	8.0	8.0	8.00	yes
13960	Agrolab	14.9	14.5	14.6	14.6	14.57	yes
KW 42 HNU	HHV AU	11.3	11.3	11.3	11.4	11.33	yes
KW 42 HHM	HHV AU	12.1	12.0	12.2	12.2	12.13	yes
KW 42 HHS	HHV AU	15.1	14.9	15.0	15.1	15.00	yes
KW 43 HHT	HV St. Johann	5.6	5.8	5.8	5.8	5.80	yes
KW 43 HPE	HV St. Johann	7.9	7.7	7.8	7.8	7.77	yes
KW 43 HHM	HV St. Johann	11.4	11.3	11.4	11.4	11.37	yes
HHS KW 44-10964	HVG Mainburg	19.0	18.8	19.0	19.1	18.97	yes
HHS KW 44-10028	HVG Mainburg	13.1	12.7	12.7	12.9	12.77	yes
HHS KW 44-14308	HVG Mainburg	16.6	16.2	16.3	16.4	16.30	yes

8.7 Wöllmer Analysis of the New Breeding Lines from Hüll

The primary role of the hops in brewing is to impart a delicate bitterness to the beer. The alpha acids content is an indicator of the degree of bitterness; another factor is the quality of the bitterness. As well as alpha acids, hop contains a large number of other bittering substances, which contribute to the bitterness quality (Fig. 8.12). Dr. Dresel has elucidated in his thesis what many of these substances are, using LC-MS (Thesis TUM 2013).

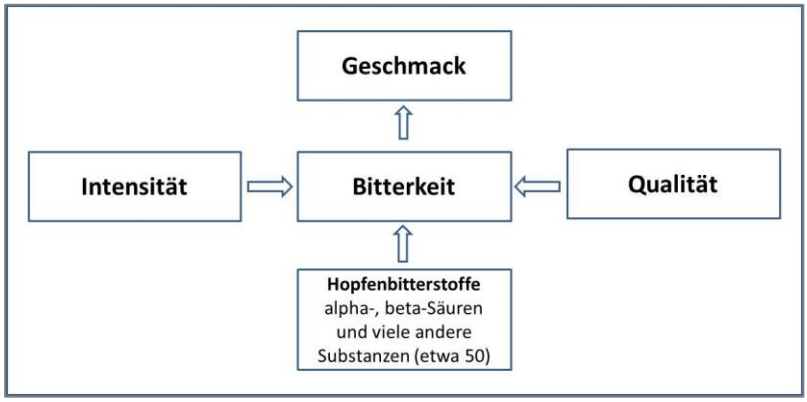


Fig. 8.12: A large number of substances are responsible for the intensity and quality of the bitterness

A hundred years ago, Wöllmer developed a method of differentiating hard and soft resins. The total resin is extracted with ether and split into two resin fractions. The portion soluble in hexane is designated the soft resin fraction; the portion that is not soluble is termed the hard resin fraction. Soft resin is made up of alpha and beta acids and some nonspecific components (Fig. 8.13).

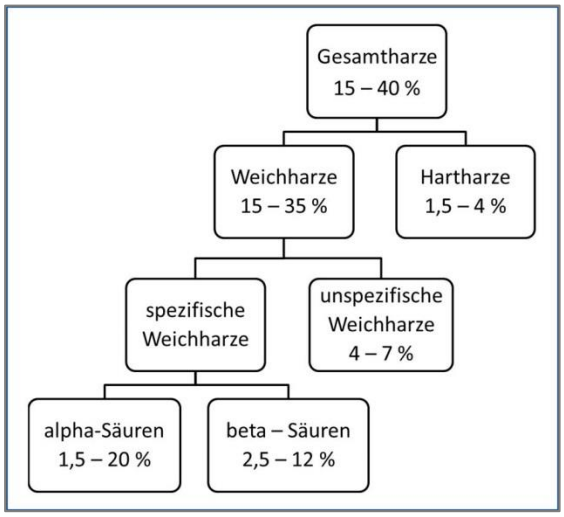


Fig. 8.13: Analysis scheme for a Wöllmer analysis

Nonspecific compounds occurring in soft resin are, for example, cis-allo-isohumulones, hulupones, tricyclohumenes, tricyclolupones, dehydrotricyclolupones and many other substances.
Hard resin consists of compounds only slightly soluble in water, such as xanthohumol, and substances derived therefrom, e.g. desmethylxanthohumol, xanthohumol B and C. 8-prenylnaringenin and 6-prenylnaringenin are present in trace amounts. Hard resin components easily soluble in water are glycosidically bound quercetins, kaempferols and multifidols. These compounds were analysed by HPLC in the course of earlier work and the results published (Kammhuber, K.: Differentiation of the World Hop Collection by Means of the Low Weight Molecular Polyphenols, Brewing Science, March/April 2012, Vol.65, pp.16-23). Tab. 8.7 gives the results for the new Hüll cultivars.

Tab. 8.7: Wöllmer analyses of the new breeding lines from Hüll (2016 Crop)

Cultivar	Total resin	α acids CV	α acids HPLC	Soft resin	Hard resin	ß-Fraction	ß acids HPLC	Xanthohumol HPLC
Ariana	25.87	12.09	12.02	23.11	10.67	11.01	6.84	0.69
Ariana	25.53	12.31	12.07	23.03	9.78	10.72	6.86	0.69
Callista	20.88	4.21	3.52	18.36	12.05	14.16	10.32	0.75
Callista	21.09	4.47	3.76	18.97	10.02	14.50	10.25	0.77
Hallertau Blanc	21.03	9.36	8.88	18.94	9.91	9.58	5.90	0.55
Hallertau Blanc	21.15	9.61	9.07	19.22	9.15	9.61	5.92	0.55
Huell Melon	25.35	7.86	7.46	22.71	10.43	14.85	10.86	0.86
Huell Melon	26.26	8.16	7.80	23.72	9.69	15.55	11.34	0.91
Mandarina Bavaria	25.48	11.00	10.49	22.69	10.95	11.68	6.93	0.84
Mandarina Bavaria	25.31	11.05	10.49	23.19	8.39	12.13	6.84	0.84
Opal	21.79	8.87	8.12	19.59	10.10	10.72	5.86	0.51
Opal	22.72	9.53	8.65	20.48	9.86	10.95	6.20	0.53
Polaris	38.42	22.39	21.94	34.27	10.79	11.88	5.46	0.98
Polaris	38.90	23.56	22.36	35.27	9.32	11.71	5.70	1.09
Saphir	19.53	4.66	3.71	17.01	12.93	12.35	6.53	0.50
Saphir	20.53	4.97	3.99	18.04	12.15	13.07	6.96	0.52
Smaragd	20.73	7.91	6.94	18.60	10.28	10.69	6.07	0.37
Smaragd	20.25	7.90	6.94	18.66	7.86	10.76	6.05	0.37

Size data: total resin, soft resin, alpha acids, beta acids xanthohumol in % hops, hard resin in % of total resin

ß-fraction = soft resin - conductometric value

Bitterness value according to Wöllmer: bitterness value = alpha acids + ß-fraction/9

Since the ß-fraction is relatively constant, the bitterness value was later equated to the alpha acids concentration. A first pointer to nonspecific soft resins is the quotient alpha-CV/alpha-HPLC. The alpha-CV is nonspecific, the alpha-HPLC highly specific.The higher this value, the higher the concentration of nonspecific soft resins. Fig. 8.14 gives the results for the new Hüll breeding lines (in each case a double determination).

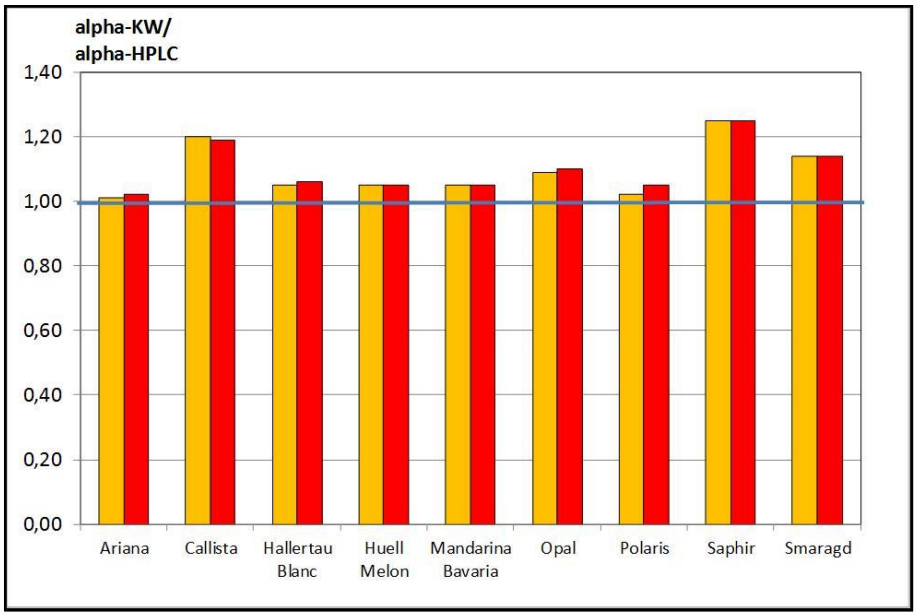


Fig. 8.14: Quotient alpha-CV/alpha-HPLC

The quotient is highest for the cultivar *Saphir* and also relatively high for cultivar *Callista*. High alpha cultivars, such as *Polaris* have a value close to one.

For more evidence, deduct the alpha and beta acids from the soft resin and look at the percentage of nonspecific substances. (Fig. 8.15).

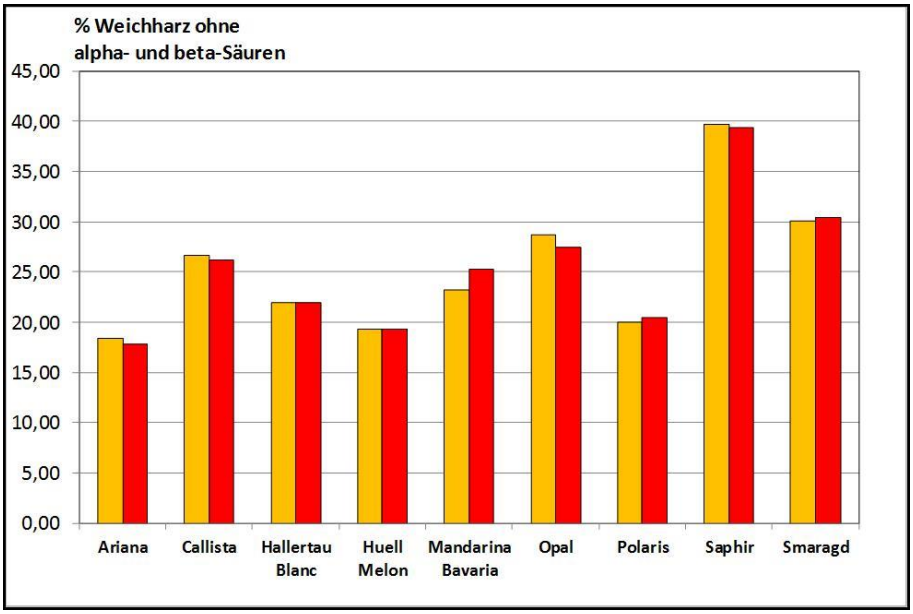


Fig. 8.15: Proportion of soft resin without alpha and beta acids

With roughly 40 %, cultivar *Saphir* has the largest proportion of nonspecific soft resins, followed by *Smaragd* and *Opal*. *Callista* also has a relatively high concentration of non-specific soft resins. A high concentration of nonspecific resins is considered to be an indicator of a delicate, agreeable and harmonious bitterness.

8.8 Purchase of New Near Infrared Reflectance Spectroscopy Equipment

In spring 2017, a new piece of NIRS equipment was purchased, the funding for which was provided solely by the Society of Hop Research. (Fig. 8.16).

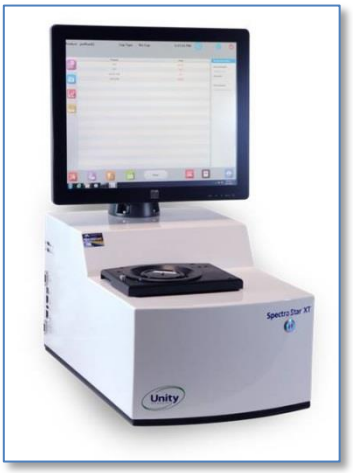


Fig. 8.16: The new NIRS equipment

The new equipment is compatible with the equipment at AQU in Freising. The same measuring cells can be used as with the old equipment. The wavelength range is 600 - 2500 nm in 1 nm steps. At the moment a calibration procedure is underway by means of mathematical transformation to adapt the old calibration to the new equipment.

As many samples as possible with wet chemical reference values need to be included so that new calibrations can be created. As soon as the results delivered by the new equipment are as good as those from the old equipment, the new equipment will take over from it.

8.9 Verification of Varietal Authenticity 2017

Verification of varietal authenticity is a mandatory task for Working Group IPZ 5d to provide administrative assistance for the food control authorities.

Varietal verifications for the food control authorities	37
(Landratsämter ─ *rural district administration offices*)	
Number not accepted	0

9 Publications and Specialist Information

9.1 Overview of PR Activities

	Number		Number
Practice-relevant information and scientific papers	21	Guided tours	47
LfL publications	2	Exhibitions and posters	5
Specialist information	8	Expert assessments and advisory opinions	8
Radio and TV broadcasts	1	Theses for Diploma, Bachelor and Master degrees	-
Conferences, trade events, and seminars	8	Participation in Working Groups	31
Lectures and talks	99	Foreign guests	156

9.2 Publications

9.2.1 Practice-relevant information and scientific papers

Quotation
Euringer, S.; Seigner, E. (2017): Neues Projekt zur Welkeforschung finanziert von der GfH. Hopfen-Rundschau, 68(9), Hrsg.: Verband Deutscher Hopfenpflanzer e.V., 302 - 302
Fuß, S. (2017): Pflanzenstandsbericht April 2017. Hopfen-Rundschau, 68(5), Hrsg.: Verband Deutscher Hopfenpflanzer e.V., 155
Fuß, S. (2017): Pflanzenstandsbericht Mai 2017. Hopfen-Rundschau, 68(6), Hrsg.: Verband Deutscher Hopfenpflanzer e.V., 192
Fuß, S. (2017): Pflanzenstandsbericht August 2017. Hopfen-Rundschau, 68(9), Hrsg.: Verband Deutscher Hopfenpflanzer e.V., 298
Kühne, S., Roßberg, D.; Röhrig, P.; von Mering, F.; Weihrauch, F.; Kanthak, S.; Kienzle, J.; Patzwahl, W.; Reiners, E.; Gitzel, J. (2017): The Use of Copper Pesticides in Germany and the Search for Minimization and Replacement Strategies. Organic Farming, 3(1), 66 - 75
Kammhuber, K. (2017): Ergebnisse von Kontroll- und Nachuntersuchungen für Alphaverträge der Ernte 2016. Hopfen-Rundschau, 68 (8), Hrsg.: Verband Deutscher Hopfenpflanzer e.V., 272 - 274
Kammhuber, K. (2017): Influence of the Date of Harvest on the Sulphur Compounds of the "Special Flavour Hop" Varieties Cascade, Mandarina Bavaria, Hallertau Blanc, Huell Melon, and Polaris. Brewing Science, Ausg.: Vol. 70, S. 124 bis 130, Hrsg.: Fachverlag Hans Carl GmbH, Nürnberg
Lutz, A.; Seigner, E., Kneidl, J. (2017): Development of a new Huell hop cultivar: innovative strategies together with the hop and the brewing industry. Proceedings of the Scientific-Technical Commission, International Hop Growers`Convention I.H.G.C., Hrsg.: Scientific-Technical Commission of the International Hop Growers`Convention, 11 - 14

Münsterer, J. (2017): Pflanzenstandsbericht Juni 2017. Hopfen-Rundschau, 68(7), Hrsg.: Verband Deutscher Hopfenpflanzer e.V., 237

Münsterer, J. (2017): Pflanzenstandsbericht Juli 2017. Hopfen-Rundschau, 68(8), Hrsg.: Verband Deutscher Hopfenpflanzer e.V., 277

Seigner, E.; Lutz, A. (2017): Entwicklung von leistungsstarken, gesunden Hopfen mit hohen Alphasäuregehalten und besonderer Eignung für den Anbau im Elbe-Saale-Gebiet, 1 - 13

Seigner, E.; Lutz, A. (2017): Neuer Trend in der Hopfenzüchtung – für mehr Vielfalt beim Bieraroma. Ländlicher Raum, Ausgabe 01 Januar/Februar/März 2017, Hrsg.: Agrarsoziale Gesellschaft e.V., 17 - 18

Jereb, M., Weihrauch, F. (2017): Einsatz und Etablierung von Raubmilben zur nachhaltigen Spinnmilbenkontrolle in der Sonderkultur Hopfen, Ökologischen Landbau weiterdenken: Verantwortung übernehmen, Vertrauen stärken. Beiträge zur 14. Wissenschaftstagung Ökologischer Landbau, Freising-Weihenstephan, 7. bis 10. März 2017, Hrsg.: Wolfrum, S., H. Heuwinkel, H.J. Reents, K. Wiesinger & K.-J. Hülsbergen, 270 - 273

Kühne, S., Roßberg, D.; Röhrig, P.; von Mering, F.; Weihrauch, F.; Kanthak, S.; Kienzle, J.; Patzwahl, W.; Reiners, E.; Gitzel,J. (2017): The Use of Copper Pesticides in Germany and the Search for Minimization and Replacement Strategies. Organic Farming, 3(1), 66 - 75

Mumm, R., van Tol, R.W.H.M.; Weihrauch, F. (2017): Elucidation of the role of volatile compounds in the chemical communication of the hop flea beetle Psylliodes attenuatus. Proceedings of the Scientific-Technical Commission, 2017, Proceedings of the Scientific-Technical Commission of the International Hop Growers´ Convention, St. Stefan am Walde, Austria, 25-29 June 2017, Hrsg.: Scientific-Technical Commission of the International Hop Growers´ Convention, 60 - 64

Undas, A.K., Delatte, T.; Verstappen, F.; van Tol, R.; Weihrauch, F.; Lutz, A.; Bouwmeester, H. (2017): The role of metabolomics to elucidate resistance markers against Damson-hop aphid. Proceedings of the Scientific-Technical Commission of the International Hop Growers´ Convention, St. Stefan am Walde, Austria, 25-29 June 2017, Hrsg.: Scientific-Technical Commission of the International Hop Growers´ Convention, 65 - 65

Weihrauch, F. (2017): Pflanzenschutztreffen der europäischen Commodity Expert Group (CEG) Minor Uses Hopfen. Hopfen-Rundschau, 68(12), Hrsg.: Verband Deutscher Hopfenpflanzer e.V., 414 - 415

Weihrauch, F., Baumgartner, A.; Eisenbraun, D.; Wolf, S.; van Tol, R.W.H.M; Mumm, R. (2017): Flea-beetle control in organic hops: Are there options? Proceedings of the Scientific-Technical Commission of the International Hop Growers´ Convention, St. Stefan am Walde, Austria, 25-29 June 2017, Hrsg.: Scientific-Technical Commission of the International Hop Growers´ Convention, 59 - 59

Weihrauch, F., van Tol, R.; Mumm, R. (2017): Kontrolle des Hopfen-Erdflohs Psylliodes attenuatus im ökologischen Hopfenbau: Gibt es Optionen?, Entomologentagung 2017/Entomology Congress in Freising 13.–16.03.2017 Programm und Zusammenfassungen/Program and Abstracts, 53 - 53

Winterholler, M., Burbach, K.; Krach, E.J.; Sachteleben, J.; Schlumprecht, H.; Suttner, G.; Voith, J.; Weihrauch, F. (2017): Rote Liste und Gesamtartenliste der Libellen (Odonata) Bayerns - Stand 2017, lfu_nat_00343, Hrsg.: Bayerisches Landesamt für Umwelt, 1 - 15

Wolf, S., Sichelstiel, W. (2017): An overview on forecasting systems for Downy and Powdery mildew in Hallertau hops. Proceedings of the Scientific-Technical Commission of the International Hop Growers´ Convention, St. Stefan am Walde, Austria, 25-29 June 2017, Hrsg.: Scientific-Technical Commission of the International Hop Growers' Convention, 51 - 51

9.2.2 LfL publications

Name	Working Group	LfL Publications	Title
Hops Department	IPZ 5	LfL Information	Annual Report 2016 - Special Crop Hop
Portner, J.	IPZ 5a	LfL Information	Hop 2017 - Green Pamphlet (Grünes Heft)

9.2.3 Radio and TV broadcasts

Date	People	Title	Channel
01.07.2017	Portner, J.	Germany, world champion hops exporter	ntv

9.3 Conferences, Talks and Lectures, Guided Tours, Exhibitions

9.3.1 Seminars, symposiums, trade conferences, workshops

Date	Event	Venue	Target group
17.1.2017-18.1.2017	Basics seminar *Hop Drying*	Hüll	Hop growers
18.1.2017-19.1.2017	Basics seminar *Conditioning of Hops*	Hüll	Hop growers
24.1.2017-25.1.2017	Workshop *Hop Drying*	Hüll	Hop growers
23.2.2017-24.2.2017	Workshop *Catch Crop Cultivation*	Hüll	Hop growers
05.04.2017	Briefing meeting for demonstration farms	Wolnzach	Demonstration farms JKI BLE
25.6.2017-29.6.2017	Conference of the Scientific-Technical Commission, I.H.G.C.	St. Stefan am Walde, Austria	Scientists and experts from the hops and brewing industries
20.11.2017	Hops Advisory Board	Hüll	Hops and brewing industries

9.3.2 Internal events

Title	Type of event	Venue	Start	Finish
Briefing meeting for demonstration farms	Workshop	Wolnzach	05.04.2017	05.04.2017

9.3.3 Expert assessments and advisory opinions

Date	Organized by	Title	Sponsored by
16.01.2017	Weihrauch, F.	Evaluation of 5 project drafts	BMBF / PT Jülich
23.01.2017	Portner, J.	Putting up fencing round hop yards	LRA Kelheim
02.02.2017	Portner, J.	Using treated waste water for hop irrigation	LfL
22.08.2017	Fuß, S.	Official hop harvest forecast in the Hallertau region 2017	StMELF
23.09.2017	Weihrauch, F.	Peer review	Journal *Entomological Science*
04.10.2017	Seigner, E.	Peer review	Journal *Brewing Science*
06.10.2017	Weihrauch, F.	Peer review	Journal *Brewing Science*
14.12.2017	Kammhuber, K.	Peer review	Journal *Journal of the Institute of Brewing*

9.3.4 Specialist information

Zitat
Euringer, S.; Seigner, E., Lutz, A.; Fuss, S.: 'Maßnahmen gegen die Verticillium-Welke bei Hopfen', Hüll (Poster)
Euringer, S.; Seigner, E., Lutz, A.; Fuss, S.: 'Verticillium-Welke bei Hopfen', Hüll (Poster)
Seigner, E., Forster, B.; Lutz, A.: 'Detached leaf assay to test for downy mildew tolerance in hops', St. Stefan am Walde, 28.06.2017, Tagung der Wissenschaftlich-Technischen Kommission, Wissenschaftlich-Technische Kommission des Internationalen Hopfenbaubüros (Poster)
Seigner, E.; Hagemann, M.: 'Optimierung der Hopfenzüchtung mittels Genom-und Metaboliten-Analyse - Präzisionszüchtung für Hopfen' (Projekt-Zwischenbericht)
Seigner, E.; Lutz, A.: 'Entwicklung von leistungsstarken, gesunden Hopfen mit hohen Alphasäuregehalten und besonderer Eignung für den Anbau im Elbe-Saale-Gebiet' (Projekt-Zwischenbericht)
Seigner, E.; Lutz, A.: 'Innovationen bei der Entwicklung neuer Hüller Hopfensorten - Phase 2: Praxisanbauprüfungen und Brauversuche', Niederlauterbach, 24.08.2017, IGN-Hopfentag, IGN Hopfenvermarktungs- und Vertriebs-GmbH (Poster)
Seigner, E.; Lutz, A.: 'Innovations in the development of new Hüll hop cultivars' (Poster)
Seigner, L., Liebrecht, M., Seigner, E., Lutz, A., Keckel, L., Hüttinger, J.: 'Monitoring von gefährlichen Virus- und Viroidinfektionen von Hopfen in Deutschland - Monitoring- jahr 2017' (Internet-Beitrag)

9.3.5 Lectures and talks

Speaker	Subject/Title	Event	Venue/ date	Attendees
Doleschel, P.	The significance of the project *Demo Farms - Integrated Plant protection - Hop*	On-farm demo day - plant protection at Moser farm	Geibenstetten 23.05.17	110
Doleschel, P.	Climate Change - a challenge for Bavarian hop farming and hop research	Event run by local section of SPD Wolnzach	Wolnzach 20.07.17	30
Doleschel, P Kammhuber, K. Portner, J. Sichelstiel, W. Seigner, E. Weihrauch, F.	Bavarian State Research Center for Agriculture, LfL, hop research and advisory service in Bavaria 2016	General Meeting of Society of Hop Research (GfH)	Wolnzach 06.04.17	40
Euringer, S.	Current status of *Verticillium* research	Project presentation	Hüll 08.11.17	5
Euringer, S.	*Verticillium* research: current status and planning	Annual review discussion GfH-LfL	Hüll 15.11.17	14
Fuß, S.	Interesting facts about nozzle technology in hop farming	On-farm demo day at Moser demo farm	Geibenstetten 23.05.17	110
Kammhuber, K.	Qualitative and quantitative characterization of aroma compounds in special flavour hops and aroma hops, taking account of bound aroma substances	Presentation of project applications for StMELF	Freising 28.09.17	15
Kammhuber, K.	Current status of hop aroma analytics	Spring staff meeting	Freising 22.03.17	20
Kammhuber, K.	Possibilities and limitations of near infrared spectroscopy in hop analytics	Science and Technology Advisory Committee (TWA)	Wolnzach 06.04.17	20
Kammhuber, K.	Presentation of research work of Working Group IPZ 5d	General meeting of Society of Hop Research GfH	Wolnzach 06.04. 17	40

Speaker	Subject/Title	Event	Venue/ date	Attendees
Lutz, A.	Flavour hops - suitable for organic hop farming?	Hop farming day at Bioland Week 2017	Plankstetten 07.02.17	30
Lutz, A.	New aroma hops from Hüll	Beer: out-of-the-box thinkers' workshop	Bad Staffelstein 22.03.17	80
Lutz, A.	Development of a new Huell hop cultivar: innovative strategies together with the hop and the brewing industry	Conference of the Scientific-Technical Commission	St. Stefan am Walde 26.06.17	60
Lutz, A.	Hüll new aroma cultivars with special flavour potential hops	Retirement of Bernhard Engelhard at GfH	Wolnzach 19.07.17	35
Lutz, A.	*Ariana* and *Callista* - growing two new aroma cultivars with special flavour potential cultivars	Hops Convention IGN Quality Hops Syndicate Niederlauterbach	Eichelberg 24.08.17	100
Lutz, A.	Hop farming in Kelheim rural district	Hops tour	Abensberg 31.08.17	50
Lutz, A.	Beers from Hüll hop cultivars	Federation of German Agricultural Investigation and Research Institutions (VDLUFA) Conference	Freising 11.09.17	70
Lutz, A.	Hop breeding then and now	Moosburg malt brewers' association (Gerstenbrauerverband e.V.)	Moosburg 14.09.17	80
Lutz, A.	New aroma hops from Hüll	Annual review discussion GfH-LfL	Hüll 15.11.17	14
Lutz, A.	Hop varieties and aroma assessment	Start of new term - Altweihenstephan Brewers` Federation	Freising 26.10.17	35
Münsterer, J.	Influence of harvest date and the drying process on the brewing value of flavour cultivars *Mandarina Bavaria, Hallertau Blanc* and *Polaris*	LfL Hop farming meetings	Osselts-hausen 14.02.17	55
Münsterer, J.	Influence of harvest date and the drying process on the brewing value of flavour cultivars *Mandarina Bavaria, Hallertau Blanc* and *Polaris*	LfL Hop farming meetings	Niederlauterbach 15.02.17	130
Münsterer, J.	Influence of harvest date and the drying process on the brewing value of flavour cultivars *Mandarina Bavaria, Hallertau Blanc* and *Polaris*	LfL Hop farming meetings	Tettenwang 16.02.17	45
Münsterer, J.	Influence of harvest date and the drying process on the brewing value of flavour cultivars HC, MB und PA	Meeting of the Society of Hop Research technical-scientific working committee	Wolnzach 06.04.17	25
Münsterer, J.	Correct cleaning of plant protection equipment, inside and out	On-farm demo day: filling and cleaning plant protection equipment, nozzle technology and user protection	Geibenstetten 23.05.17	110
Münsterer, J.	Influence of harvest date and the drying process on the brewing value of flavour cultivars *Mandarina Bavaria, Hallertau Blanc* and *Polaris*	LfL Hop farming meetings	Spalt 06.02.17	35

Speaker	Subject/Title	Event	Venue/ date	Attendees
Münsterer, J.	Influence of harvest date and the drying process on the brewing value of flavour cultivars *Mandarina Bavaria, Hallertau Blanc* and *Polaris*	LfL Hop farming meetings	Hedersdorf 06.02.17	22
Münsterer, J.	Influence of harvest date and the drying process on the brewing value of flavour cultivars *Mandarina Bavaria, Hallertau Blanc* and *Polaris*	LfL Hop farming meetings	Mainburg 07.02.17	115
Münsterer, J.	Influence of harvest date and the drying process on the brewing value of flavour cultivars *Mandarina Bavaria, Hallertau Blanc* and *Polaris*	LfL Hop farming meetings	Lindach 08.02.17	50
Münsterer, J.	Influence of harvest date and the drying process on the brewing value of flavour cultivars *Mandarina Bavaria, Hallertau Blanc* and *Polaris*	LfL Hop farming meetings	Oberhatzkofen 10.02.17	45
Münsterer, J.	Influence of harvest date and the drying process on the brewing value of flavour cultivars *Mandarina Bavaria, Hallertau Blanc* and *Polaris*	LfL Hop farming meetings	Biburg 13.02.17	48
Obster, R.	User protection in application of plant protection products	On-farm demo day: filling and cleaning plant protection equipment, nozzle technology and user protection	Geibenstetten 23.05.17	110
Obster, R.	“Effective plant protection with forecasting systems, warning service and call to action"	11 Meeting of the Advisory Board of the Society of Hop Research	München 12.09.17	20
Portner, J.	Implications of the new fertilization ordinance for hop	Hops round table discussion	Uttenhofen 01.02.17	20
Portner, J.	Implications of the new fertilization ordinance for hop	Informational event agricultural trade	Wörth a.d. Isar 03.02.17	20
Portner, J.	Implications of the new fertilization ordinance for hop	LfL Hop farming meeting	Spalt 06.02.17	35
Portner, J.	Implications of the new fertilization ordinance for hop	LfL Hop farming meeting	Hedersdorf 06.02.17	22
Portner, J.	Implications of the new fertilization ordinance for hop	LfL Hop farming meeting	Mainburg 07.02.17	115
Portner, J.	Implications of the new fertilization ordinance for hop	LfL Hop farming meeting	Lindach 08.02.17	50
Portner, J.	Implications of the new fertilization ordinance for hop	LfL Hop farming meeting	Oberhatzkofen 10.02.17	45
Portner, J.	Implications of the new fertilization ordinance for hop	LfL Hop farming meeting	Biburg 13.02.17	48
Portner, J.	Implications of the new fertilization ordinance for hop	LfL Hop farming meeting	Osselts-hausen 14.02.17	55
Portner, J.	Implications of the new fertilization ordinance for hop	LfL Hop farming meeting	Niederlauterbach 15.02.17	130

Speaker	Subject/Title	Event	Venue/ date	Attendees
Portner, J.	Implications of the new fertilization ordinance for hop	LfL Hop farming meeting	Tettenwang 16.02.17	45
Portner, J.	Implications of the new fertilization ordinance for hop	Informational event	Niederulrain 17.02.17	19
Portner, J.	The latest on plant protection	On-farm demo day: filling and cleaning plant protection equipment, nozzle technology and user protection	Geibenstetten 23.05.17	110
Seigner, E.	Research and work on *Verticillium* wilt disease on hop	Work discussion *Verticillium* wilt disease on hop	Hüll 09.01.17	7
Seigner, E.	Crossbreeding with Tettnanger landrace	Hops briefing	Stuttgart 08.03.17	13
Seigner, E.	Genome-based marker-assisted breeding for the quality hops of the future	9th Meeting of the steering committee of German Agricultural Innovation Partnership (DIP)	Bonn 16.03.17	10
Seigner, E.	Research and work on *Verticillium*-wilt disease on hop: *Verticillium*-free planting material	Meeting of the Society of Hop Research technical-scientific working committee	Wolnzach 06.04.17	25
Seigner, E.	*Verticillium* wilt on hops: Real-time PCR and meristem culture - essential tool to produce healthy planting material	Conference of the Scientific-Technical Commission	St: Stefan am Walde 26.06.17	60
Seigner, E.	Hop breeding	Conference of the Scientific-Technical Commission	St. Stefan am Walde 26.06.17	60
Seigner, E.	Business meeting of the Scientific Technical Commission	Conference of the Scientific-Technical Commission	St. Stefan am Walde 26.06.17	30
Seigner, E.	Improved selection system to test for downy mildew tolerance of hops	Conference of the Scientific-Technical Commission	St. Stefan am Walde 28.06.17	
Seigner, E.	Applied research for German hop growers and the brewing industry	Visit of a delegation from Taiwan	Hüll 11.08.17	6
Seigner, E.	Innovations in the development of Hüll hop varieties	Hops Day at IGN Quality Hops Syndicate Niederlauterbach	Eichelberg 24.08.17	100
Seigner, E.	Marker-assisted breeding for hop: powdery mildew resistance	Project meeting	13.11.2017	8
Seigner, E.	Genome-based marker-assisted breeding for the quality hops of the future	Project meeting	Hüll 13.11.17	8
Seigner, E.	Genome-based marker-assisted breeding for the quality hops of the future	Annual review discussion LfL-GfH	Hüll 15.11.17	14
Seigner, E.	Hop research at the LfL State Research Center for Agriculture	Informational event for Munich vocational school	Hüll 07.12.17	62
Sichelstiel, W.	Current authorization status of plant protection agents for hop cultivation	Technical discussion	Wolnzach 16.01.17	24
Sichelstiel, W.	Available products and application strategies for the plant protection season in 2017	Round table discussion agricultural trade	Uttenhofen 01.02.17	17

Speaker	Subject/Title	Event	Venue/ date	At-tende-es
Sichelstiel, W.	Available products and application strategies for the plant protection season in 2017	Round table discussion agricultural trade	Wörth 03.02.17	20
Sichelstiel, W.	Available products and application strategies for the plant protection season in 2017	Hop farming meeting	Spalt 06.02.17	35
Sichelstiel, W.	Available products and application strategies for the plant protection season in 2017	Hop farming meeting	Hedersdorf 06.02.17	22
Sichelstiel, W.	Available products and application strategies for the plant protection season in 2017	Hop farming meeting	Mainburg 07.02.17	115
Sichelstiel, W.	Available products and application strategies for the plant protection season in 2017	Hop farming meeting	Lindach 08.02.17	50
Sichelstiel, W.	Available products and application strategies for the plant protection season in 2017	Hop farming meeting	Biburg 13.02.17	48
Sichelstiel, W.	Available products and application strategies for the plant protection season in 2017	Hop farming meeting	Osselts-hausen 14.02.17	55
Sichelstiel, W.	Available products and application strategies for the plant protection season in 2017	Hop farming meeting	Niederlau-terbach 15.02.17	130
Sichelstiel, W.	Available products and application strategies for the plant protection season in 2017	Hop farming meeting	Tettenwang 16.02.17	45
Sichelstiel, W.	Available products and application strategies for the plant protection season in 2017	Hop farming meeting	Oberhatz-kofen 10.02.17	45
Weihrauch, F.	Interesting facts about the biology and means of controlling the hop flea beetle	BayWa round table discussion on hop	Uttenhofen 01.02.17	20
Weihrauch, F.	Interesting facts about the biology and means of controlling the hop flea beetle	LfL hop farming meeting	Hedersdorf 06.02.17	22
Weihrauch, F.	Interesting facts about the biology and means of controlling the hop flea beetle	LfL hop farming meeting	Spalt 06.02.17	35
Weihrauch, F.	Interesting facts about the biology and means of controlling the hop flea beetle	LfL hop farming meeting	Mainburg 07.02.17	115
Weihrauch, F.	Projects in 2016 at Hüll funded by external partners, organic farming	Hop farming day at Bioland Week 2017	Plankstetten 07.02.17	35
Weihrauch, F.	Interesting facts about the biology means of controlling the hop flea beetle	LfL hop farming meeting	Lindach 08.02.17	50
Weihrauch, F.	Interesting facts about the biology and means of controlling the hop flea beetle	LfL hop farming meeting	Oberhatz-kofen 10.02.17	45
Weihrauch, F.	Interesting facts about the biology and means of controlling the hop flea beetle	LfL hop farming meeting	Biburg 13.02.17	48

Speaker	Subject/Title	Event	Venue/ date	Attendees
Weihrauch, F.	Interesting facts about the biology and means of controlling the hop flea beetle	LfL hop farming meeting	Osseltshausen 14.02.17	55
Weihrauch, F.	Interesting facts about the biology and means of controlling the hop flea beetle	LfL hop farming meeting	Niederlauterbach 15.02.17	130
Weihrauch, F.	Interesting facts about the biology and means of controlling the hop flea beetle	LfL hop farming meeting	Tettenwang 16.02.17	45
Weihrauch, F.	Deployment and establishment of predator mites for sustainable control of the two-spotted spider mite in the speciality crop hop	14th Scientific organic farming conference	Freising 09.03.17	30
Weihrauch, F.	Management of the hop flea beetle *Psylliodes attenuatus* in organic hop farming: What are the options?	Entomologist Conference 2017	Freising 15.03.17	35
Weihrauch, F.	Flea beetle control in organic hops: Are there options?	Conference of the Scientific-Technical Commission of the International Hop Growers‘ Convention, I.H.G.C.	St. Stefan am Walde 27.06.17	60
Weihrauch, F.	Plant protection issues in organic hops in Germany	56th Congress of the International Hop Growers’ Convention, I.H.G.C.	Yakima, WA, USA 31.07.17	110
Weihrauch, F.	Report on the 2017 Meeting of the Scientific-Technical Commission	56th Congress of the International Hop Growers‘ Convention, I.H.G.C.	Yakima, WA, USA 31.07.17	110
Weihrauch, F.	Integrated Pest Management in German Hop Cultivation	International Conference on Plant Protection in Hop Growing in the Framework of the 56th Congress of the International Hop Growers' Convention	Yakima, WA, USA 02.08.17	95
Weihrauch, F.	Minimizing the use of copper-based plant protection agents in organic and integrated hop cultivation systems	Hops tour 2017	Schweinbach 31.08.17	185
Weihrauch, F.	Two-spotted spider mite management with low acaricide application levels – is there a plan B?	Trade conference *Plant Protection in German Hop Farming - current situation and prospects*	Oberulrain 01.09.17	70
Weihrauch, F.	Possibilities and limitations of plant protection in organic and integrated hop cultivation systems	Meeting of the agricultural committee of the German Brewers’ Federation e.V.	München 14.09.17	21
Weihrauch, F.	Results of copper monitoring by the organic farms associations and progress on implementation of the strategy paper for hop	European conference on the use of copper as a plant protection agent	Berlin 16.11.17	90
Weihrauch, F.	Management of the two-spotted spider mite in hop farming – how things stand after 10 years	35th Conference of the study group *Beneficial Arthropods and Entomopathogenic Nematodes*	Berlin 29.11.17	37

Speaker	Subject/Title	Event	Venue/ date	Attendees
Wolf, S.	An overview on forecasting systems for Downy and Powdery mildew in Hallertau hops	Conference of the Scientific-Technical Commission of the International Hop Growers‘ Convention, I.H.G.C.	St. Stefan am Walde 27.06.17	60
Wolf, S.	Chemical hop stripping	LfL hop farming educational trip	Affalterbach 09.08.17	45
Wolf, S.	Plant protection in hop growing 2017	Trade conference *Plant Protection in German Hop Farming - current situation and prospects*	Oberulrain 01.09.17	70
Wolf, S.	Conventional plant protection in the hop growing year 2017	Meeting of the agricultural committee of the German Brewers’ Federation e.V.	München 14.09.17	21
Wolf, S.	Controlling wireworm (Agrigotes ssp.) with *Metarhizium brunneum* in hop cultivation	35th Conference of the study group *Beneficial Arthropods and Entomopathogenic Nematodes*	Berlin 28.11.17	37

9.3.6 Guided tours

Date	Name	Subject/ Title	Guests	Nos.
04.07.2017	Doleschel, P.	Importance of hop farming and hop research in the Hallertau region, hop research at Hüll, breeding of new cultivars as a prerequisite of sustainable hop production, practical demonstration of different aroma hops	Delegation of Erich Irlsdorfer, Member of the German Bundestag	15
30.08.2017	Doleschel, P. Seigner, E. Kammhuber,K.	LfL, hop research, hop breeding, hop analytics, new aroma varieties with special flavour potential	German Corn Commitee	8
31.07.2017	Kammhuber, K	Hop research at Hüll	AB-Inbev	3
22.08.2017	Kammhuber,K. Seigner, E. Weihrauch, F.	LfL hop research, plant protection, hop analytics, hop breeding	Hop growers and scientists	2
21.11.2017	Kammhuber,K. Kneidl, J. Weihrauch, F.	Hop breeding, hop analytics, integrated and organic plant protection, organic hops	Students from HSWT, food chain management degree course	40
27.06.2017	Kammhuber,K.	Hop research in general, special interest Xanthohumol	AB-Inbev	3
05.07.2017	Kammhuber,K.	Hop research in general, special interest analytics and organic hop cultivation	Götaland local government Department of Agriculture	3
17.08.2017	Lutz, A.	LfL hop research	LfL pensioners	50
06.07.2017	Lutz, A.	LfL hop research, hop breeding	Federal Office of Plant Varieties	2
17.07.2017	Lutz, A.	LfL hop research, hop breeding, plant protection, hop analytics	Bav. Ministry of the Environment and Consumer Protection, Ref. 64	15

Date	Name	Subject/ Title	Guests	Nos.
19.05.2017	Lutz, A.	LfL hop research, hop breeding, plant protection, chemical analysis	Students, University Weihenstephan-Triesdorf	20
27.10.2017	Lutz, A.	Hop varieties and aroma assessment	AB-InBev, brewers	3
17.08.2017	Lutz, A.	Hop varieties, hop harvest, the right timing	Hop growers from ISO-opertions	60
06.09.2017	Lutz, A.	Hop breeding, varieties	BraufactuM	52
05.05.2017	Lutz, A.	Hop research, hop breeding,	US growers and breeders, A-B InBev	4
13.09.2017	Lutz, A. Kammhuber,K.	LfL hop research, hop breeding, hop analystics	Journalist from Craftbier magazine	1
29.08.2017	Lutz, A. Kneidl, J.	Hop breeding, varieties and breeding lines	Eiswerk Paulaner	7
23.06.2017	Lutz, A. Münsterer, J.	LfL hop research, hop breeding, and hop growing	Pfaffenhofen Agricultural College	15
28.07.2017	Lutz, A. Münsterer, J.	LfL hop research, hop breeding and plant cultivation	Pfaffenhofen Agricultural College	12
29.08.2017	Lutz, A. Münsterer, J. Kammhuber,K	LfL hop research, hop breeding, hop growing, plant protection	Agrolab	15
28.09.2017	Lutz, A. Seigner, E.	LfL hop research, hop breeding	Carlsberg Commodity Management	6
15.09.2017	Lutz, A. Seigner, E.	LfL hop research, hop breeding, hop aroma	AB-InBev, head brewmaster	2
15.09.2017	Lutz, A. Seigner, E.	Hop research, hop breeding	AB-InBev, management	10
08.09.2017	Lutz, A. Seigner, E.	Hop breeding	Barth-Haas Group	5
07.12.2017	Lutz, A. Seigner, E.	Hop breeding, aroma analytics, hop growing	Students from Munich vocational school, master brewers	62
07.03.2017	Lutz, A. Weihrauch, F.	Hop breeding, organic hop cultivation	WiTa exploratory ex-cursion *Eco Hops and Organic Beer*	28
05.07.2017	Lutz, A. Wolf, S.	LfL hop research, hop breeding and plant protection	Bayer - advisors for fruit and speciality crops	10
24.08.2017	Seigner, E.	Hop growing, varieties, in vitro culture	Hop growers and scientists	2
21.06.2017	Seigner, E.	LfL hop research, hop breeding, hop production	Baltika Carlsberg, BayWa	4
20.03.2017	Seigner, E.	Hop breeding, Huell Special Flavour hops	Mitsui	1
22.03.2017	Seigner, E.	Hop research, hop breeding, chemical analysis	Barth Haas Group	6
10.07.2017	Seigner, E.	Hop research, hop breeding, hop analytics	AB-InBev, craft brewers	35
23.06.2017	Seigner, E.	Hop research, hop breeding, hop analytics	Tsingtao Brewery, HVG Hop Sales Cooperative	7
20.03.2017	Seigner, E. Engelhard, B. - GfH	Production of the new aroma cultivars Callista and Ariana	Mitsui International	1
08.09.2017	Seigner, E. Kammhuber,K.	LfL hop research, hop breeding, hop analytics	The Kloser Group	6

Date	Name	Subject/ Title	Guests	Nos.
30.08.2017	Seigner, E. Kammhuber,K.	LfL hop research, hop breeding, hop analytics, hop aroma	Brewery college Bremen	24
13.09.2017	Seigner, E. Kammhuber,K.	LfL hop research, hop breeding, hop analytics, plant protection, membership of the Society of Hop Research	Chinese brewery	5
20.09.2017	Seigner, E. Kammhuber,K.	LfL hop research, hop breeding, new aroma hops with special flavour potential, aroma analytics	Brewers and beer sommeliers	25
18.09.2017	Seigner, E. Kammhuber,K.	LfL hop research, hop breeding, new aroma hops with special flavour potential, aroma analytics	Polar Brewery	7
25.08.2017	Seigner, E. Kammhuber, K	LfL hop research, hop breeding, new aroma hops with special flavour potential, aroma analytics	AB-InBev, Brewmaster Class	45
22.08.2017	Seigner, E. Kammhuber, K	Hop research, hop breeding, new aroma hops	Diageo, Innovationteam; Barth-Haas Group	8
18.07.2017	Seigner, E. Kammhuber,K Euringer, S.	LfL hop research, hop breeding, plant protection, hop analytics, Verticillium research ─ new project	Students, TUM Beverage and Brewing Technology	18
06.06.2017	Seigner, E. Münsterer, J.	LfL hop research, breeding, plant protection, diseases and pests, hop analytics	Students and Prof. von Tiedemann, University of Göttingen	35
05.04.2017	Sichelstiel, W.	Hop Research Center at Hüll	FU Pfaffenhofen	15
16.05.2017	Sichelstiel, W. Kammhuber,K Seigner, E.	Hop research	EU Project Group, AFL PAF, StMELF	15
07.03.2017	Sichelstiel, W. Lutz, A.	Hop research, hop breeding	Barth-Haas Group	6
24.03.2017	Weihrauch, F.	Hop research in general, organic hops in particular	Scientists from SLU	5

9.3.7 Exhibitions and Posters

Author(s)	Title	Event/venue	Organizers
Euringer, S.; Seigner, E.	Measures to combat *Verticillium* wilt disease on hop	Hüll	
Euringer, S.; Seigner, E.	*Verticillium* wilt disease on hop	Hüll	
Seigner, E.	Detached leaf assay to test for downy mildew tolerance in hops	Conference of the Scientific-Technical Commission, St. Stefan am Walde	Scientific-Technical Commission of the International Hop Growers' Convention
Seigner, E.; Lutz, A.	Innovations in the development of new Hüll hop cultivars		
Seigner, E.;	Innovations in the develop-	IGN-Hops Convention	IGN Hop Sales and

Author(s)	Title	Event/venue	Organizers
Lutz, A.	ment of new Hüll hop cultivars	Niederlauterbach	Marketing GmbH

9.4 Participation in Working Groups, Memberships

Member	Organization
Doleschel, P.	Bavarian Plant Breeding Society
	DLG e.V., German Agricultural Society
	DLG Committee for Plant Breeding und Seed Science
	GIL, Society of Computer Science in Agriculture, Forestry and Food Science e.V.
	Society of Hop Research
	Society for Plant Cultivation Sciences e.V.
	Society of Plant Breeding
	ISIP e.V. (Information System for Integrated Plant Production)
	Potato Health Service Bavaria e.V.
	LKP
	Test team for seed potatoes in Bavaria
Fuß, S.	Board of examiners for Qualified Agriculturalist at Landshut Authority for Continuing Education
Kammhuber, K.	Working Group for Hop Analytics (AHA)
	European Brewery Convention (Hops Sub-committee) analysis committee
	Society of German Chemists (GDCH)
Münsterer, J.	Board of examiners for Qualified Agriculturalist at Landshut Authority for Continuing Education
Portner, J.	WG Sustainability in Hop Growing
	JKI Advisory Committee ─ equipment approval procedure for assessing plant protection equipment
	JKI-Federal States WG *Monitoring Plant Protection Equipment*
	Boards of examiners Niederbayern, Oberbayern-Ost und Oberbayern-West, for Master's Certificate Qualified Agriculturalist
Seigner, E.	Society of Hop Research e.V.
	Society of Plant Breeding
	Scientific-Technical Commission of the International Hop Growers' Convention: Chairperson (up to 26.06.2017)
Sichelstiel, W.	DPG, German Phytomedicinal Society
	EU Commodity Expert Group (CEG) Minor Uses in Hops: Chair (up to 22.10.2017)
	Society of Hop Research
Weihrauch, F.	Consortium of Bavarian Entomologists e.V.
	British Dragonfly Society
	DGaaE, German Society for General and Applied Entomology
	DGaaE, Study Group Neuropta
	DGaaE, Study Group Beneficial Arthropods and Entomopathogenic Nematodes
	DGfO, German Society of Orthopterology
	DPG, German Phytomedicinal Society
	EU Commodity Expert Group (CEG) Minor Uses in Hops: Chair (acting)
	Society of German-speaking Odonatologists e.V.
	Society of Hop Research e.V.
	Munich Entomological Society e.V.
	Red List Working Group Germany's Neuroptera
	Red List Working Group Bavaria's Dragonflies and Neuroptera

Member	Organization
	Scientific-Technical Commission of the International Hop Growers' Convention: Chair (as of 26.06.2017)
	Worldwide Dragonfly Society
Wolf, S.	EU Commodity Expert Group (CEG) Minor Uses in Hops

10 Personnel IPZ 5 - Hops Department

The following members of staff were employed at the Bavarian State Research Center for Agriculture (LfL), Institute for Crop Science and Plant Breeding at Hüll, Wolnzach, and Freising in 2017
(AG = Arbeitsgruppe - *WG Working Group*):

IPZ 5

Coordinator:
LD Wolfgang Sichelstiel (until 22.10.2017)
Director at LfL Dr. Doleschel Peter (acting coordinator from 23.10.2017)
Hertwig Alexandra
Krenauer Birgit

IPZ 5a

AG Hopfenbau, Produktionstechnik
(WG Hop Farming/ Production Techniques)
LD Portner Johann
Fischer Elke
LA Fuß Stefan
LAR Münsterer Jakob
B.Sc. Obster Regina (from 01.03.2017)
M.Sc. Stampfl Johannes (from 23.03.2017)

IPZ 5b

AG Pflanzenschutz im Hopfenbau
(*WG Hop Plant Protection)*
LD Sichelstiel Wolfgang (until 22.10.2017)
Dipl.-Biol. Dr. Weihrauch Florian (acting lead from 23.10.2017)
BTA Eisenbraun Daniel (until 31.03.2017)
M.Sc. Euringer Simon (from 01.06.2017)
Felsl Maria
LI Meyr Georg
BTA Mühlbauer Marlene (from 15.05.2017)
Weiher Johann
M.Sc. Wolf Silvana

IPZ 5c
AG Züchtungsforschung Hopfen
(WG Hop Breeding Research)
RD Dr. Seigner Elisabeth

Brummer Brigitte
Dandl Maximilian (until 31.07.2017)
LTA Enders Renate
CTA Forster Brigitte
Graßl Herbert
Grebmair Hermann
CTA Hager Petra
LTA Haugg Brigitte
Hock Elfriede
Agr.-Techn. Ismann Daniel
LTA Kneidl Jutta
LR Lutz Anton
Maier Margret
Mauermeier Michael
Pflügl Ursula
Suchostawski Christa (until 31.10.2017)

IPZ 5d
AG Hopfenqualität und -analytik
(WG Hop Quality and Analytics)
ORR Dr. Kammhuber Klaus

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

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