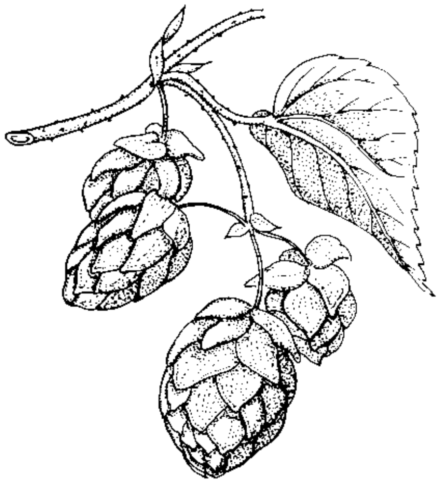
Bayerische Landesanstalt für Landwirtschaft

Gesellschaft für Hopfenforschung e.V.

Annual Report 2016

Special Crop: Hops



Bavarian State Research Center for Agriculture

- Institute for Crop Science and Plant Breeding -

and

Society of Hop Research e.V.

March 2017

LfL-Information

Published by: Bayerische Landesanstalt für Landwirtschaft (LfL)
Bavarian State Research Center for Agriculture
Vöttinger Straße 38, 85354 Freising-Weihenstephan
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First edition: March 2017
Nominal fee: 5.-- €

Foreword

2016 was of special significance for the hop growing and brewing industries. German brewers celebrated 'Five Hundred Years of the Bavarian Beer Purity Law (Reinheitsgebot)' – the oldest food law still pertaining in Germany, which safeguards the quality of both Bavarian and German beer. Festive events, countless special reports in the press, on radio and TV, local and national beer festivals and, not least, the 'Beer in Bavaria' exhibition, organized by the Bavarian government, drew the attention of the public to the quality of beer and of the raw materials which go into its production – hops and malt.

The Gesellschaft für Hopfenforschung (*Society of Hop Research*) was able to look back on 90 years of research at Hüll, carried out since 1974 in collaboration with the Free State of Bavaria. The multifarious research activities, focusing on production technology, fertilization, plant protection, component compounds, quality assurance and, above all, the successful breeding programme, contributed hugely to the successes in hop production in Germany and to securing the crucial raw materials for the brewing industry.

After the drought in 2015, hop growers were able to feel satisfied once again with the high yield of the hop harvest and the good prices obtained. As a result of attractive contracts, the acreage under hop is on the increase again. The optimism of the farmers is evidenced by their creation of new hop yards in all hop producing regions.

However, as all the stakeholders in the hop market are well aware, the direction of travel is not always upwards. It is crucial, then, to make the most of the opportunities in times when things are going well, yet without ever losing sight of the risks. One opportunity presenting itself is the continuing worldwide growth in demand for craft beers. Plant Variety Rights have been applied for in the case of *Callista* and *Ariana*, two more new breeds of special flavor hops from Hüll. Feedback from hop growers and brewers alike has raised hopes that these two cultivars will prove a useful addition in this particular market sector. The withdrawal by US growers from the bittering hops sector has opened up new market opportunities for the high yield, high alpha varieties from Hüll.

And yet, in spite of the opportunities, there are always risk factors. The market itself is a risk, and, added to that, hop growers face ever more risks during the growing process. They have to cope with the ongoing impact of climate change, the loss of plant protection agents with the simultaneous introduction of stricter requirements governing approval of new products, or the spread of *Verticillium* wilt disease. Hop research is tasked with finding solutions to these issues, and this year sees the start of research projects focusing on *Verticillium* wilt disease and on improving efficiency of fertilizer use with the aid of irrigation. The close collaboration of the various different working groups concerned with production technology, plant protection, breeding, analytics and ecology, on the one side, with, on the other, the hop growers, the hops industry, the brewers, and the scientists, gives some idea of the scope of the research.

Current trials, ongoing research, and advisory projects are outlined in the pages of this report. Hop research is well prepared to meet the challenges in support of the future of hop growing in Bavaria and Germany. In this kind of work, success is never a matter of course. It depends in large part on the commitment, hard work, perseverance and creativity of the colleagues at Hüll, Wolnzach and Freising, and it is to them that we would like here to express our special thanks.

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 Research Projects and Key Research Priorities, Hops Department

1.1 Current Research Projects

Increasing drying rates and improving quality of hops in a belt dryer (ID 5382)

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenbau, Produktionstechnik (IPZ 5a) (*Bavarian State Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Cultivation, Production Techniques (IPZ 5a)*)
Funding:	Erzeugergemeinschaft HVG e.G. *(Hop Producer Group)*
Project lead:	J. Portner
Project staff:	J. Münsterer
Collaboration:	Ingenieurbüro Dipl.-Ing. Christian Euringer, Geisenfeld-Gaden Hop farms in the Hallertau region
Scheduled to run:	2015 – 2017

Objective:

The intention is to facilitate well-targeted regulation of air velocity and drying temperature in the front third of the top drying tier in a belt dryer, thus significantly to increase the drying rate, and to eliminate frequently occurring problems adversely affecting quality. This involves technical refits and optimization of the air flow systems.

Thanks to an air flow simulation it was possible to establish the flow conditions prevailing in the belt dryer. It was found that a more even distribution of air over the drying surfaces could be achieved, even at higher air velocities, by inserting perforated plates between the drying belts. This is to be further trialled by installing the plates and testing the effect in an existing belt dryer under real world conditions.

Method

With the help of technical drawings of original plans, and data for the heating and blower capacity available, HTCO in Freiburg was able to simulate the flow conditions prevailing in a commercial belt dryer. On the basis of the results of the flow simulation, perforated plates were then fitted between the belts in a commercial dryer. Air and temperature distribution in the dryer were recorded during the drying process with the help of thermal imaging technology and data loggers.

Results

After insertion of the perforated plates, the flow resistance of the drying air being blown in increases, and it was found that the air distribution from the lateral air intake was more even. This meant that the distribution of air was more uniform, even when air velocities were higher. Thanks to the higher air velocities, it was possible in the dryer fitted with the plates to remove the moisture more quickly at the point when water release was greatest than was possible in structurally identical dryers without plates.

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, AG Hopfenbau, Produktionstechnik (IPZ 5a) *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Cultivation, Production Techniques (IPZ 5a))*
Funding:	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
Collaboration:	Julius Kühn-Institut (JKI) Zentralstelle der Länder für EDV-gestützte Entscheidungshilfen und Programme im Pflanzenschutz (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 1 - 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, whereby the precise extent of disease and pest infestation was ascertained. 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 are recorded on a special app or in online programs and then sent on to the JKI for evaluation.
In order to demonstrate integrated plant protection measures to interested hop growers, a field day was organized at the Kronthaler farm in Dietrichsdorf, where the possible applications of sensor technology were shown in a number of different settings. There were also displays of equipment for incorporating cover crops; and – in the interests of soil protection – the demonstration of a rain simulator and mulch cover determination in the field.

The plant protection management conference held every year at the onset of harvest, for representatives from the plant protection industry, hops organizations and specialist bodies plus licensing authorities, took place on the Obster demonstration farm at Buch. After the specialist talks came an impressive performance using spraying equipment, both with and without reduction of accidental drift.

Results

The combination of consultation and the implementation of non-chemical plant protection measures was successful across the board. The expedient treatments with chemical plant protection agents were satisfactory, with one exception: a case of aphid infestation affecting crop yield was discovered in the hop cones on one of the demonstration farms. This could have been prevented if additional plant protection treatment had been carried out at the flowering stage.
The field day and the specialist plant protection conference were both 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 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.

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))*
Funding:	Ministerium für Ländlichen Raum und Verbraucherschutz (*Ministry for* Rural Affairs and Consumer Protection), Baden-Württemberg Hopfenpflanzerverband (Hop Growers' Association) Tettnang; Gesellschaft für Hopfenforschung e.V. (Society for Hop Research) (2011-2014)
Project leads:	Dr. E. Seigner, A.Lutz
Project staff:	A. Lutz, J. Kneidl, D. Ismann and breeding team (all from IPZ 5c) Dr. K. Kammhuber, C. Petzina, B. Wyschkon, M. Hainzlmaier and S. Weihrauch (all IPZ 5d)
Collaboration:	Straß Hop Experimental Station of the LTZ (*Augustenberg Center for Agricultural Technology*), Baden-Württemberg, F. Wöllhaf
Scheduled to run:	01.05.2011 – 31.12.2019

Objective

The aim is to develop a cultivar with a classic noble 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 4.4.

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 Umwelt and Landwirtschaft (*Ministry for the Environment and Agriculture in the state of Thuringia)*
	Ministerium für Landwirtschaft und Umwelt Sachsen-Anhalt *(Ministry for Agriculture and the Environment in Saxony-Anhalt)*
	Ministerium für Umwelt und Landwirtschaft Sachsen *(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:	A. Lutz, J. Kneidl. H. Grebmair and hop breeding team (all IPZ 5c)
	Dr. K. Kammhuber, C. Petzina, B. Wyschkon, M. Hainzlmaier and S. Weihrauch (all IPZ 5d)
Collaboration:	Hopfenpflanzerverband Elbe-Saale e.V.*(Elbe-Saale Hop Growers' Association)*
	Thüringer Landesanstalt für Landwirtschaft (TLL) Hopfenbetrieb Berthold
Scheduled to run:	01.01.2016 – 31.12.2019

Objective

To breed and test new robust and high yielding hop breeding lines with high alpha acids content and broad spectrum resistance, making the hops resistant chiefly to crown rot pathogens, 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 suitablility for that particular location.
For details on implementation and insights gained so far see **Fehler! Verweisquelle konnte nicht gefunden werden.**.

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)*)
Funding:	Gesellschaft für Hopfenforschung e.V.(*Society of Hop Research*) (2013 - 2014; 2017 - 2018) Erzeugergemeinschaft Hopfen HVG e.G. (*HVG Hop Producer Group*) (2015 – 2016)
Project leads:	Dr. E. Seigner, A. Lutz
Project staff:	A. Lutz, J. Kneidl S. Hasyn (EpiLogic)
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 for powdery mildew resistance in the greenhouse at Hüll and then in the laboratory, by means of a special leaf test. Powdery mildew isolates of all the currently known virulence genes are made available by EpiLogic, Agrarbiologische Forschung und Beratung, Freising, allowing the varied work in connection with breeding for resistance to mildew to be performed.

Description of the work

Eleven previously characterized single-spore isolates of *Sphaerotheca macularis,* the fungus causing powdery mildew in 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/index.php

Resistance test on seedlings from the various breeding programmes in the greenhouse at Hüll. Hops highly susceptible to infection, known as inoculator plants, infected with the PM strains typical of the Hallertau region, provide a continuing source of infection for the young seedlings. This is where these can prove how resistant they are to powdery mildew.

Seedlings rated PM resistant in the greenhouse are tested further in the lab at EpiLogic. Here the leaves are inoculated with more virulence-defined PM isolates and the reaction of the leaves is then assessed in comparison with the highly susceptible *Northern Brewer* cultivar

Tab. 1.1: Overview of PM resistance testing in 2016 with defined virulence PM isolates

2016	**Greenhouse test**		**Leaf test in lab at EpiLogic**	
	Plants	**Assessment**	**Plants**	**Assessment**
Seedlings from 91 crosses	Approx. 100.000 by mass screening		-	-
Breeding lines	120	182	120	734
Cultivars	18	44	7	50
Wild hop	3	6	3	17
Virulences, PM isolates	-	-	11	603
Total (individual tests)	**141**	**232**	**141**	**1 404**

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

Meristem cultures to eliminate viruses – faster availability of virus-free planting stock

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen (IPZ 5c) (*Bavarian State Research Center for Agriculture, Institute für Crop Science and Plant Breeding, WG Hop Breeding Research IPZ 5c))*
Funding:	Wissenschaftliche Station für Brauerei in München e.V. *(Scientific Station for Brewing in Munich)*
Project leads:	Dr. E. Seigner, A. Lutz
Project staff:	B. Haugg
Collaboration:	Dr. L. Seigner and team IPS 2c (Virus Diagnostics)
Scheduled to run:	01.07.2014 – 31.12.2016

Objective

Virus-free planting stock has for years played a major role in the quality campaign for hop. Results for virus and viroid monitoring from Germany's hop growing regions and the Hüll breeding yards (Seigner et al. 2014) testify to the importance of meristem culture as a method of eliminating viruses from planting stock. The aim of this work is significantly to speed up this biotechnology technique for producing virus-free hops.

For more information see 4.8.

Reference

Seigner, L., Lutz, A. and Seigner, E. (2014): Monitoring of Important Virus and Viroid Infections in German Hop (*Humulus lupulus* L.) Yards. BrewingScience - Monatsschrift für Brauwissenschaft, 67 (May/June 2014), 81-87.

Studies and research into *Verticillium* management in hop

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen (IPZ 5c) und AG Hopfenbau, Produktionstechnik (IPZ 5a) (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Breeding Research (IPZ 5c) and WG Hop Cultivation, Production Techniques (IPZ 5a))*
Funding:	Erzeugergemeinschaft Hopfen HVG e.G. *(Hop Producer Group)*
Project lead:	Dr. E. Seigner
Project staff:	P.Hager, R. Enders (from 01.04.2016), A. Lutz (all IPZ 5c)
Collaboration:	Dr: S. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia Prof. B. Javornik, Universität Ljubljana, Slovenia WG Hop Cultivation, Production Techniques, IPZ 5a
Scheduled to run:	from 2008 – 30.05.2020

Hop bines infected with *Verticillium* will wilt and die off. In the lower sections of bines infected with the fungus, the water pathways are often discoloured brown.

Objective

For about ten years now, *Verticillium* wilt has been on the increase in several areas in the Hallertau region. The disease is spread mainly by the soil-borne fungus *Verticillium albo-atrum* (= *Verticillium nonalfalfae*) but also, in a few cases, by *Verticillium dahliae*. For the first time in 2009, the presence of more aggressive wilt fungi was verified (Seefelder et al., 2009); this was leading to distinct symptoms of wilt, causing bines to die off, even in hop varieties which were previously rated as being wilt tolerant.

There is no means of combating *Verticillium* wilt fungus direct by means of plant protection agents, and, as a result, wilt fungus poses a major challenge for hop growers and hop research at the LfL.

Alongside the implementation of horticultural and phytosanitary measures (see *Green Pamphlet*), the ability to make Verticillium-free plant material readily available is a critical building block on the way to preventing the further spread of *Verticillium* hop wilt disease.
For details of this work see **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Monitoring for dangerous viroid infections in hop in Germany

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzen-schutz, AG Virologie (IPS 2c); Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen (IPZ 5c) (*Bavarian State Research Center for Agriculture, Institute for Plant Protection, WG for Pathogen Diagnostics IPS 2c); Institute for Crop Science and Plant Breeding, WG Hop Breeding Research (IPZ 5c))*
Funding:	Wissenschaftliche Station für Brauerei in München e.V. (*Scientific Station for Brewing in Munich)*
Project leads:	Dr. L. Seigner, Institut für Pflanzenschutz (IPS 2c); Dr. E. Seigner, A. Lutz (IPZ 5c)
Project staff:	L. Keckel, J.Hüttinger (IPS 2c) A. Lutz, J. Kneidl (both IPZ 5c)
Collaboration:	Dr. S. Radišek, Slovenian Institute of Hop Research and Brewing, Slovenia AG Hopfenbau, Produktionstechnik, IPZ 5a (*WG Hop Cultivation, Production Techniques*) AG Pflanzenschutz in Hopfenbau, IPZ 5b (*WG Plant Protection in Hop Growing*) IPZ 5b Local hop consultants Hopfenring e.V. Commercial hop farms Eickelmann propagation facility, Geisenfeld
Duration:	March - December 2016

Objective

In an endeavour to keep German hop production free of viroid infections, the LfL carries out broad-based monitoring for dangerous viroid infections in German hops, in a project sponsored since 2011 by the Scientific Station for Brewing in Munich (*Wissenschaftliche Station für Brauerei in München e.V.*). This has covered not only monitoring for the dreaded hop stunt viroid (HpSVd) already present in other countries such as the USA, Slovenia, Japan, Korea and China, but also, from 2014 on, screening for the no less dangerous citrus viroid IV (CVd IV = citrus bark cracking viroid, CBCVd), which was first detected in hop in 2013 in Slovenia (Radišek et al., 2013).

Hop saplings are swapped all over the world, so there is a real danger that these two viroids could inadvertently be imported into German hop cultivation, causing considerable economic damage. The viroids are easily spread by mechanical transmission from one stand to another in the crop and this cannot be hindered by plant protection measures. Therefore, our monitoring scheme for detecting and eliminating primary sources of infection is of crucial importance as a method of preventing the spread of these pathogens.

Method

The test samples came from a number of different growing regions in Germany, ranging from commercially run plots, LfL breeding yards and a propagation facility. Wild hop samples from the Hüll collection of wild hops were also tested. Plants preferably with an abnormal physical appearance were chosen for the tests, and foreign cultivars and plants from abroad held in quarantine were also examined.

Screening for HpSVd and CVd IV was done by RT-PCR. In addition, an internal hop-specific mRNA-based control was run with the RT-PCR assay.

Results

A total of 327 samples were analysed during nationwide viroid monitoring for HpSVd and CVd IV. None of the samples tested positive for infection with HpSVd or CVd IV. Obviously neither of the two viroid infections has yet found its way into German hop cultivation. However, monitoring must continue and, in particular, imports of plant material must be carefully inspected, so that any primary sources of infection are regularly eradicated. Above all, hop plant material from the USA poses a high risk because infection with HpSVd is widespread in the country. (Seigner et al. 2016: Hopfenviroide eine andauernde Gefahr (*Hop Viroids – a continuing risk*). Hopfenrundschau 09/2016, 238-239.).

Tab. 1.2: Viroid infections capable of causing serious damage in hop

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).

An internal hop-specific mRNA-based control was always run parallel to the RT-PCR assay (Seiner et al., 2008) to make sure that the RT-PCR assay was working correctly.

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Seigner, L., Kappen, M., Huber, C., Kistler, M., Köhler, D., 2008: First trials for transmission of *Potato spindle tuber viroid* from ornamental *Solanaceae* to tomato using RT-PCR and an mRNA based internal positive control for detection. Journal of Plant Diseases and Protection, 115 (3), 97–101.

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Acknowledgement

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

Marker-assisted selection in Hop

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 Max-Planck-Institut für Entwicklungsbiologie
Funding:	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten *(Bavarian State Ministry for Food, Agriculture and Forestry)* Ministerium für Ländlichen Raum und Verbraucherschutz, *(Ministry for Rural Affairs and Consumer Protection)*, Baden-Württemberg Hopfenpflanzerverband *(Hop Growers' Associaton)* Tettnang; Erzeugergemeinschaft Hopfen HVG e.G. *(HVG Hop Producer Group)* Universität Hohenheim.
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/Analytics)* IPZ 5d: Dr. K. Kammhuber, C. Petzina, B. Wyschkon, M. Hainzlmaier and 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. 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 *(Hop Growers' Association)* Tettnang
Scheduled to run:	01.07.2015 - 31.03.2017

Objective

The purpose of the project is to provide the German hop breeding community with an innovative tool in the form of marker-assisted selection to facilitate faster breeding of robust, high yield varieties for the hops and brewing industries, in response to the need to react more efficiently to new climatic, agricultural, and consumer demands. In the first phase of the project (2015-2017) a genetic map for hop is being developed. In the second phase (2017–2019), phenotypic and genetic data will then be processed by means of association mapping, followed by further development work to create an application-oriented, marker-assisted selection procedure. Marker-assisted selection will permit faster assessment of the breeding potential of future breeding populations and, for the first time, make it possible to predict the breeding potential of male plants.

Method

- creation of a mapping population
- acquisition of phenotypic data: assessment of agronomic traits and chemical analysis of the component compounds
- association and QTL mapping

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

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung (IPZ 5c) *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Breeding Research (IPZ 5c))*
Funding:	Wissenschaftsförderung der Deutschen Brauwirtschaft (Wifö) *(Science Funding from the German Brewing Industry)*
Project leads:	Dr. E. Seigner, A. Lutz
Project staff:	A. Lutz, J. Kneidl, E. Seigner und Züchtungsteam
Collaboration:	EpiLogic Agrarbiologische Forschung und Beratung, Freising Dr. F. Felsenstein und Stefanie Hasyn
Scheduled to run:	01.01.2016 - 31.12.2017

Objective

With the aid of the reliable greenhouse and laboratory testing systems for PM resistance using the detached leaf assay, it is possible also to arrive at useful assessments for individual plants in the mapping population. These phenotypic data are afterwards combined with the sequence data from the project *Marker-assisted Selection in Hop*, in order to develop preliminary QTL mapping for various PM resistance genes.

Method

- PM resistance test system in the greenhouse
- Leaf assay in the EpiLogic laboratory (see Seigner et al., 2002)

Result

In the spring of 2016, 300 FI individual plants from a special mapping population were examined in the greenhouse for resistance, using virulence-defined PM isolates. The leaves of seedlings that had not shown PM infections in the greenhouse were distinguished using two special PM strains via the EpiLogic leaf test system. In order to verify the assessment done so far, a large portion of the F1 hops will undergo screening again in the greenhouse for PM resistance in 2017. The reactions to the defined virulence properties of the two PM isolates used will then be further substantiated through the subsequent detached leaf assay.

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.

The influence of harvest dates on the sulphur compounds in the flavor cultivars *Cascade, Hallertau Blanc, Huell Melon, Mandarina Bavaria and Polaris* (diploma thesis)

Träger:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenqualität und -analytik (IPZ 5d) *(Bavarian Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Quality and Analytics (IPZ 5d))*
Project lead:	Dr. K. Kammhuber
Project staff:	Maximilian Hundhammer
Collaboration:	Prof. M. Rychlik, Dr. Gerold Reil, Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt *(TUM School of Life Sciences, Weihenstephan)*
Scheduled to run:	01.10.2015 - 01.02.2016

Objective

Sulphur compounds, with their very low odour threshold values, play a part in special flavor hops. The purpose of this study was to find out whether harvest date decisions had any influence on the content levels of a number of selected sulphur compounds.

Method und results

The following aroma-active compounds were tested: dimethyl disulphide, S-Methyl thio isovalerate, 4-Mercapto-4-methyl-2-pentanone (4-MMP), S-Methyl thio hexanoate. These commercially available substances are the main sulphur compounds found in hop. Analysis and quantitative evaluation were performed using the new headspace gas chromatography/ mass spectrometry equipment in the laboratory at Hüll. It was not possible to detect 4-MMP in the mass spectrometer because of insufficient sensitivity. When the other substances were evaluated, it was found that the sulphur compounds intensified significantly with later harvesting. Hops harvested at a later date often have aromas reminiscent of onion or garlic, something which was confirmed by the analytical testing done in this context.

Deployment and establishment of predator mites for sustainable spider mite control in hop as a speciality crop

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Pflanzenschutz Hopfen (IPZ 5b) (*Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Plant Protection (IPZ 5b)*)
Funding:	Bundesanstalt für Landwirtschaft und Ernährung (BLE) (*Federal Agency for Agriculture and Food (BLE*)) Bundesprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft (BÖLN-Projekt 2812NA014)
Project lead:	Dr. F. Weihrauch
Project staff:	M. Jereb, A. Baumgartner, D. Eisenbraun, M. Felsl, L. Wörner
Scheduled to run:	01.05.2013 - 31.05.2016

Objective

In the battle against the two-spotted spider mite, *Tetranychus urticae,* there are currently no effective plant protection products available for use in organic cultivation systems, the only promising alternative being the deployment of predatory mites as biological control agents. In hop growing, however, it is not possible to keep infestation by the two-spotted spider mite in check over any length of time by using predator mites established in the crop (as is often the case in viticulture and fruit growing in Germany), because the parts of the hop plants above the soil, where the predators might find cover during the winter, are completely removed during harvesting.

The aim of this project was to create suitable overwintering sites as habitat augmentation by providing ground cover in the vehicle lanes, in an effort to maintain predator mite populations at a stable size over several growing seasons. To this end, tests were carried out mainly with tall fescue grass, *Festuca arundinacea,* as well as other plants, as undersown ground cover in the lanes. In addition, there were attempts to optimize the deployment of purpose-bred predator mites with respect to both numbers released and judicious timing, and to develop a standard method of distribution as an effective and economically viable alternative to acaricide use.

Findings and conclusions

In the course of the three-year project, involving 15 individual trials, only two trials produced conclusive results, showing significant differences in favour of the variants involving predator mites as against the control. In two of the plots where predator mites were deployed and where spider mite infestation was severe, the damage at harvest was similar to that in the untreated control. In the 11 other individual trials, infestation levels generally remained so low that it was impossible to discern whether the predator mites had any predation effect at all.

Before any new predator mites were released at Hüll and Oberulrain in the spring of 2014, some were found for the first time in the crop, having survived in the yard and then spread from there. When the tall fescue grass was sampled at these sites in spring 2015 and 2016, individual predator mites were also found in isolated cases.

It was discovered that the method of suppressing *T. urticae* used in 2015, whereby trimmed wood from vineyards (sections of first-year growth) was distributed early in the year in the crop, was very effective. Thus, it was possible, in a year with a high level of infestation, to keep spider mite numbers well below the damage threshold. A further positive aspect of using this material is the low cost, since the wood is discarded as waste during the spring maintenance work in wine growing, so that transport costs only are incurred. At Benzendorf in 2015, a combination of *P. persimilis* and *N. californicus* proved an effective method of control. However, these two allochthonous species are unable to overwinter in central Europe, with the result that new populations have to be bought and released every year.

Of the types of ground cover that were trialled, the species of tall fescue grass used in growing mandarin oranges in Spain appears to be a viable option for establishing an autochthonous *T. pyri* population, although there are still issues around implementing a system of management that actually works in connection with routine practices in hop growing.

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)*)
Funding:	Erzeugergemeinschaft Hopfen HVG e.G. (*HVG Hop Producer Group*)
Project lead:	Dr. F. Weihrauch
Project staff:	Dr. F. Weihrauch, A. Baumgartner, D. Eisenbraun, M. Felsl, O. Ehrenstraßer
Collaboration:	Naturland-Hof Pichlmaier, Haushausen; Agrolytix GmbH, Erlangen Hopsteiner (Hallertauer Hopfenveredelungsgesellschaft m.b.H.), Mainburg
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.

However, as things stand at the moment, organic operations growing all kinds of produce can hardly do without copper as an active agent. For this reason, a four-year test programme running from 2010 to 2013 was set up by the BLE (*Federal Institute for Food and Agriculture*) through BÖLN (*Federal Organic Farming Programme*) to investigate 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 needed to be reduced by at least one 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 and to ascertain with a critical eye whether a further reduction in the use of copper is possible.

Results

2016 will be remembered for a very long time for the occurrence of excessive levels of infestation (also in all other crops, particularly in wine growing), making it exactly the reverse of the year before, when infestation was almost non-existent. The situation had an impact on the copper minimization trials because infestation in the cones reached unacceptable levels of over 70% across the board, resulting in lower yields in all the trial plots. The best outcomes, relatively speaking, were achieved when mixes were used (Funguran progress + Kumar; CuCaps + capsules of hop extract; CuCaps + Flavonin AgroComplete). The results from 2016 serve to demonstrate that exceptions must be made in years of extreme conditions, and the amount of copper available for suppressing downy mildew should be allowed to exceed 3 kg/ha. At the same time, it would then be necessary to create a ‘copper account’ for all farms and all varieties to cover a period of five years.

Developing methods of keeping the hop flea beetle (Psylliodes attenuatus) in check in organic hop farming

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e) (*Bavarian State Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Ecology (IPZ 5e))*
Funding:	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (BioRegio 2020 – Landesprogramm Ökologischer Landbau) (*Bavarian State Ministry for Food, Agriculture and Forestry (BioRegio 2020 – State Programme Organic Farming))*
Project lead:	Dr. F. Weihrauch
Project staff:	Dr. F. Weihrauch, A. Baumgartner, D. Eisenbraun, M. Felsl
Collaboration:	Wageningen University & Research, NL; Julius-Kühn-Institut, Institut für Biologischen Pflanzenschutz, Darmstadt
Scheduled to run:	01.03.2015-28.02.2018

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 und Results

In the second year of the trial, the effectiveness of the most promising mechanical methods was again tested. Once again, in 2016, it was found that trapping the beetles using yellow trays was the most effective method. This time, ß-caryophyllene, ocimene and cis-3-Hexenyl-acetate (the hop shoots give off all these substances in large quantities in spring) were tried out as a lure. However, none of these volatile substances helped achieve a catch that was greater than that of the untreated control. With the mechanical method using glue traps, satisfactory numbers can be caught (the average catch being 4 beetles per plant and alleyway), but the technique is highly labour-intensive. A quantitative determination at midsummer of the number of individuals hatching out to become the new generation of hop flea beetles, using photo eclectors, revealed surprising results: a conservative extrapolation estimates that the 'annual production' of hop flea beetles in the trial yard is around 1.2 million per hectare, or 600 beetles per hop plant.
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, in April 2016, approximately 6 000 hop flea beetles were caught and taken to the Netherlands, where, in the laboratories at Wageningen, numerous tests continue with the aim of analysing the odoriferous substances exuded by male and female beetles and the infested hop plants.

The use of microencapsulated extracts of hop as an innovative biological fungicide to combat downy mildew in hop cultivation

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenökologie (IPZ 5e)
Funding:	Wissenschaftsförderung der Deutschen Brauwirtschaft e.V., Berlin
Project leads:	Dr. F. Weihrauch
Project staff:	Dr. F. Weihrauch, A. Baumgartner, M. Felsl
Collaboration:	Naturland-Hof Loibl, Schweinbach
	Lehrstuhl für Prozessmaschinen und Anlagentechnik (iPAT), Friedrich-Alexander-Universität Erlangen-Nürnberg
	Hallertauer Hopfenveredelungsgesellschaft m.b.H. (Hopsteiner), Mainburg
Scheduled to run:	01.07.2016 - 31.12.2018

Objective

In Germany, various steps are being taken to try to reduce the quantites of pure copper applied per hectare as plant protection every year. Alternative active fungicide agents to replace copper are also being sought. In this context, the discovery was made at the Staatliches Weinbauinstitut 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 matrix substances and adjuvants are used, the cost of the end product can be kept down to normal market levels.

Method

The current research project envisages developing right through to the approval stage a prototype biological plant protection agent, based on microencapsulated extracts of hop, to control downy mildew fungi in hop,. The desired outcome of the research work is to be the formulation of the optimal 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 will be field tested for the first time in the trial yard at Schweinbach in 2017. The hop research centre at Hüll will analyse the biological efficacy of these HopCaps in 2017 and 2018 and devise a spray recommendation suitable for implementation by organic hop farmers.

1.2 Key Research Priorities

1.2.1 Research focus: hop cultivation, 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

Optimal drying requires the right balance between drying temperature, air velocity and depth of the material to be dried. Ideally, the same air conditions should prevail across the entire drying area of the moveable tier, the middle tier and the top tier. To achieve this, an optimal air distribution setting is required, while, at the same time, the right quantity of hop must be evenly distributed throughout the top tier.

Method

In commercial kilns, data loggers were used to record the temperature conditions above the air distribution system between the tiers and above the top tier. A permanently fitted thermal imaging camera was also used in a commercial plant to measure the surface temperatures of the hop on the top tier. The most important drying parameters and settings were recorded in drying reports.

Result

It was easily possible to show that an uneven drying performance is caused, not only by big temperature differences in the drying air from the air distributor, but also by an unevenly spread load on the top tier. Therefore, the filling and drying taking place on the top tier have a far greater impact on whether the drying process is uniform or not than has hitherto been realized!

Devising fertigation strategies for hop cultivation

Project staff: S. Fuß, J. Stampfl (master's thesis)
Scheduled to run: 2016

Objective

In hop cultivation in Germany, most of the nutrients that the plants need are applied by spreading fertilizer in granulate form or in fertilizer solutions during hop stripping. The problem is that these are often not available in dry years or that they are not fully absorbed, due to low yields. If this is the case, there is a danger that both surface and ground water can be contaminated with nitrogen. Because of such environmental issues coupled with stricter laws, especially with regard to the fertilizer ordinance, it is vital that efficiency in fertilizer use should be improved. One approach could be the well-placed feeding in of nutrients in the required amounts with the irrigation water (fertigation). Since neither test results nor a knowledge base with respect to the plant nutrient requirements are available, fertilization has always been practised on the basis of guesswork, rather than being accurately targeted. In view of this situation, it is obvious that research urgently needs to be done.

Method and first findings

In 2016, the first fertigation trials took place at two sites in the Hallertau region, involving aroma variety *Perle* and high alpha *Herkules*. The idea was not only to establish the best possible place to position the drip hoses but also to investigate what impact fertigation might have on yield and component compounds. To achieve this, part of the nitrogen was spread according to normal practices, and a part was applied as liquid fertilizer in the irrigation water. The results from the trial where the drip hose was positioned ‘on the hill’ were then compared with the results of the trial where the drip hose was placed on the ground beside the rows of hops. The findings suggest that positioning the drip feed system on the hills had a positive effect on yields and components, even though there was little call for irrigation in 2016. On the basis of the results in 2016, it has not yet been possible to establish verifiable differences in yields because of the high levels of precipitation and nutrient mobilization from the soil.

Outlook

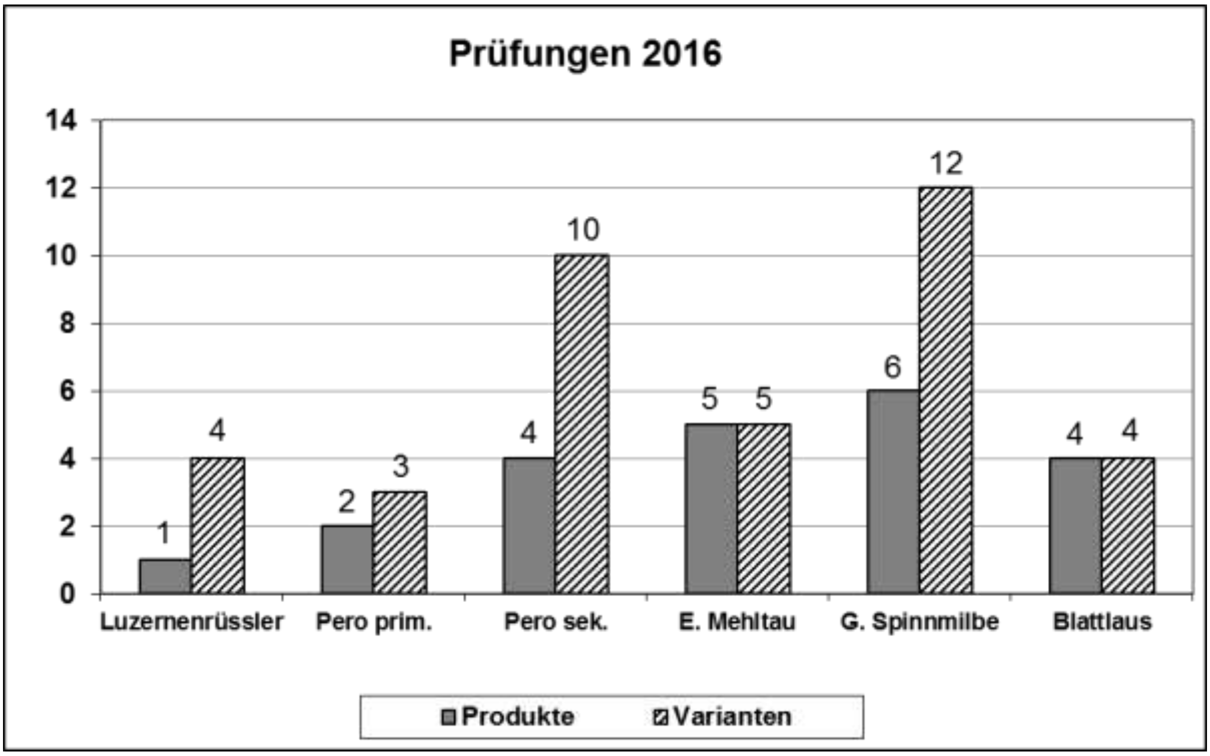
Well-directed fertilization through fertigation promises to deliver a wide range of benefits for plant cultivation and the environment - more than enough reason for continuing to investigate how the method can best be put to use in hop growing in the future. Mr Johann Stampl’s thesis, which deals in depth with this subject field, will certainly make an important contribution.

1.2.2 Research focus: plant protection in hop

2016 trials of plant protection products for approval/registration and advisory service documentation.

Project lead: W. Sichelstiel

Project staff: S. Wolf, L. Wörner, J. Weiher, G. Meyr, M. Felsl, O. Ehrenstraßer



In the course of the 2016 official testing of agents for hop, a total of 22 products were tested in 38 variants. 119 plots were designated as trial areas.

1.2.3 Research focus: breeding

Development of hop breeding material and cultivars with broad spectrum resistance and good agronomic traits within the aroma, high alpha, and special flavor varieties

Project leads:	A. Lutz, Dr. E. Seigner
Project staff:	A. Lutz, J. Kneidl, S. Seefelder, E. Seigner, Team IPZ 5c team
Collaboration:	Dr. K. Kammhuber, Team IPZ 5d team
	Beratungsgremium der GfH *(Hop Advisory Board)*
	Forschungsbrauerei Weihenstephan *(Research Brewery*, Technische Universität München-Weihenstephan, Lehrstuhl für Getränke- und Brau-technologie Prof. Becker und Dr. Tippmann *(Chair of Brewing and Beverage Technology)*
	Bitburger-Braugruppe Versuchsbrauerei *(Experimental Brewery of Bitburger Brewery Group)*, Dr. S. Hanke
	National and international brewing partners
	Partners from the hop trading and hop processing industries
	Verband Deutscher Hopfenpflanzer *(Association of German Hop Growers)*
	Hop growers

Objective

Breeding efforts at Hüll are directed at developing modern, high yielding cultivars of the noble aroma and high alpha varieties, and, more recently, hops with special fruity aromas (special flavor hops), which will also meet the market requirements of the brewing industry and satisfy the needs of both craft brewers and German hop growers alike.

Material and method

In pursuit of this goal, 91 crosses were performed in 2016. The selection procedure, illustrated in the diagram in Fig. 1.1, applies in general to all breeding programmes.

Fig. 1.1: Selection process for Hüll breeding cultivars

Results

Breeding lines from the noble aroma and high alpha ranges showing most promise have reached an advanced stage in the selection process. Since 2011, activities with respect to breeding cultivars with fine hoppy/spicy aroma profiles have been further stepped up. Promising lines with fine Tettnanger aroma profiles from our breeding project to improve Tettnanger landrace (see 4.4) are being extensively tested in collaboration with the Straß experimental station of the Landwirtschaftliches Technologiezentrum (LTZ) in Baden-Württemberg. Efforts to develop robust, high yield, high alpha cultivars were further intensified in 2016 with the start of our high alpha breeding project in collaboration with the Elbe-Saale Hop Growers' Association (see 4.5).

Following the market launch in 2012 of the first special aroma hops, *Mandarina Bavaria, Huell Melon and Hallertau Blanc,* two further cultivars, *Ariana and Callista*, with their very own aroma profiles, were released by the GfH (*Society of Hop Research*) for agricultural production in the spring of 2016. More new breeding lines with novel aroma profiles are at present undergoing on-farm growing trials and are also being carefully tested to determine their brewing attributes (see 4.3). In contrast to other special aroma hops, otherwise known as flavor or impact hops, the special flavor cultivars bred by the LfL are particularly well adapted to suit the growing conditions prevalent in Germany, which means that they are well able to withstand the pathotypes occurring domestically and can cope with typical German weather conditions and soil properties. As a result, they have good agronomic traits and a high yield potential. Added to that, it must be pointed out that intensive individual and, in particular, standardized brewing trials have demonstrated the full range of flavour potential that these Hüll special flavor cultivars possess.

	Ertrag kg/ha	Qualität			Widerstandsfähigkeit gegenüber				
		hopfiges Aroma plus	Ölgehalt (ml/100g)	α-Säuren (%)	Vert. Welke (mild)	Perono-spora	Echtem Mehltau	Roter Spinne	Blatt-laus
Mandarina Bavaria	2.100	Mandarine, Grapefruit	1,5 - 2,5	7- 10	+/-	+/-	+ +	+	+
Huell Melon	1.900	Honig-melone, Aprikose, Erdbeere	1,2 - 2,4	7 - 8	+/-	+	+ +	+/-	+
Hallertau Blanc	2.300	Mango, Stachel-beere, Weißwein	1,3 - 2,1	9 - 11	+/-	+	+ + +	+	+
Callista	2.000	Aprikose, Maracuja	1,3 - 2,1	2 - 5	+/-	+	+ +	+/-	+
Ariana	2.300	Johannis-, Brombeere	1,5 - 2,4	10 - 13	+ + +	+/-	+ + +	+/-	-

Fig. 1.2: Overview of Hüll special flavor cultivars with respect to resistance or tolerance to disease   +++ very good, ++ very good to good, +: +/- medium; - low

Improving screening systems for assessing tolerance of hop towards downy mildew *(Pseudoperonospora humuli)*

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

Project staff: B. Forster

Background and objective

Downy mildew infection in hop, caused by the fungus *Pseudoperonospora humuli* repeatedly poses a major challenge for growers. The rainy summer of 2016 also saw increased levels of downy mildew infection on commercial hop farms. For decades now, the downy mildew warning service has been providing support for hop growers in their battle against this disease in particular. Breeding work is contributing significantly towards solving the problem, by striving to develop hops with markedly improved tolerance towards this fungus.

Greenhouse screening system

In order to test early for downy mildew tolerance, every year, thousands of seedlings planted in trays are sprayed with a fungal spore suspension and then screened.

The test in the plastic covered greenhouse has its shortcomings, when an accurate estimate of the level of tolerance or susceptibility of individual seedlings is required. Added to that, it is never possible in this mass screening setting to create uniform conditions for infection (the same concentration of spores, sufficient wetting, no drying out, accompanied by prevention of infection around the outer edges of the trays, etc.). In 2013, this greenhouse screening procedure was further optimized as part of a student research project. At the time, information taken from Coley-Smith (1965), Hellwig, Kremheller and Agerer (1991), Beranek and Rigr (1997), Darby (2005), Parker et al. (2007), Mitchell (2010), and Lutz and Ehrmeier (provided personally) was re-evaluated and included in the project. (See Annual Report 2013)

Establishing a leaf test system in the laboratory

Objective

A further aim is to use a generally standardized test system involving detached leaves (detached leaf assay) in the laboratory in order to assess, reliably and with greater accuracy, either tolerance towards or susceptibility to downy mildew.

For more details on these studies, please consult 4.7.

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1.2.4 Research focus: hop quality and analytics

Performance of all analytical studies in support of the Working Groups in the Hops Department, in particular, WG 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 (*WG Hop Farming/Production Techniques*), AG Pflanzenschutz Hopfen (*WG Hop Plant Protection*), AG Züchtungsforschung Hopfen (*WG Hop Breeding Research*)

Hop is cultivated and farmed, above all, for its compounds. Therefore, analytical testing of its 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.

Using gas chromatography/ mass spectrometry to develop aroma analytics

Project lead:	Dr. K. Kammhuber
Project staff:	S. Weihrauch, Dr. K. Kammhuber
Collaboration:	AG Züchtungsforschung Hopfen (*WG Hop Breeding Research*), Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt (*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 subtances have been identified. Some compounds are important in differentiating between varieties, but are not aroma active. The main objective of this project is to determine the aroma active compounds in order to provide help in breeding and developing new special flavor hops.

Development of an NIRS calibration model for 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 further expansion every year.

The Society of Hop Research is providing funding for the purchase of new equipment.

Development of analysis methods for hop polyphenols

Project lead: Dr. K. Kammhuber

Collaboration: Arbeitsgruppe für Hopfenanalytik (*WG 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, although there are no official standardized models available at present. All the laboratories involved in polphenol 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. Active substance analyses are being been carried out, using HPLC methods, on the following plants:

- Leonorus japonicus (motherwort): flavonoids, stachydrine, leonurine
- Saposhnikovia divaricata (Fang-feng): Prim-O-Glucosylcimifugin, 5-O-Methylvisamminoside
- Salvia miltiorrhiza (red sage): salvaniolic acid, tanshinone
- Paeonia lactiflora (white Chinese paeony): paenoniflorin

In 2015, rose oils and stone pine oils were also examined using the GC/MS equipment.

2 Weather Conditions and Growth Development in 2016 - impact on technical aspects of production in the Hallertau region

LD Wolfgang Sichelstiel, Dipl.-Ing. agr.

Across the world, 2016 was the hottest year since records began. However, in contrast to the dry conditions of 2015, the weather in 2016 was favourable to hop cultivation, in spite of the fact that intensified efforts were needed to keep crops healthy. The spring brought relatively dry conditions favourable for carrying out the necessary spring maintenance work. In the second third of May, warm moist air prevailed over central Europe, repeatedly bringing precipitation, sometimes in the form of torrential rain and thunderstorms. This general weather situation remained constant until mid-August and was only interrupted by a brief dry spell during the first ten days of July. Summer precipitation was evenly distributed and was accompanied by warm temperatures - ideal conditions for hop growth, but also, unfortunately, conducive to the development of fungal diseases. September was warm and dry, and the harvest yielded a large crop volume with high alpha acids levels.

Specific weather anomalies and their implications

The third winter in succession without ground frost

The winter 2015/2016 was again very mild, with average temperatures at Hüll 4.0°C above the long-term monthly mean. Only in January was the increase more moderate. At 175.3 mm, the average level of precipitation in the three winter months was only slightly above the long-term mean. Once again, hardly any frost penetrated the ground, so that there was no frost action to make the soil friable. March and April stayed warm and dry

March and April stayed warm and dry

March and April were notable for slightly below average temperatures and not enough rain. The mean monthly temperatures reached 3.9°C and 8.3°C, respectively. At 38.0 ltr/m² in March and 38.8 ltr/m² in April, rainfall reached only 87.3% and 69.4% respectively of the 50-year precipitation mean at Hüll. The hop plants started sprouting a little too early. Uncovering and pruning was done on schedule on stable ground that could be driven over, and in many places, the wires were also put in place in the spring. In yards where pruning was done early, crowning commenced mid-month and training the hops began during the last ten days of April. Control measures to deal with the hop flea beetle and wireworm were necessary in some plot subsections, and primary infection with downy mildew occurred only in isolated cases.

A new general weather situation from mid-May onward

With an average temperature of 13.3°C and average precipitation of 88.0 ltr/m², measured at the Hüll weather station, the month of May was 1.4°C too warm as against the 50-year mean, but rainfall was normal. It was still dry during the first ten days of the month, but then, from May 12 onward, the weather was warm and humid with repeated rainfall, occasionally during thunderstorms and as torrential rain. By this time, training had been completed. Subsequent cultivation operations were carried out in conditions that were too wet. Primary tillage was finished by the end of the month, and defoliation began. Existing hop stands had developed at an average rate and had reached a height of 3 to 4.5 mtrs. Primary infection with downy mildew occurred late, but was extensive in parts. Massively increasing spore counts triggered the first spray alert on May 27. Powdery mildew was detected in places, although damage from Rosy rustic moth larvae or wireworms was hardly registered at all. The last days of May saw the start of aphid migration and infestation by the two-spotted spider mite.

Average growth conditions in June

At Hüll, rainfall for the month was above average at 132.0 ltr/m², and was accompanied by an average temperature of 16.8°C, which was 1.5°C higher than the long-term mean. The hops developed normally, in most locations reaching trellis height by the end of the month. Side shoots formed in the lower sections of the bines and the formation of lateral branches was only inadequate in heavy clay soils and on acreage with soil structure problems. Early maturing varieties produced the first burrs by the end of the month. In heavy soils, it was not possible to complete secondary tillage in all yards by the end of June. Conditions throughout June were conducive to secondary downy mildew infection, resulting in spray alerts going out to growers on June 6 and 17. At the same time, there were also outbreaks of primary infection on wet ground. An increase in powdery mildew pressure called for a number of control measures. Aphid migration fell towards the end of the month and did not warrant counter measures. In contrast, action was required, in many cases, in the last third of June, to keep the two-spotted spider mite in check. At the end of June, the first foci of infection with hop wilt disease became noticeable.

The warm and humid weather continued in July

In July, the hops were supplied with ample rainwater and were able to bring forth plentiful burrs. 134.9 ltr/m² of rain fell, approximately 30% more than average. At 18.8°C, the temperature was equivalent to the average in the last ten years. Flowering commenced about a week later than usual. Early maturing varieties began producing the first cones. Conditions were good for growth, but also encouraged the occurrence of pests and diseases. Powdery mildew infection pressure continued, and the warning service issued two spray alerts for downy mildew. Infestation by the two-spotted spider mite also continued, necessitating secondary treatment in many cases. Hop aphids were present in greater numbers than in previous years and had to be suppressed in many places. *Verticillium* wilt disease spread and caused the first signs of die-back.

High summer from mid-August into September

Although the first weeks in August were humid and moderately warm, the second half of the month brought more stable high summer weather, which continued without a break into September. The average temperature in August reached 17.4°C, missing the mean of the last ten years by only 0.1°C, but the September average of 15.6°C outdid the mean by 2.1°C. Rainfall at 66.7 ltr/m² in August managed to reach only about half the ten-year average, but the September average of 66.4 ltr/m² was just above the ten-year mean, with 90% of it falling on three consecutive days from September 17 to 19. Thanks to the plentiful supply of water over the summer, the hops were able to convert large numbers of developing cones into actual yield. In addition, the sunny weather in the run-up to harvest helped with the production of the component compounds. Yellowing and a reduction in the numbers of cones was noted only in locations with light soils with no irrigation or with soil structure problems. Disease pressure remained at high levels throughout the entire season. In August, the warning service issued two further spray alerts for downy mildew. Powdery mildew was able to infect large numbers of chiefly late maturing varieties not due to be harvested until the second half of September and adversely affected external quality. Only early maturing and more resistant varieties were less affected. In a number of yards, major problems arose from infestation by the two-spotted spider mite, and it was only with some difficulty that it could be kept under control. The hop harvest began in the first few days of September and continued into the 40th calendar week. The harvest volume was large in the Hallertau region, yielding 55% more than the poor harvest of the previous year. Alpha acids levels were also higher than the average levels of 2015. Most varieties even exceeded the average for the last ten years.

Hüll weather data (monthly means and monthly totals) for 2016, compared with 10-year and 50-year means

Month		Temperature at a height of 2 m Mean (°C)	Min.∅ (°C)	Max.∅ (°C)	Relative humidity (%)	Precipi-tation (mm)	Days with precipitation >0,2 mm	Sunshine (hrs.)
January	2016	0.1	-3.7	4.0	92.5	73.3	22.0	32.1
∅	10-yr.	-0.2	-3.4	3.2	89.5	59.2	13.7	55.0
	50-yr.	-2.4	-5.1	1.0	85.7	51.7	13.7	44.5
February	2016	3.7	0.3	7.7	84.8	80.5	17.0	49.6
∅	10-yr.	-0.2	-4.2	4.5	86.3	39.2	12.0	81.9
	50-yr.	-1.2	-5.1	2.9	82.8	48.4	12.8	68.7
March	2016	3.9	-0.2	8.8	82.4	38.0	12.0	134.5
∅	10-yr.	4.2	-0.9	10.2	80.0	55.7	12.9	147.4
	50-yr.	2.7	-2.3	8.2	78.8	43.5	11.3	134.4
April	2016	8.3	2.8	14.2	78.8	38.8	13.0	171.8
∅	10-yr.	9.6	3.1	16.4	73.6	52.4	10.7	205.2
	50-yr.	7.4	1.8	13.3	75.9	55.9	12.4	165.0
May	2016	13.3	7.9	18.9	74.4	88.0	16.0	207.8
∅	10-yr.	13.5	7.6	19.6	74.9	113.5	16.1	204.8
	50-yr.	11.9	5.7	17.8	75.1	86.1	14.0	207.4
June	2016	16.8	11.8	22.5	81.1	132.0	20.0	191.6
∅	10-yr.	16.9	10.8	23.1	75.4	110.4	14.2	220.7
	50-yr.	15.3	8.9	21.2	75.6	106.1	14.2	220.0
Juli	2016	18.8	12.6	25.2	78.5	134.9	12.0	237.1
∅	10-yr.	18.9	12.3	25.9	74.6	103.5	13.4	253.0
	50-yr.	16.9	10.6	23.1	76.3	108.4	13.9	240.3
August	2016	17.4	11.0	24.6	80.0	66.7	10.0	259.0
∅	10-yr.	17.5	11.4	24.6	79.9	111.0	13.9	222.3
	50-yr.	16.0	10.2	22.5	79.4	94.9	13.3	218.4
September	2016	15.6	9.9	22.9	83.0	66.4	7.0	221.0
∅	10-yr.	13.6	8.0	20.1	84.3	60.6	11.1	159.5
	50-yr.	12.8	7.4	19.4	81.5	65.9	11.4	174.5
October	2016	7.9	3.9	12.4	92.0	38.5	16.0	96.0
∅	10-yr.	8.7	4.2	14.4	88.5	49.7	10.0	115.3
	50-yr.	7.5	2.8	13.0	84.8	60.0	10.4	112.9
November	2016	3.3	0.1	6.8	93.8	82.0	14.0	52.8
∅	10-yr.	4.5	1.0	8.5	91.3	56.5	11.3	66.7
	50-yr.	3.2	-0.2	6.4	87.5	58.8	12.6	42.8
December	2016	0.1	-2.3	2.8	94.5	5.3	6.0	36.2
∅	10-yr.	1.0	-2.1	4.4	91.4	62.8	15.2	51.1
	50-yr.	-0.9	-4.4	1.6	88.1	49.1	13.3	34.3
∅ 2016		9.1	4.5	14.2	84.7	844.4	158.0	1690.0
10 – year mean		9.0	4.0	14.6	82.5	874.4	154.5	1783.0
50 – year mean		7.4	2.5	12.5	81.0	828.8	153.3	1663.2

The 50-year mean is based on the data from 1927 through 1976,
the 10-year mean is based on the data from 2006 through 2015.

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	No. of farms	Hop acreage per farm in ha	Year	No. of farms	Hop acreage per farm in ha
1975	7 654	2.64	2010	1 435	12.81
1980	5 716	3.14	2011	1 377	13.24
1985	5 044	3.89	2012	1 295	13.23
1990	4 183	5.35	2013	1 231	13.69
1995	3 122	7.01	2014	1 192	14.52
2000	2 197	8.47	2015	1 172	15.23
2005	1 611	10.66	2016	1 154	16.12

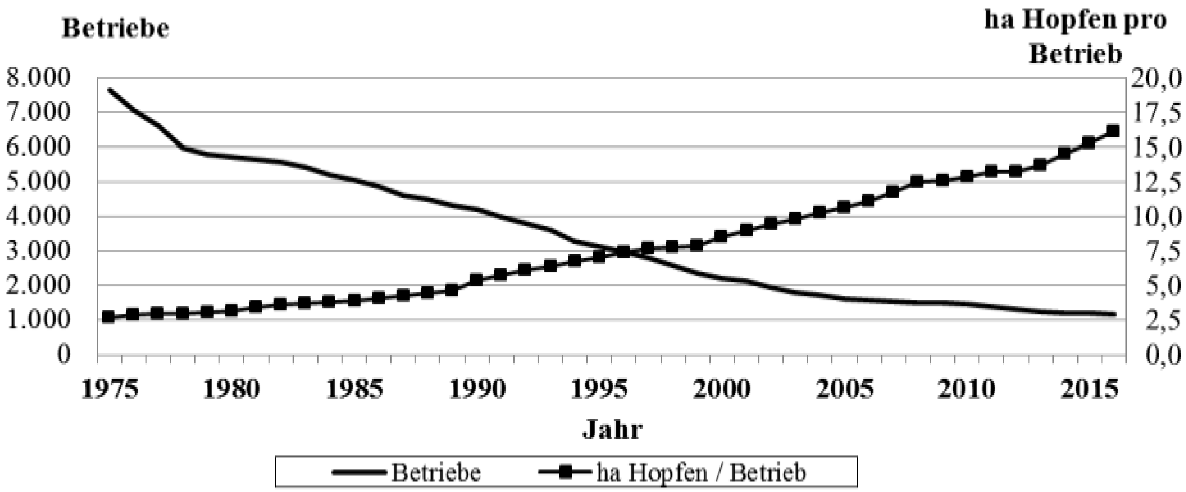

Fig. 3.1: Number of hop farms and their hop acreages in Germany

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

Hop growing region	Hop acreages in ha 2015	Hop acreages in ha 2016	increase + / decrease - 2016 to 2015 ha	increase + / decrease - 2016 to 2015 %	Hop farms 2015	Hop farms 2016	increase + / decrease - 2016 to 2015 farms	increase + / decrease - 2016 to 2015 %	Hop acreage per farm in ha 2015	Hop acreage per farm in ha 2016
Hallertau	14 910	15 510	600	4.0	947	931	- 16	- 1.7	15.74	16.66
Spalt	363	376	13	3.6	55	55	± 0	± 0	6.60	6.83
Tettnang	1 237	1 282	44	3.6	139	135	- 4	- 2.9	8.90	9.49
Baden, Bitburg u. Rheinpfalz	20	22	2	10.0	2	2	± 0	± 0	10.00	11.00
Elbe-Saale	1 325	1 409	84	6.3	29	31	2	6.9	45.69	45.44
Germany	**17 855**	**18 598**	**743**	**4.2**	**1 172**	**1 154**	**- 18**	**- 1.5**	**15.23**	**16.12**

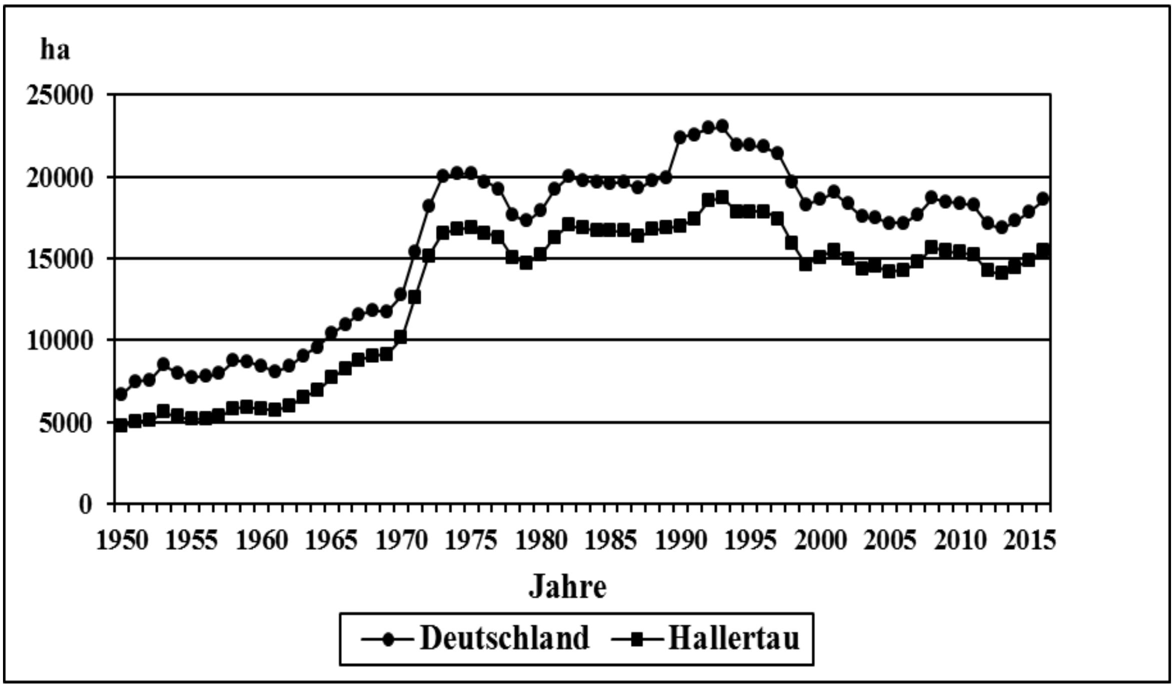

Fig. 3.2: Hop growing acreages in Germany and the Hallertau region

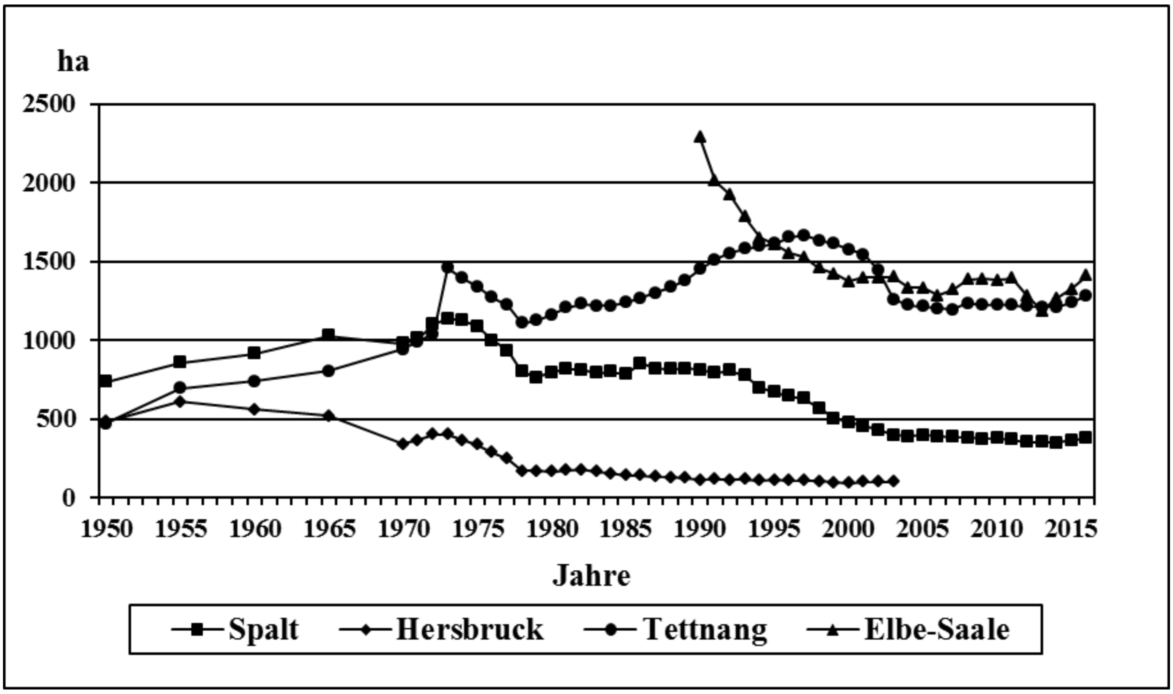

Fig. 3.3: Hop growing acreages in the Spalt, Hersbruck and Elbe-Saale regions

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

Hop varieties

Once again, the acreage under hop in Germany rose significantly in 2016, by 743 hectares, and has now reached 18 598 hectares.

While the acreage of the traditional aroma varieties like *Hallertauer Mittelfrüher*, *Tettnanger*, *Hersbrucker Spät, Perle und Hallertauer Tradition* decreased, acreage of the newer aroma hops *Saphir, Opal* and *Smaragd* and the special varieties *Saazer und Spalter* grew in size. Seen in total, this sector shrank by 125 hectares, or 2.9 %.

In the bittering hops sector, it appears that the loss of acreage for *Northern Brewer* has now been brought to a halt. Other bittering and high alpha varieties *Hallertauer Magnum* (-157 ha) and *Hallertauer Taurus* (-108 ha) have increasingly been supplanted by *Polaris* (+46 ha) and *Herkules* (+732 ha), which means that *Herkules* is now the most frequently grown cultivar and accounts for 26.3 %, or over a quarter of total German acreage under hop.

Two new cultivars from Hüll, *Callista (CI)* and *Ariana (AN)*, have now been added to the group of flavor varieties, boosting the trend towards increased cultivation of flavor hops (+ 69 %) in Germany, the result being that 790 hectares are now given over to growing this type in 2016, accounting for 4.2 % of the total acreage. Further gains are to be expected in the next few years.

For a detailed overview of variety distribution by region see Tab. 3.3.

Tab. 3.3: Hop varieties by hectare in the German hop growing regions in 2016

Aroma varieties

Hop growing region	**Total hop acreage**	**HA**	**SP**	**TE**	**HE**	**PE**	**SE**	**HT**	**SR**	**OL**	**SD**	**SA**	**other**	**Aroma varieties**	
														ha	**%**
Hallertau	15 510	553			934	2 780	440	2 704	400	137	49	7	8	8 012	51.7
Spalt	376	36	119		5	25	81	33	19	1	1		2	324	86.2
Tettnang	1 282	142		732	0	61	9	58	31	1	11			1 045	81.5
Baden, Bitburg and Rheinpfalz	22	1				8		4						14	62.2
Elbe-Saale	1 409					219	5	28				106		358	25.4
Germany	**18 598**	**733**	**119**	**732**	**940**	**3 093**	**534**	**2 827**	**450**	**140**	**62**	**113**	**10**	**9 752**	**52.4**
Variety by **%**		3.9	0.6	3.9	5.1	16.6	2.9	15.2	2.4	0.8	0.3	0.6	0.1		

Variety changes in Germany

2015 (in ha)	17 855	751	114	744	955	3 187	534	2 914	423	130	47	74	3	**9 877**	**55.3**
2016 (in ha)	18 598	733	119	732	940	3 093	534	2 827	450	140	62	113	10	**9 752**	**52.4**
Change (in ha)	743	-18	5	-13	-16	-94	1	-87	26	10	14	39	7	**-125**	**-2.9**

Tab. 3.4: Hop varieties by hectare in the German hop growing regions in 2016

Bittering and high alpha varieties

Hop growing region	NB	BG	NU	TA	HM	TU	MR	HS	PA	other	Bittering varieties	
											ha	%
Hallertau	156	17	128		1 526	340	18	4 540	58	36	6 820	44.0
Spalt					3		3	32		2	40	10.6
Tettnang						0		173	4	15	193	15.0
Baden, Bitburg and Rheinpfalz				0	3			5	0		8	36.0
Elbe-Saale	109		24		663	17		135	43	6	997	70.7
Germany	**266**	**17**	**152**	**0**	**2 196**	**357**	**21**	**4 884**	**106**	**59**	**8 057**	**43.3**
Variety by **%**	1.4	0.1	0.8	0.0	11.8	1.9	0.1	26.3	0.6	0.3		

Variety changes in Germany

2015 (in ha)	238	17	162	1	2 353	465	26	4 152	60	37	**7 511**	**42.1**
2016 (in ha)	266	17	152	0	2 196	357	21	4 884	106	59	**8 057**	**43.3**
Change (in ha)	28	0	-10	-1	-157	-108	-5	732	46	22	**546**	**1.3**

Tab. 3.5: Hop varieties by hectare in the German hop growing regions in 2016

Flavor varieties

Hop growing region	CI	AN	CA	HC	HN	MB	MN	CO	Flavor varieties	
									ha	%
Hallertau	31	21	57	131	111	302	18	7	678	4.4
Spalt	0		4	3	1	3			12	3.2
Tettnang			6	9	12	15	2		44	3.5
Baden, Bitburg and Rheinpfalz			0	0		0			0	1.8
Elbe-Saale			9	11	9	26			55	3.9
Germany	**31**	**21**	**76**	**154**	**134**	**346**	**20**	**7**	**790**	**4.2**
Variety by **%**	0.2	0.1	0.4	0.8	0.7	1.9	0.1	0.0		

Variety changes in Germany

2015 (in ha)			41	109	101	207	5	5	**467**	**2.6**
2016 (in ha)	31	21	76	154	134	346	20	7	**790**	**4.2**
Change (in ha)	31	21	36	45	33	139	15	2	**322**	**1.6**

3.2 2016 Yields

The 2016 hop harvest in Germany produced 42 766 090 kg (= 855 322 cwt) and was much bigger than expected, thanks to the increase in acreage (by 743 ha) and favourable weather conditions, contrasting with the drought conditions of 2015, when the crop had amounted to only 28 336 520 kg (566 730 cwt). This means that the 2016 volume is 14 429 570 kg (= 288 591 cwt) greater than the previous year's figure – an increase of 50.9 %.

With a yield per hectare of 2 299 kg, a calculation based on acreage in total, the quantity harvested was far above average and counts as one of the best harvests ever.

Alpha acids levels were average to slightly above average in 2016. The aroma varieties *Hallertauer Mittelfrüher* and *Perle* produced particularly positive results. Among the bittering hops, alpha acids levels in *Hallertauer Magnum* and *Herkules* were half a percentage point above the long-term average; in *Northern Brewer* and *Taurus* they were 1% and in *Polaris* even 2% higher. Altogether, the quantity of alpha acids produced in Germany is estimated to be just over 4 750 t, which amounts to around 2 250 t or about 90 % more than in 2015.

Tab. 3.6: Per-hectare yields and relative figures for Germany

	2011	**2012**	**2013**	**2014**	**2015**	**2016**
Yield kg/ha and (cwt/ha)	2 091 kg (41.8 cwt) (Hagelschäden)	2 013 kg (40.3 cwt)	1 635 kg (32.7 cwt) (Hagelschäden)	2 224 kg (44.5 cwt)	1 587 kg (31.7 cwt)	2 299 kg (46.0 cwt)
Acreage in ha	18 228	17 124	16 849	17 308	17 855	18 598
Total crop in kg and cwt	38 110 620 kg = 762 212 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

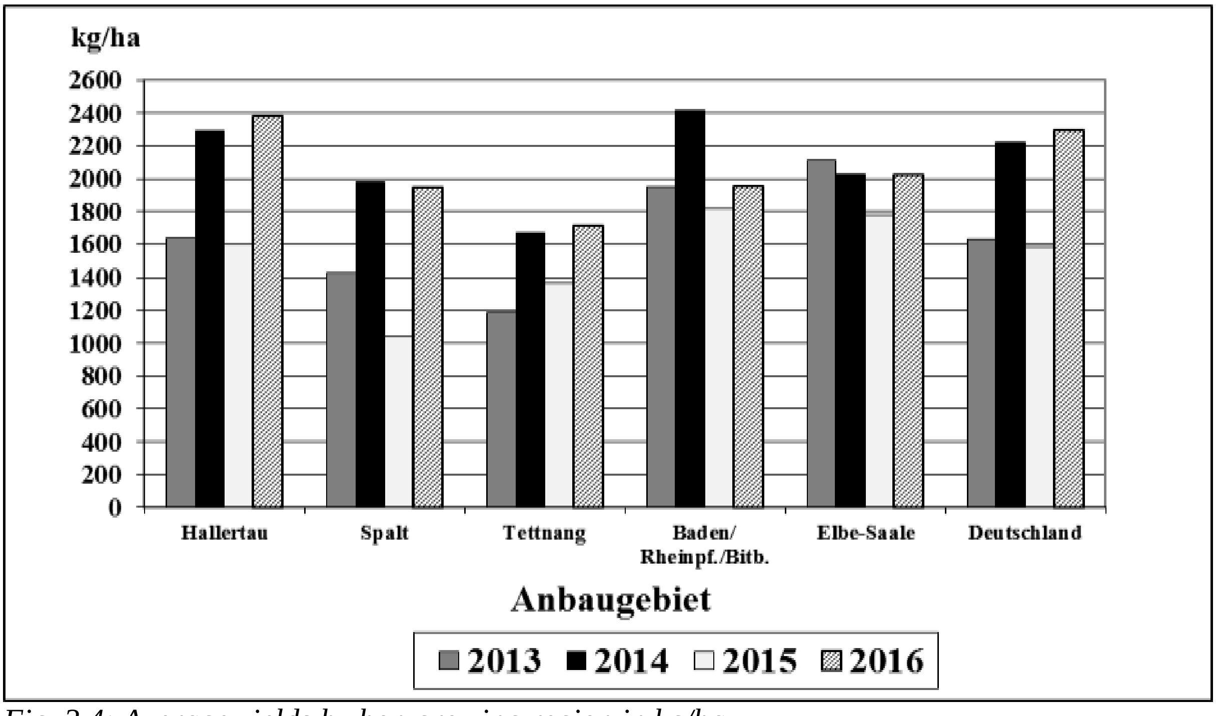

Fig. 3.4: Average yields by hop growing region in kg/ha

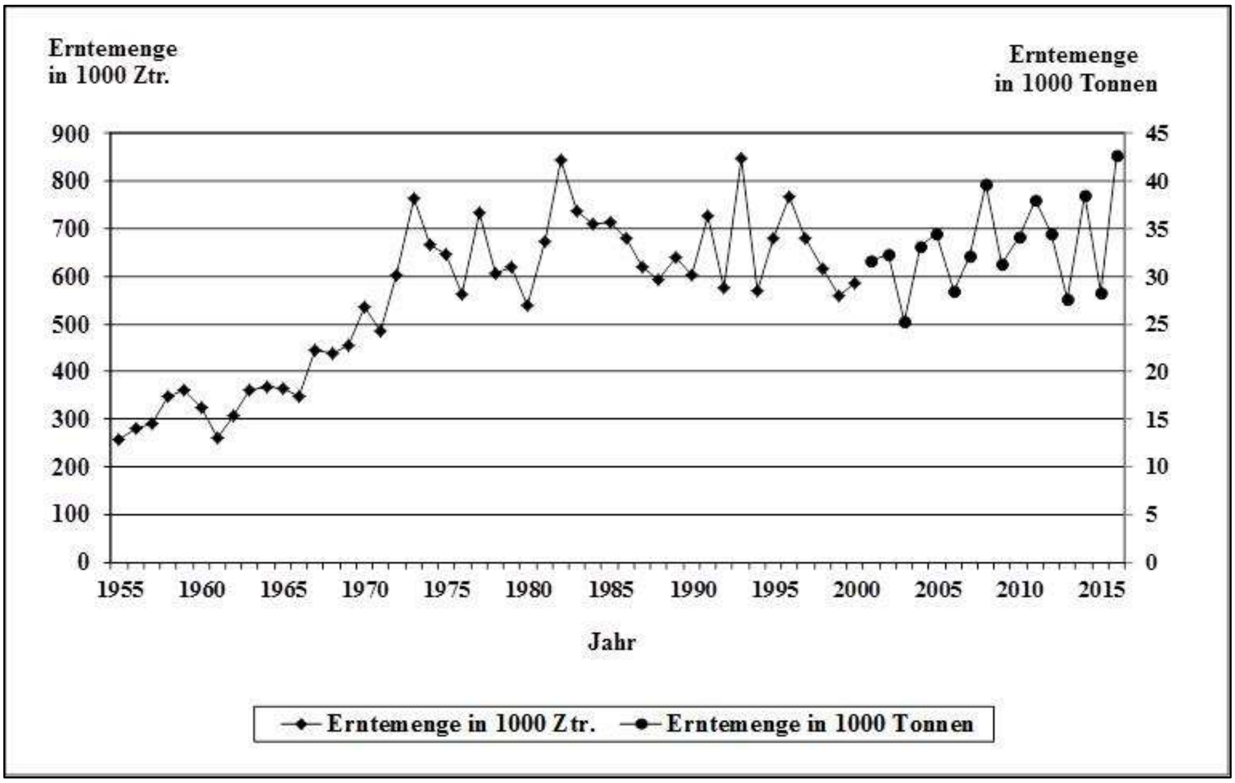

Fig. 3.5: Crop volumes in Germany

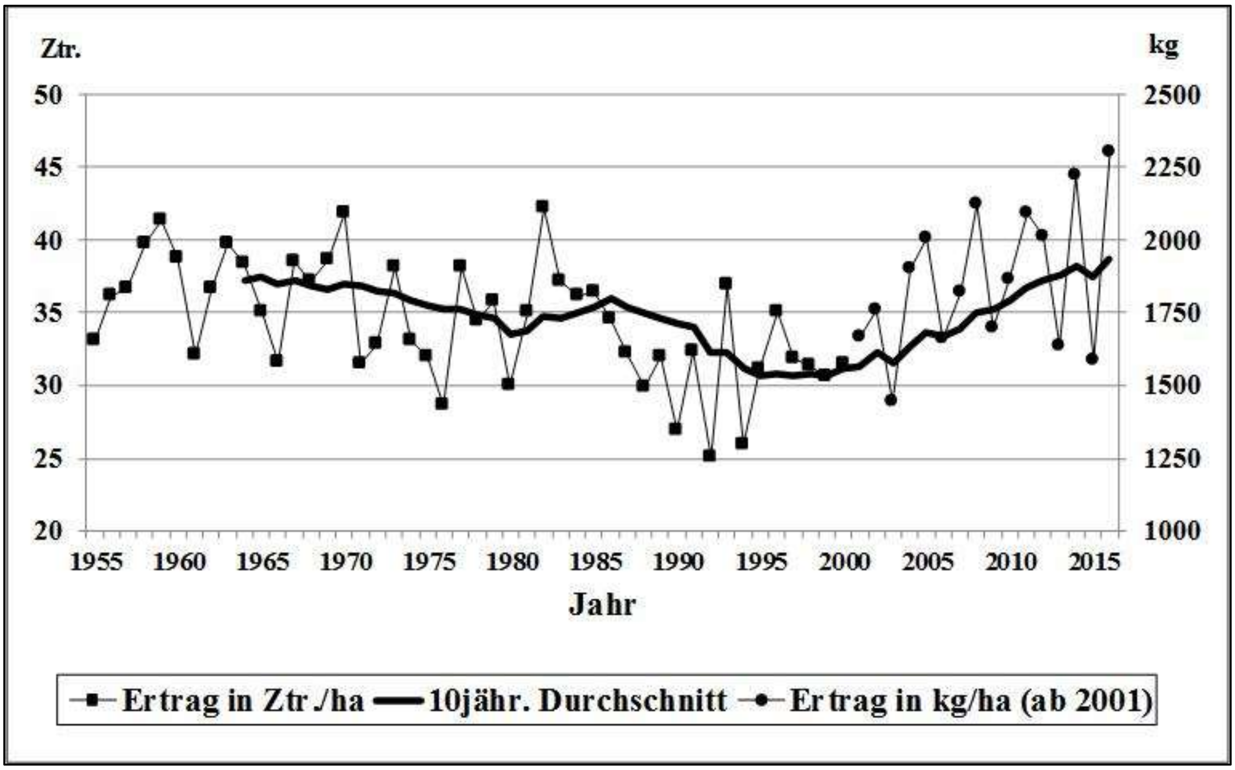

Fig. 3.6: Average yields (in cwt and kg/ha) in Germany

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

Hop growing region	Yields in kg/ha total acreage								
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Hallertau	2 190	1 706	1 893	2 151	2 090	1 638	2 293	1 601	2 383
Spalt	1 680	1 691	1 625	1 759	1 383	1 428	1 980	1 038	1 942
Tettnang	1 489	1 320	1 315	1 460	1 323	1 184	1 673	1 370	1 712
Bad. Rhine./ Palatinate and Bitburg	1 988	1 937	1 839	2 202	2 353	1 953	2 421	1 815	1 957
Elbe-Saale	2 046	1 920	1 931	2 071	1 983	2 116	2 030	1 777	2 020
∅ yield per ha **Germany**	**2 122 kg**	**1 697 kg**	**1 862 kg**	**2 091 kg**	**2 013 kg**	**1 635 kg**	**2 224 kg**	**1 587 kg**	**2 299 kg**
Total crop Germany (t and cwt)	39 676 t 793 529	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
Acreage Germany (ha)	18 695	18 473	18 386	18 228	17 124	16 849	17 308	17 855	18 598

Tab. 3.8: Alpha acid values for the various hop varieties

Region/variety	2007	2008	2009	2010	2011	2012	2013	2014	2015	**2016**	Ø 5 years	Ø 10 years
Hallertau Hallertauer	3.9	4.4	4.2	3.8	5.0	4.6	3.3	4.0	2.7	**4.3**	**3.8**	**4.0**
Hallertau Hersbrucker	2.6	2.9	3.4	3.5	4.5	3.0	1.9	2.1	2.3	**2.8**	**2.4**	**2.9**
Hallertau Hall. Saphir	4.6	5.1	4.5	4.5	5.3	4.4	2.6	3.9	2.5	**4.0**	**3.5**	**4.1**
Hallertau Opal	7.4	9.4	9.0	8.6	9.7	9.0	5.7	7.3	5.9	**7.8**	**7.1**	**8.0**
Hallertau Smaragd	6.1	6.7	6.4	7.4	8.0	6.0	4.3	4.7	5.5	**6.2**	**5.3**	**6.1**
Hallertau Perle	7.9	8.5	9.2	7.5	9.6	8.1	5.4	8.0	4.5	**8.2**	**6.8**	**7.7**
Hallertau Spalter Select	4.7	5.4	5.7	5.7	6.4	5.1	3.3	4.7	3.2	**5.2**	**4.3**	**4.9**
Hallertau Hall. Tradition	6.0	7.5	6.8	6.5	7.1	6.7	5.0	5.8	4.7	**6.4**	**5.7**	**6.3**
Hallertau Mand. Bavaria						8.8	7.4	7.3	7.0	**8.7**	**7.8**	
Hallertau Hall. Blanc						9.6	7.8	9.0	7.8	**9.7**	**8.8**	
Hallertau Huell Melon						7.3	5.3	5.4	5.8	**6.8**	**6.1**	
Hallertau Polaris						20.0	18.6	19.5	17.7	**21.3**	**19.4**	
Hallertau North. Brewer	9.1	10.5	10.4	9.7	10.9	9.9	6.6	9.7	5.4	**10.5**	**8.4**	**9.3**
Hallertau Hall. Magnum	12.6	15.7	14.6	13.3	14.9	14.3	12.6	13.0	12.6	**14.3**	**13.4**	**13.8**
Hallertau Nugget	10.7	12.0	12.8	11.5	13.0	12.2	9.3	9.9	9.2	**12.9**	**10.7**	**11.4**
Hallertau Hall. Taurus	16.1	17.9	17.1	16.3	17.4	17.0	15.9	17.4	12.9	**17.6**	**16.2**	**16.6**
Hallertau Herkules	16.1	17.3	17.3	16.1	17.2	17.1	16.5	17.5	15.1	**17.3**	**16.7**	**16.8**
Tettnang Tettnanger	4.0	4.2	4.2	4.0	5.1	4.3	2.6	4.1	2.1	**3.8**	**3.4**	**3.8**
Tettnang Hallertauer	4.3	4.7	4.5	4.2	5.1	4.7	3.3	4.6	2.9	**4.4**	**4.0**	**4.3**
Spalt Spalter	4.6	4.1	4.4	3.7	4.8	4.1	2.8	3.4	2.2	**4.3**	**3.4**	**3.8**
Elbe-S. Hall. Magnum	13.3	12.2	13.7	13.1	13.7	14.1	12.6	11.6	10.4	**13.7**	**12.5**	**12.8**

Source: Hop Analysis Working Group (AHA)

4 Hop Breeding Research

RDin Dr. Elisabeth Seigner, Dipl.-Biol.

The breeding work carried out at the Hüll Hop Research Center pursues three specific objectives:

- to develop noble aroma varieties with the fine aroma profiles typical of hop
- to create robust, top performing high alpha hops
- to breed special aroma varieties (special flavor hops) with unique fruity/floral aroma profiles.

In selecting new breeds created at Hüll, it is not only their constituent compounds and the resulting brewing quality, that are crucial; at the same time, raised resistance to the most common diseases and pests and the traits essential for enhanced agronomic performance are likewise of prime importance.

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

Fig. 4.1: Harvested hops are recorded as they pass through the picking machine

Abb 4.2: Packing and weighing the crop samples after drying

4.1 Crosses in 2016

In 2016, a total of 91 crosses were carried out.

4.2 Hüll Special Flavor Hops - unique aroma compositions and key advantages for hop growers and brewers

Objective

Beers of character with greatly increased hopping rates and special aroma profiles, first promoted by US craft brewers, have now triumphed worldwide. With the aim of providing German hop growers with the means to supply special aroma varieties to this booming beer and hops market, the first crosses targeted at developing robust, high yielding hops, capable of imparting unique aroma profiles to the beer, were produced in 2006 by Anton Lutz.

In the meantime, five special flavor hops - Fig. 4.3 (see also Fig. 1.2) - from this breeding programme, having undergone a series of extensive on-farm growing trials and brewing tests, were developed to the stage where they were ready for the market and then released by the Society of Hop Research (GfH) for agricultural cultivation. Cultivars *Mandarina Bavaria*, *Huell Melon*, *Hallertauer Blanc*, *Ariana*, and *Callista* are already being grown in Germany on an acreage of more than 450 hectares, which means that they have now succeeded in breaking into the lucrative market for special hops – a market which had previously been cornered almost exclusively by the US growers with their flavor varieties (= aroma and dual purpose types).

Fig. 4.3: The five Hüll special aroma cultivars

Today, US growers have given over 81% of their total acreage (21 440 ha) to supplying this special aroma/dual purpose hops market with an absolutely huge number of different types of hop.

At the same time, in contrast, acreage under high alpha varieties has been reduced to 19% (Fig. 4.4 – see details on https://www.usahops.org/img/blog_pdf/76.pdf).

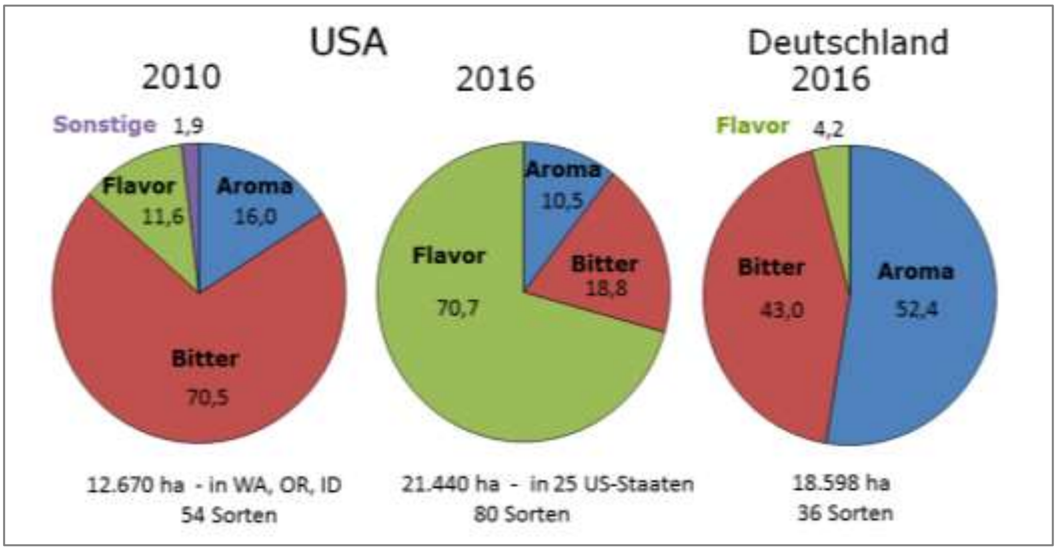

Fig. 4.4: Changes in acreages devoted to growing aroma, bittering and flavor hops in the USA between 2010 and 2016, and the situation in Germany in 2016. Details given in % of the total acreage; additional information on total hop growing acreage, main hop producing states (WA = Washington, OR = Oregon, ID = Idaho), and number of varieties grown (acc. to I.H.G.C. list of varieties).

4.3 New Breeding Line 2011/02/04 Released by the Society of Hopf Research for Large-scale Field Trials and Standardized Test Brewing

When judging the samples from the 2015 harvest, the panel of experts from the GfH, headed by Anton Lutz, put forward breeding line 2011/02/04 for dry hopping brewing trials performed in accordance with standardized procedures, on account of its pleasant aroma composition, which combines hints of citrus fruits, pineapple and thyme. In the spring of 2016, the dry hopped beers made with this breeding line by the TUM experimental brewery were assessed by more than 40 beer tasters and compared with *Cascade* and another Hüll special aroma line. The tasters were won over by the highly fruity beer flavours, the descriptors used most often being lemon/ grapefruit, blackcurrant, pineapple, and passion fruit (Fig. 4.5).

Tab. 4.1: Components of breeding line 2011/02/04 and cone characteristics

Inhaltstoffe	
Bittersubstanzen (EBC 7.7)	
Alphasäuren (%)	**9,4 %** (7,5 – 11 %)
Betasäuren (%)	**8,6 %** (7,5 – 11 %)
Cohumulon (rel. in % der α-Säuren)	**23 %** (19 – 25 %)
Gesamtölgehalt ml /100 g (EBC 7.10)	**2,8** (2,35 – 3,35)

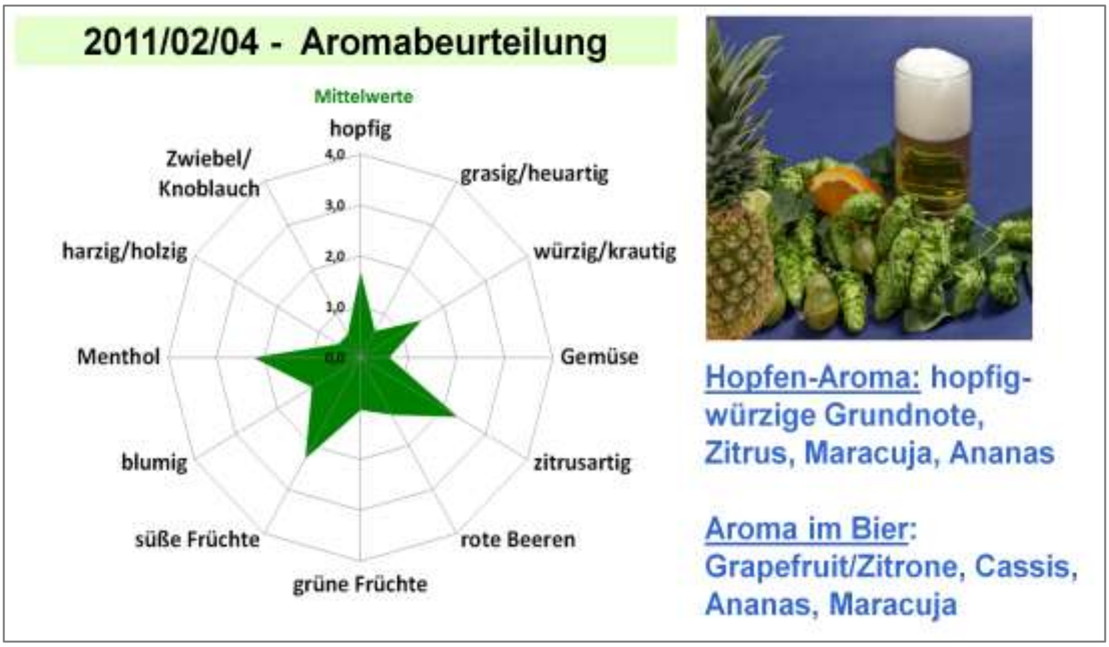

Fig. 4.5: Aroma diagram of beeding line 2011/02/04 with description of its aroma in cones and flavour in beers

Breeding line 2011/02/04 stood out as highly promising, not only for its dry hopping results, but also for its agronomic traits and it resistance characteristics (Tab. 4.2) and was thus released by the Society of Hop Research (GfH) for large-scale on-farm growing trials (see breeding diagram Fig. 1.1). This means that farmers can begin per-hectare cultivation in the spring of 2017. Furthermore, standardized brewing trials to assess its bittering and wet and dry hopping qualities have also been commissioned by the GfH.

Tab. 4.2: Agronomic traits and reaction to fungi and pests of breeding line 2011/02/04, based on findings from tests conducted by the LfL

Agronomische Eigenschaften (bisherige Prüfergebnisse)	
Vorteile	sehr homogen, wüchsig, gute Windefähigkeit, guter Behang, hohes Ertragspotential, kompakte Dolden
Nachteile	kleine Dolden, bei Überreife Doldensterben und Botrytis
Reife	mittelspät (kurz vor oder wie Hersbrucker Spät)
Ernte	gute Pflücke und Trocknung
Ertragspotenzial	hoch (über Hallertau Tradition und Perle)

Widerstandsfähigkeit gegenüber	
Verticillium-Welke	bisher gut
Peronospora Primärinfektion	hoch
Peronospora Sek. Infektion	hoch
Echtem Mehltau	resistent
Botrytis	mittel - hoch
Spinnmilbe	mittel
Blattlaus	mittel

Fig. 4.6: Crops from breeding line 2011/02/04 in the Stadlhof breeding yard

References

Lutz, A. und Seigner, E. (2015): Innovationen rund um die Hüller Hopfenzüchtung. Brauwelt Nr. 3: 57-59.

Seigner, E. und Lutz, A. (2015): Jahresbericht 2014, Sonderkultur Hopfen. Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung und Gesellschaft für Hopfenforschung e.V. http://www.lfl.bayern.de/mam/cms07/ipz/dateien/hopfen_jahresbericht_2014.pdf, S. 40 ff.

4.4 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.

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, thanks to their relatedness, good agronomic performance.

Result

Seedling assessment

From 21 specifically created crosses extracted since 2010 from Tettnanger landrace and male hop breeding lines from Hüll aroma breeding programmes, it has been possible to plant out for seedling assessment at the Hüll breeding yard 840 female seedlings, which had been preselected for their resistance and vigour. In 2016, 8 seedlings were harvested and their cone components subjected to chemical analysis. An organoleptic evaluation of their aroma then followed. Two of these breeding lines have been earmarked for the field trial with advanced selections in 2017. Seedlings from the 3 last crosses will be planted out in the breeding yard at Hüll in spring 2017. In addition, seedlings from four 2016 crosses are lined up for preliminary selection at Hüll.

Field trial with advanced selections

For this test stage, 12 plants each are being grown over a 4-year period at two locations in the Hallertau and at the Straß experimental station in Tettnang**.** Two highly promising lines (2012/29/13 and 2013/45/37) reached the field trial with advanced selections stage in 2015 and now, in 2016, the first harvest results have come through (Tab. 4.3), and this hop will be grown only at Hüll in replications for the time being. Advanced selections from this line cannot begin in 2017 at Stadelhof and Straß until the *Verticillium* has been successfully eliminated.

Breeding line 2013/45/37, in particular, with its pleasant aroma and good yield potential was rated highly promising after its first season.

Tab. 4.3: Harvest results from the 2015 field trial with advanced selections, comparing two breeding lines with Tettnanger landrace

Eigenschaften	Tettnanger	Sämling 2012/29/13*	Sämling 2013/45/37
Ort der Prüfung		nur Hüll	Hüll, Stadelhof, Straß
Aroma-einschätzung	fein, hopfen-würzig	fein, anhaltend, hopfenwürzig	fein, hopfenwürzig
Ölkomponenten	Farnesen	Farnesen	Farnesen
α-Säuren (%)	3,7	4,0 - 4,3	5,3 – 7,0
β-Säuren (%)	6,0	6,7 - 6,8	8,5 – 9,3
Cohumulon (%)	23	16 - 17	16 - 17
Xanthohumol (%)	0,36	0,28 - 0,30	0,44 - 0,49
Agronom. Einschätzung	kopfbetont, Neigung zur Frühblüte, große Dolden, geringes Ertragspotenzial	kopfbetont, Doldenverlaubung, geringer Behang, große Dolden, mittlerer Ertrag	kopfbetonte Rebe, mittlerer - guter Behang, späte Reife, gutes Ertragspotenzial

[1] in % by weight; [2] % rel. of alpha acids; 2016 no harvest at Straß; *eliminiation of *Verticillium*

Another six more seedlings (Tab. 4.4) from those bred in 2012, 2013 and 2014 were propagated in 2016 and planted out for the new field trials with advanced selections, following testing for viruses and wilt disease. Although none of the breeding lines showed any signs of wilt disease in the breeding yard, the highly sensitive Real-Time PCR detected *Verticillium* in the bines near the base in three of the breeding lines (2013/045/033, 2013/45/744 and 2014/044/013 – marked * in Tab. 4.4 and, for this reason, these were at first only accepted for growing tests at Hüll. In the meantime, the wilt fungus has been eliminated in all three lines through cultivation of meristems, and the three are now available for field trials with advanced selections at Stadelhof and Straß.

Tab. 4.4: Results and assessments oft he seven seedlings chosen fort he field trials with advanced selections begun in 2016, in comparison with Tettnanger

	Sämling 2012/29/24	Sämling* 2013/45/33	Sämling* 2013/45/744	Sämling 2014/43/19	Sämling* 2014/44/13	Sämling 2014/46/16
Ort	Hüll, Stadelhof, Straß	Hüll	Hüll	Hüll, Stadelhof, Straß	Hüll, Stadelhof	Hüll, Stadelhof, Straß
Aroma	fein, angenehm, hopfenwürzig	angenehm hopfenwürzig	hopfen-würzig, krautig	fein, hopfen-würzig	fein, angenehm, hopfenwürzig	fein, hopfenwürzig schwach
Öl	Farnesen (-)	Farnesen	Farnesen ?	Farnesen	Farnesen	Farnesen (-)
Alpha	5,1	8,5	4,1	12,0	10,7	6,1
Beta	4,4	3,1	7,7	4,1	4,5	3,7
Coh.	24	25	21	23	25	21
Xan	0,45	0,39	0,52	0,84	0,55	0,56
Agr.	kopfbetont, große Dolden, gute Stress-toleranz, mittleres Ertragspot.	zylin., Behang ab 3m, kompakte Dolden, mittl. - gutes Ertrags-potenzial	kopfbetont, Behang bis weit nach unten, Doldenver-laubung, mittl. - gutes Ertragspot.	wüchsig, ausladend, guter Behang, schöne, komp Dolden, gutes Ertrags-potenzial	kopfbetont, windet gut, mittl. Behang, sehr schöne Dolden, mittleres Ertragspot.	wüchsig, zylin., mittl.-guter Behang etwas offene Dolden, Zerblätt., mittl.-gutes Ertragspot.

[1] in % by weight; [2] % rel. of alpha acids; * elimination of *Verticillium* successfully completed during the 2016 season

Outlook

In terms of breeding efforts, a first decisive phase began in 2015 with the 4-year field trials with advanced selections for the first lines from the *Tettnanger* breeding programme. Now, for the first time, the potential of a breeding line can be assessed under various different soil and weather conditions. Judgements with respect to growth vigour, yield, disease resistance, components and aroma are thus far more reliable.

Following on from the field trials with advanced selections comes the trial procedure whereby a breeding line has to stand the test of being planted in trial plots on real world hop farms (row planting and large-scale growing trials). This test stage will not commence for the new lines from the breeding programme before 2019/2012 at the earliest.

Reference

Seigner, E. und Lutz, A.: Kreuzungsprogramm mit der Landsorte Tettnanger. Hopfen-Rundschau International 2015/2016, 66-67.

4.5 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 towards fungi and pests, in particular towards the pathogens causing crown rot. All these properties ensure that hop production is economically viable in the prevailing conditions specific to the Elbe/Saale region. Eventually, competitive new varieties are to achieve approval with a view to securing the area’s long-term ability to compete as a hop producing region on world markets.

Implementation

- **Crosses**

All crossbreeding work for the first stage of the project 2016-2019, from crosses to seedling assessment (see similar selection process Fig. 1.1), to be performed by the LfL in their greenhouses and breeding yards. The LfL is to provide breeding lines and cultivars, selected from their own breeding material for the desired traits, for the crossbreeding programme. The crosses, the nursery work and preliminary screening for resistance/tolerance towards powdery and downy mildew are to be carried out at Hüll. The subsequent 3-year seedling assessment, involving individual plants and the field trials with advanced selections will also take place at Hüll. All further stages of selection are to take place simultaneously in the Elbe/Saale region and the Hallertau.

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 will be analysed by means of NIRS (near-infrared spectroscopy), and an organoleptic evaluation of the aroma quality carried out. Only for promising seedlings earmarked for the field trials with advanced selections will detailed analyses of the bitter compounds be performed by means of HPLC (high performance liquid chromatography).

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

New breeding lines with good prospects from the current LfL breeding programmes are being tested in real world conditions in field trials in the Elbe-Saale region in order to find out which are suitable for cultivation in the local conditions and can deliver the required performance traits and resistance to diseases.

Results

34 crosses were performed in 2016 with the above objective in mind. In addition, the first findings were collected from the row planting trial, which has been underway on a hop farm in the Elbe/Saale region since 2014.

Currently, three high alpha breeding lines are being tested on the farm against cultivars *Hallertauer Magnum*, *Herkules*, *Polaris* and *Ariana.* Only high alpha lines noted for their good plant health in the breeding yard at Hüll were taken into consideration.

Ariana, the new special flavor cultivar which gained approval in 2016, with its all-round resistance and tolerance to diseases is also being tested in the same location to assess its ability to withstand the pathogens causing the crown rot prevalent in the area. If the results are positive, *Ariana* would be deployed as a source of all-round resistance within this breeding programme.

Tab. 4.5: Results of row planting trial with Hüll high alpha lines (row with 102 plants per breeding line) on land of an Elbe/Saale grower, with Hallertauer Magnum, Herkules and Polaris as references varieties; Mt-Res = resistance to powdery mildew; 1 α acids content in % air-dry by weight acc. to EBC 7.4

Eigenschaften	Hallert. Magnum*	Herkules*	Polaris*	Sämling 2010/75/764	Sämling 2010/80/728	Sämling 2011/71/19
Pflanzjahr	1998	2001	2012	März 2014	Juni 2015	Juni 2015
α-Säuren (%)[1]	14,5	13,7	17,0	13,0 (9,8 -19,5)	19,0 (19,9 – 25,9)	17,2 (18 – 21,2)
Aroma-einschätzung	angenehm	angenehm	angenehm, Spezialaroma	angenehm	mittel	angenehm
Ertrags-leistung (kg/ha)	2.827	2.502	2.436	3.072	2.252	2273
kg α / ha	410	343	414	399	428	391
Stock-gesundheit	robust	gering	gut – sehr gut	mittel - gut	gut (Hüll)	gut (Hüll)
Agronom. Einschätzung	starke Belaubung, geringer Behang	Ertrags-potential reduziert wegen Stockfäule	robust, mittlere – schwache Windefähigkeit	kopfbetont, wuchtig, α-Säuren sehr schwankend	geringe Behangstärke, begrenztes Ertragspotential, volle Mt-Res	guter Habitus, hohes Ertragspotential, gute Mt-Res

No real comparisons can be drawn as regards yield for the two lines 2010/80/728 and 2011/71/19 in 2016, which were not planted until the end of June 2015. This is because there were gaps in the crops which had to be filled with 20 new plants, which meant that the plots were still heterogeneous at harvest. The high alpha line 2014/75/764, planted in 2014, produced highly encouraging yield results and alpha acids levels in the year of planting, but the harvest output in the two years following was disappointing. The crop appeared to be less homogeneous, and alpha acids levels fluctuated considerably.

Outlook

It will only be possible to make reliable observations about the lines involved in the row planting trials when each trial has run for five years with each breeding line. The first fact-based information on new and highly promising breeding lines from the crossbreeding programme will not be available until after the 3-year seedling assessment in the Hüll breeding yard, i.e. in 2020/2021 at the earliest.

4.6 Studies and Research Concerned with the Problem of *Verticillium* in Hop

Objective

Hop wilt disease, caused by the soil-borne fungi *Verticillium albo-atrum (= nonalfalfae)* and, more rarely, *Verticillium dahliae,* is a major issue at present which concerns both hop growers and hop research. Since 2005, hops found with symptoms of wilt have been on the increase in commercial hop cultivation in the Hallertau. Even cultivars rated as wilt-tolerant, such as *Northern Brewer* and *Perle* have been affected. Examination of the virulence of the *Verticillium* strains found in the Hallertau, using artificial infection tests and, above all, molecular genetic methods (Seefelder et al., 2009), has delivered evidence that not only mild, but also aggressive, *Verticillium* species (termed 'progressive' in the relevant literature in English) are now at large in Germany. Although the Hüll breeding lines are able to tolerate mild strains of wilt fungus, these highly aggressive forms lead to complete wilting and death of the plant, and even to root death (the reason why the strains are often termed 'lethal'), in all cultivars available from Hüll.

Since there are no plant protection agents available to combat *Verticillium*, other methods need to be investigated and put into practice. Strict implementation of phystosanitary measures (see *Green Pamphlet*) includes the use of healthy *Verticillium*-free root cuttings. Reliable methods of detecting wilt fungus, derived from hop, such as that developed by Maurer et al., 2013 are essential to be able to guarantee that *Verticillium*-free base material from the *Verticillium*-infested breeding yard at Hüll can be used for the LfL's trial sites (breeding yard at Stadelhof) and for on-farm growing trials. It is also imperative that the breeding of wilt-tolerant hops is speeded up.

Method

Verification of *Verticillium*-free hops using phytopathological and molecular techniques

In order to secure Verticillium-free planting materials for the LfL's own growing trials and for the propagators under contract to the GfH (*Society of Hop Research*), hop bines from highly promising breeding lines or from mother plants used for cultivar propagation are examined for evidence of *Verticillium*. The following methods are available in our laboratory; the highly sensitive PCR technique is given top priority because it can detect even the lowest levels of *Verticillium* infection.

- Molecular detection of *Verticillium albo-atrum (= nonalfalfae)* and *V. dahliae* via Real-Time PCR direct from hop bines *(in planta test),* Maurer, Radišek, Berg and Seefelder (2013).

- Molecular detection using PCR with specific primers (Carder et al., 1994; Radišek et al. 2004; Bulletin OEPP/EPPO 2007; Seefelder and Oberhollenzer, unpublished) for verification of Real-Time results and to distinguish mild and lethal species of *Verticillium*.
- Phytopathological method: sections of hop bine are placed on a fungus selection medium. The fungal growth is then examined under the microscope to identify possible infection with *Verticillium albo-atrum (= nonalfalfae*) and *V. dahliae.* Findings were checked and substantiated in part using the PCR technique.

Results

Verticillium-free plant material and various lines of research

In 2016 over 1200 hop samples were examined for *Verticillium*. At the beginning of the year, the main focus was on examining lines from the Hüll breeding programme. Subsequently, the detection methods were also used to clarify different approaches to research into *Verticillium*. Thus, artificial inoculation with *Verticillium* of pot plants from the greenhouse was looked into. This was done by Dr. Seefelder with the aim of also establishing a pathogenicity system here at the LfL (cf. Radišek et al., 2003). The Real-Time PCR was also used to test methods of eliminating *Verticillium* from hop planting material.

Infection of Ariana for the first time with a lethal strain of *Verticillium*

It was also possible, using the molecular detection methods available, to find the cause of the symptoms of wilt occurring for the first time in a farm crop in the special flavor cultivar, *Ariana*, which had been introduced as a wilt-tolerant hop in 2016. Its introduction came with the warning that, notwithstanding its resistance to wilt disease, *Ariana* should not be grown in locations that were badly affected by the disease. If a wilt-tolerant hop is grown in wilt-contaminated areas, without the soil having been decontaminated beforehand, this will encourage the development of new and even more aggressive, ‘super-virulent’ strains of *Verticillium* (Talboys, 1987), resulting in a breakdown of resistance in previously wilt-resistant hops. In the first year of agricultural cultivation, on severely wilt-contaminated soil, *Ariana* displayed clear symptoms of wilt, and molecular tests confirmed that it had been infected by lethal forms of *Verticillium*.

Evaluation and optimization of the molecular detection techniques

At the same time, work was done to optimize the Real-Time PCR testing system, with a view to distinguishing mild and lethal forms of *Verticillium albo-atrum* (cf. Guček et al. 2016), using the Multiplex Real-Time PCR approach, and verifying the results through an integrated, so-called internal control to rule out any ‘false negatives’.

Creation of a reference collection for *Verticillium*

Work is proceeding at the moment on building up a new reference collection for *Verticillium*, based on single spore isolates. This involves preserving both mild and lethal *Verticillium* strains (Hüll breeding yard, *Verticillium* screening plots and individual commercial farm plots) 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 bank is also to be available for future lines of research into issues associated with *Verticillium*.

Field selection of hops with resistance/tolerance to *Verticillium*

Breeding hops with tolerance towards mild forms and, primarily, the highly virulent *Verticillium* strains is another significant step towards securing long-term hop production in the Hallertau and in Germany as a whole.

Work on this began in 2012, and a former commercial farm plot contaminated with aggressive strains of Verticillium was planted with 54 breeding lines and cultivars for a field growing trial (8 plants per test block) to test them for tolerance to wilt (Seefelder and Niedermeier, unpublished; Kindsmüller, 2015).

Enlarging on the knowledge gained from this trial, selection involving 29 breeding lines and 6 cultivars (7 plants per block with 3 replications) continued at a different location where infestation by lethal *Verticillium* had been verified. In spite of the extreme weather conditions, it was possible, even in the first year of the trial, to distinguish between wilt-tolerant and highly sensitive lines and cultivars (Fig. 4.7). In 2016, a further five breeding lines and nine cultivars were added for a field comparison with the wilt-resistant cultivar *Wye Target*. In the old test crop in the selection plot contaminated with *Verticillium*, the conclusions arrived at in 2015 were verified and corroborated. Where the newly planted hops were concerned, even in cultivars known from experience to be highly susceptible it was not possible to tell conclusively whether they were tolerant or susceptible because the wilt symptoms were less clearly recognizable.

Obviously, the facts concerning wilt tolerance in certain breeding lines will need to be verified over several years before a definite assessment can be attempted.

Fig. 4.7: Left-hand photo: testing hop cultivars and breeding lines for tolerance towards Verticillium in a former farm plot with high levels of infestation and verified incidence of a highly virulent Verticillium strain. Ariana bines visible on the left in the background (arrow). Right-hand photo: healthy Ariana plants beside bines of a breeding line susceptible to Verticillium, affected/decimated by wilt diseasestark durch Welke betroffenen/dezimierten Reben eines Verticillium-anfälligen Stammes

Verticillium tolerance – a crucial selection criterion in the development of hop cultivars

Based on the knowledge gained with respect to wilt tolerance in hop breeding lines from the different breeding programmes when they are trialled in the next few years on the two field selection plots, in future resistance to the *Verticillium* fungus, especially to the lethal species, will be an important selection criterion in the development of new hops.

However, every hop grower must know that problems of contamination with *Verticillium* cannot be solved simply by growing a wilt tolerant cultivar in the plot in question. Quite the converse in fact; heightened tolerance in a hop cultivar will eventually lead to the selection of forms of fungus with even more aggressive means of attack from among the *Verticillium* strains already present in the hop yard, creating what are known as super virulent species as a means to secure survival of the fungus.

The fact that Ariana has been infected for the first time with more virulent strains of *Verticillium* (see above), in a commercial plot where there had previously been problems with wilt on the cultivar *Saphir*, points to the selection scenario outlined above and the emergence of super virulent strains.

Outlook

Managing *Verticillium* wilt in the German hop growing regions is a long-term undertaking. Both the research and guidance contributed by the LfL and the implementation of preventive horticultural measures by hop growers are of crucial importance in the concerted effort to combat *Verticillium* in hop cultivation.

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

Background and objective

Again and again, when hops become infected with downy mildew, a condition caused by the fungus *Pseudopersonospora humuli*, growers are confronted with enormous problems. In the rainy summer of 2016, there were increasingly frequent occurrences of infection with downy mildew in hop farming. For decades now, the well-established downy mildew warning service has been helping hop growers in their attempts to target this fungal disease. One of the most effective ways of solving the problem is through breeding efforts, focused on developing hops with markedly improved tolerance towards the fungus. In the interests of early verification of tolerance, every year, thousands of seedlings undergo spraying with a fungal spore solution in the greenhouse and subsequent screening. However, it is not possible during this mass screening process to establish what level of resistance or tolerance individual hops have, so that more details concerning the tolerance of single seedlings or cultivars need to be worked out.

To do this, it will be necessary to create a generally standardized laboratory test system, using detached leaves (detached leaf assay) as an accurate and reliable method of testing whether the hop seedlings are tolerant or susceptible to downy mildew. Only tolerance towards so-called secondary infection is examined in this context, i.e. how vulnerable or resistant the hop is to the zoosporangia of the fungus, which land on the leaves from the outside. When humidity is high, the zoospores hatch out, penetrate the interior of the leaves through the leaf stomata and develop into mycelia. The leaves of susceptible hops then exhibit yellowish (chlorotic) spots which later turn brown (necrosis) – typical symptoms of fungal infection.

Method

The undersides of the leaves of hops with differing tolerance towards downy mildew were sprayed with the solution of peronospora sporangia. Five to fourteen days after inoculation, the reaction of the leaves is visually assessed; the following infection scenario unfolds: when humidity is very high (> 90%), i.e. in practice when it rains, the zoospores (mobile spores) are released 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) were monitored 5 to 7 days after inoculation (dpi) and further assessed up to 14 dpi. The leaves are rated on a scale from 0 to 5, focusing on sporulation: 0 = no symptoms; 1 = 1-10%; 2 = 11-30%; 3 = 31-60%; 4 = 61-80%; 5 = 81-100% of the leaf's surface is affected. The severity of the disease was subsequently determined according to the Townsend-Heuberger disease severity index.

Findings

Work on establishing and optimizing a leaf assay has been in progress since 2012. Taking up 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 towards 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 denoting 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 peronospora 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). Thus it was possible clearly to differentiate between the two reactions.

Fig. 4.8: Detached leaf test for tolerance to downy mildew with optimized procedural parameters

In more tolerant types of hop, either sporulation is suppressed altogether (reaction of cultivar *Hallertauer Tradition* (HT) 12 days after inoculation (dpi) – see Fig. 4.9) or minor necrosis spots appeared on the leaves as a defensive reaction in the early stages of infection (hypersensitive reaction of host cells; *Hüller Bitterer* (HB) 6 dpi – Fig. 4.9). In more susceptible/less tolerant hops, chlorotic marks appeared on the leaves only a few days after inoculation, with distinct sporulation on the leaf undersides (Hallertau Blanc (HC) – Fig. 4.9. At a later stage, these develop into dark brown necrosis spots.

Fig. 4.9: Different reaction of hop leaves from cultivars Hallertau Blanc (HC), Hüller Bitterer (HB) and Hallertauer Tradition (HT) 6 and 12 days after inoculation with downy mildew

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

Outlook

Cultivars and breeding lines will be examined with the help of this downy mildew leaf assay in the coming season. It will be essential to make sure that the tolerance/susceptibility towards secondary downy mildew infections found in a hop by means of the leaf assay in the laboratory correlates to the tolerance/susceptibility it exhibits in the field.

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4.8 Meristem Culture to Produce Healthy Plant Material

Objective

Viruses, viroids and *Verticillium* can cause devastating yield losses and harm to quality, but these diseases cannot be controlled by means of plant protection agents. Obviously, a biotechnological means of managing the conditions then takes on greater importance. The method known as meristem culture makes it possible to produce healthy, virus-free plants by regenerating plantlets from the growth zone of shoots taken from virus-infected hops, after first subjecting them to heat treatment.

Until now, this process of eliminating viruses, from preparation of the meristem, to cloning of the regenerated plants, through to virus screening, has always taken between 6 and 10 months. The intention is to accelerate the process and explore new ways of eliminating further hop pathogens, such as viroids and *Verticillium*.

Method

In order to produce virus-free hop plants, the uppermost growth zone (= meristem) at the very tip of the shoot is first heat-treated, then cut out and prepared. The meristems obtained in this way then regenerate complete plants on special culture media.

To ascertain whether the the hop plants developed from the meristems are free of viruses, the IPS 2c WG Virus Diagnostics examines the leaves for signs of the various viruses typical in hop, employing the DAS-ELISA technique (Double Antibody Sandwich Enzyme Linked Immunosorbent Assay) or an RT-PCR test (Reverse Transcriptase Polymerase Chain Reaction). As a general rule, the cheaper ELISA detection method is used when testing for hop mosaic carlavirus (HpMV) and apple mosaic ilarvirus (ApMV). The molecular technique is deployed only in testing for American hop latent carlavirus (AhpLV), hop latent virus (HpLV), hop stunt viroid (HpSVd), and hop latent viroid (HpLVD), or in cases where only very little *in vitro* starting material is available.

Results

The first step – development of the cut and prepared meristem into a small shoot – takes only a relatively short time, but the subsequent steps – further shoot growth and stages of cloning onto a solid medium – mean that eliminating a virus is a time-consuming process, with a timescale of up to ten months. With a view to speeding up the whole process, different parameters for culture production were examined and then optimized. Use of a fluid culture system meant that the time needed from preparation of the meristem to regeneration and cloning of the plantlet could be shortened to 3.5 -5 months, as against the 6-10 months needed with cultures on a solid medium. At the same time, the dependence on genotype of the capacity to regenerate was improved. Moreover, meristem culture produced stronger plants.

Outlook

Work on further optimizing the regeneration of meristems continues, the main aim being to improve the efficiency of meristem culture in eliminating pathogens.

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5 Hop Farming, Technical Aspects of Production

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5.1 Nmin Audit 2016

The use of nitrogen fertilizers in compliance with DSN (Nmin) is an established part of fertilization management on commercially run hop farms. In 2016, about half of the total number of hop farms in the Bavarian hop growing regions Hallertau and Spalt took part in the DSN audit, in the course of which, 2 797 hop yards were tested for Nmin levels, and a fertilization recommendation drawn up.

The graph below is a compilation showing the development of the number of samples taken for the purposes of the Nmin audit. The average Nmin concentration of 80 kg N/ha in the Bavarian hop yards in 2016 was significantly higher than the previous year's figure (65 kg N/ha). This is probably down to the lower levels of depletion in the previous year, and the warm winter with little precipitation, during which there was hardly any transfer and leaching of nitrogen from the soil. The average fertilization recommendation of 152 kg N/ha for the Bavarian hop yards, based on the Nmin value, was consequently lower than in the previous year.

As every year, there were again considerable fluctuations from farm to farm and, within the farms, from yard to yard, and from variety to variety. It therefore makes sense to continue running individual checks to determine the optimal application recommendation for each farm.

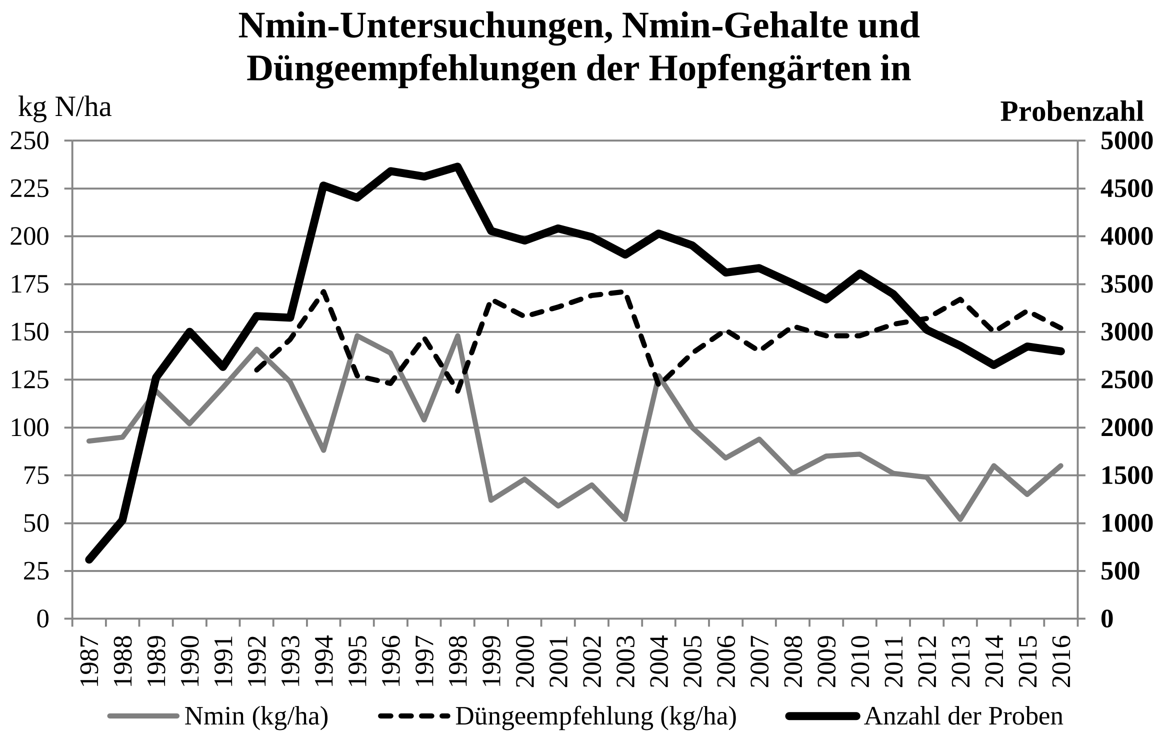


Fig. 5.1: Nmin audits, Nmin levels and recommended amounts of fertilizer application in the Bavarian hop yards over the years

The next chart shows the number of hop yards audited in the Bavarian hop producing regions, by rural administrative district, along with the average Nmin value and the average nitrogen fertilization recommendation calculated accordingly. Findings in the different rural districts and regions in Bavaria show a clear north-south divide.

The highest Nmin values are found in the rural district of Eichstätt (Jura), followed by the hop producing regions Hersbruck and Spalt in Franconia. In the Hallertau, the average Nmin values hardly differ from district to district, only the Landshut rural administrative district stands out with a slightly higher Nmin value.

Tab. 5.1: Number of samples, average Nmin levels, and fertilizer recommendations in hop yards by rural district /region in Bavaria, 2016

Rural district/ growing region	**Number of samples**	**Nmin kg N/ha**	**Fertilizer recommendation kg N/ha**
Eichstätt (exluding Kinding)	211	110	134
Hersbruck	49	98	127
Spalt (excluding Kinding)	96	95	127
Landshut	160	85	146
Kelheim	1044	77	155
Pfaffenhofen	928	76	156
Eichstätt (Kinding)	30	75	146
Freising	277	74	158
Neuburg-Schrobenhausen	2	57	158
Bavaria	**2797**	**80**	**152**

The following table lists values by cultivar and fertilizer recommendation.

Tab. 5.2: Number of samples, average Nmin levels, and fertilizer recommendation for hop cultivars in Bavaria in 2016

Cultivar	**Number of samples**	**Nmin kg N/ha**	**Fertilizer recommendation kg N/ha**
Nugget	20	57	170
Herkules	672	71	170
Mandarina Bavaria	47	67	163
Opal	29	64	158
Hall. Magnum	265	75	157
Huell Melon	22	73	157
Cascade	10	75	154
Hall. Taurus	70	82	153
Hallertau Blanc	25	80	153
Perle	534	84	146
Hersbrucker Spät	171	86	145
Hall. Tradition	504	88	144
Spalter Select	104	87	142
Saphir	75	96	137
Hallertauer Mfr.	130	76	137
Northern Brewer	28	103	135
Spalter	53	87	125
Sonstige	38	85	145
Bavaria	**2797**	**80**	**152**

5.2 Optimization of Irrigation Management in Hop Cultivation (ID 4273)

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding)*
Funding:	Dt. Bundesstiftung Umwelt *(Federal Foundation for the Environment)* und Erzeugergemeinschaft HVG e.G. *(HVG Hop Producer Group)*
Project lead:	Dr. M. Beck
Project staff:	T. Graf
Collaboration:	Dr. M. Beck, Weihenstephan-Triesdorf University Prof. Urs Schmidhalter, TU München, Weihenstephan
Scheduled to run:	01.12.2011 – 31.12.2015

Hop yields fluctuate greatly from year to year owing to variations in weather conditions, thus putting at risk the security of supply that the brewing industry needs. For this reason, irrigation systems have, in the past, become established on about 15-20% of the hop growing acreage, although this development is constrained by the amount of water that is available. In this context, questions have also arisen as to how far irrigation in hop production makes economic and ecological sense.

The aim of the project was to develop a system of irrigation management for hop which will help to stabilize crop yields in spite of scarce water resources, while taking the economic aspects into account.

The key practice-relevant issues to be resolved:

- positioning of the drip hoses
- most suitable time to irrigate and quantities to use
- means of controlling irrigation

Details and results of the trials were compiled as part of a dissertation entitled *Tröpfchenbewässerung im Hopfenbau – Feldversuche, Physiologie und Rhizosphäre (Drip Irrigation in Hop Growing – Field Trials, Physiology and Rhizosphere)* and published in December 2016. To read, go to https://mediatum.ub.tum.de/1304504.

5.3 Reaction of Cultivars *Perle*, *Polaris* and *Herkules* to a Reduction in Trellis Height (6 mtrs)

Project staff:	S. Fuß, A. Lutz
Scheduled to run:	2012 – 2016

Objective

In the wake of devastating storms in the last few years, which caused hop trellis systems in the Hallertau to collapse prior to harvest, this research aims to establish whether the trellis systems can be reduced to a height of 6 metres without affecting yields. According to calculations and estimations carried out by an engineering office, the static load would then be reduced by approx. 15-20% and the stability of the trellis system would be greatly improved in gale-force winds.

Trellis costs could also be reduced through the utilization of shorter and weaker central poles, without adversely affecting the static equilibrium. Another benefit would be improved plant protection, since the application target at the top of the plants would be more easily accessible for spraying, there would be less drift, and new application techniques could be deployed.

In projects already completed, aroma hops *Perle* and *Hallertauer Tradition* and bittering varieties *Hallertauer Magnum*, *Hallertauer Taurus* and *Herkules* were tested in several commercial hop yards for their reactions with respect to plant infection, pest infestation, yield and quality, when trellises were lowered. The findings were published in the Annual Report for 2011. Results for *Hallertauer Tradition* from another research site near Pfeffenhausen were published in 2014. Further trials were conducted at the Stadelhof research yard and completed in 2016, with the aim of drawing up general recommendations for commercial practice.

Method

Considerations in choosing all trial locations were concentrated on meticulously scrutinizing both plots and soils to make sure that starting conditions were the same for all variants. A subsection of the Stadelhof research yard was divided into two plots of equal size, equivalent in width to the distance between two poles. In one of the plots, the trellis system was lowered from a height of 7 metres to 6 metres, by inserting additional wire netting. Three hop cultivars *Perle, Polaris* and *Herkules* were then planted in the plots in such a way that each cultivar could be harvested in 8 replications. In consultation with the staff of the research yard, the test plots were managed in same way as in agricultural practice. This guaranteed that plant protection measures, fertilization and soil cultivation operations were the same in all plots.und die BodenProject staff in allen Parzellen in gleicher Weise durchgeführt.

Fig. 5.2: A 7 metre trellis system reduced to a height of 6 metres using wire netting

Yield, alpha acids content, and moisture content of the green cones harvested from the test plots were determined. In the years of testing, the cone samples were examined for cone development and incidence of disease.

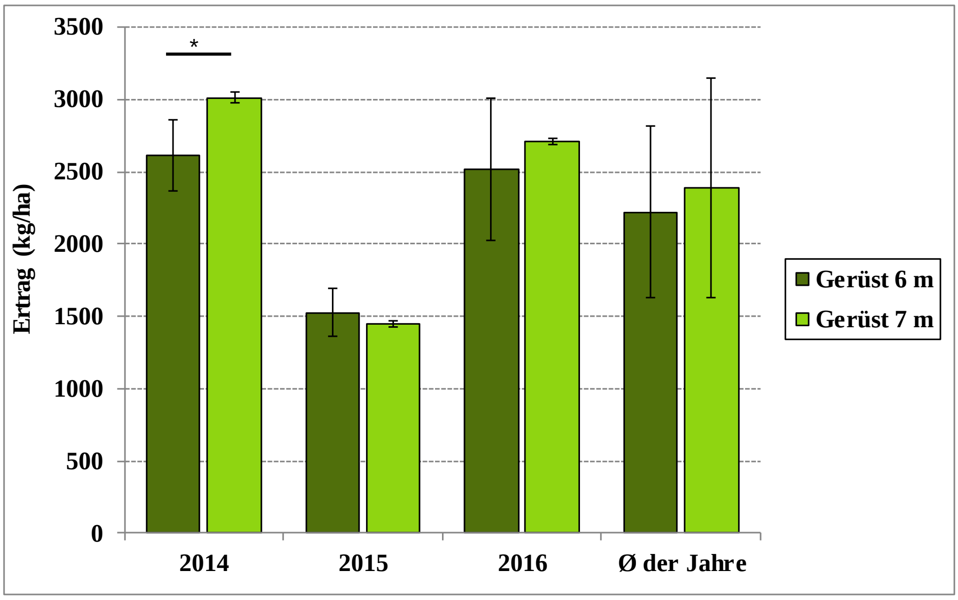


Fig. 5.3: Impact of trellis height on yield from Perle

Yield (kg/ha), with standard deviation, from aroma variety Perle (n = 24); 6 mtr and 7 mtr trellis heights compared. Intraspecific testing of significant differences in yields using multifactorial analysis of variance, and identification (p<0.05, p<0.01** and p<0.001***).*

At the Stadelhof site in the trial with *Perle*, the variants at 6 metres and 7 metres produced significant differences in yield in 2014 only. In the extremely hot and dry year, 2015, it was *Perle* especially that suffered very badly as a consequence, with the result, that yield was no higher from the 7 metre trellis. In 2016, and, on average over the years, the 7 metre system tended to produce higher yields, although this cannot be substantiated by statistics.

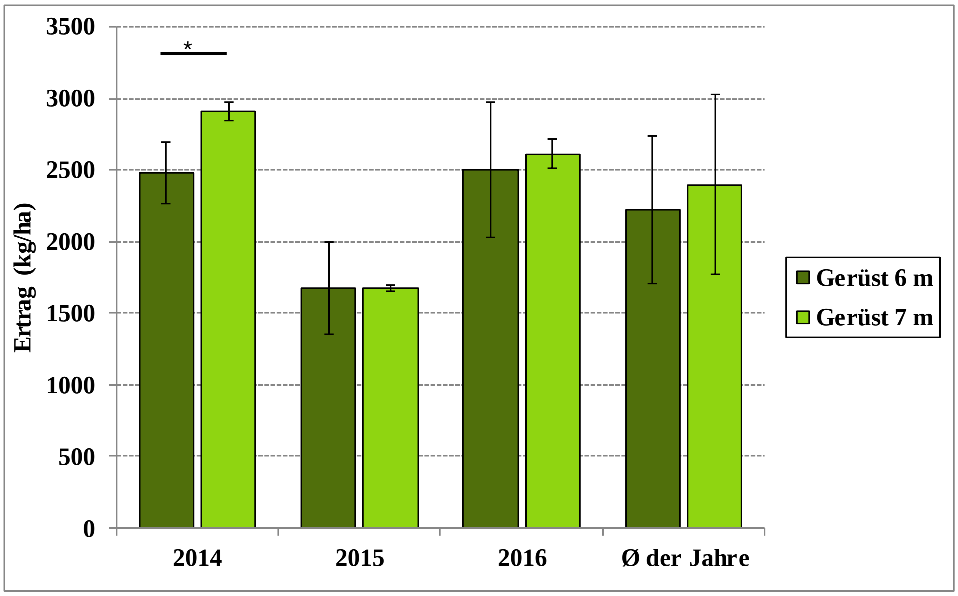


Fig. 5.4: Impact of trellis height on yield from Polaris

Yield (kg/ha), with standard deviation, from high alpha variety Polaris (n = 24); 6 mtr and 7 mtr trellis heights compared. Intraspecific testing of significant differences in yield using multifactorial analysis of variance, and identification (p<0.05, p<0.01** and p<0.001***).*

Yields from *Polaris* were almost the same as those from *Perle*. A similar tendency towards higher yields was found here, too, but this could only be partially upheld by statistical evidence.

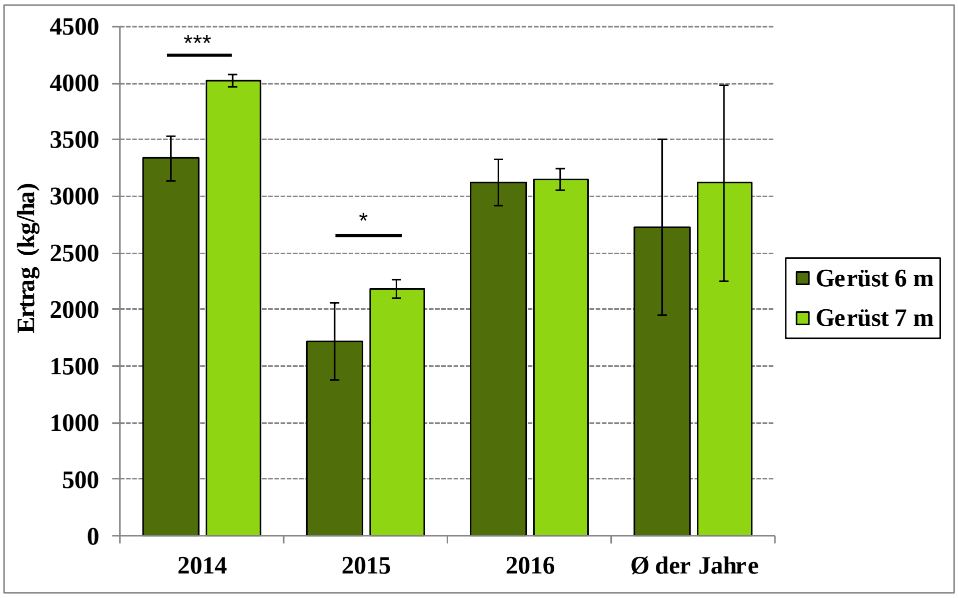


Fig. 5.5: Impact of trellis height on yield from Herkules

Yield (kg/ha), with standard deviation, from high alpha variety Herkules (n = 24); 6 mtr and 7 mtr trellis heights compared. Intraspecific testing of significant differences in yield using multi-factorial analysis of variance, and identification (p<0.05, p<0.01** and p<0.001***).*

In the case of *Herkules* there is statistical evidence to show that yields were higher in 2014 and 2015, at a trellis height of 7 metres. However, it was found that, contrary to expectations, yields from the 7 metre trellis were not higher in 2016. This could be put down to the fact that fertilizer levels in the research yard are relatively low, preventing yield reaching maximum levels in the 7 metre system.

The tendency towards higher yields differed greatly from cultivar to cultivar, but this could not always be substantiated by statistics.

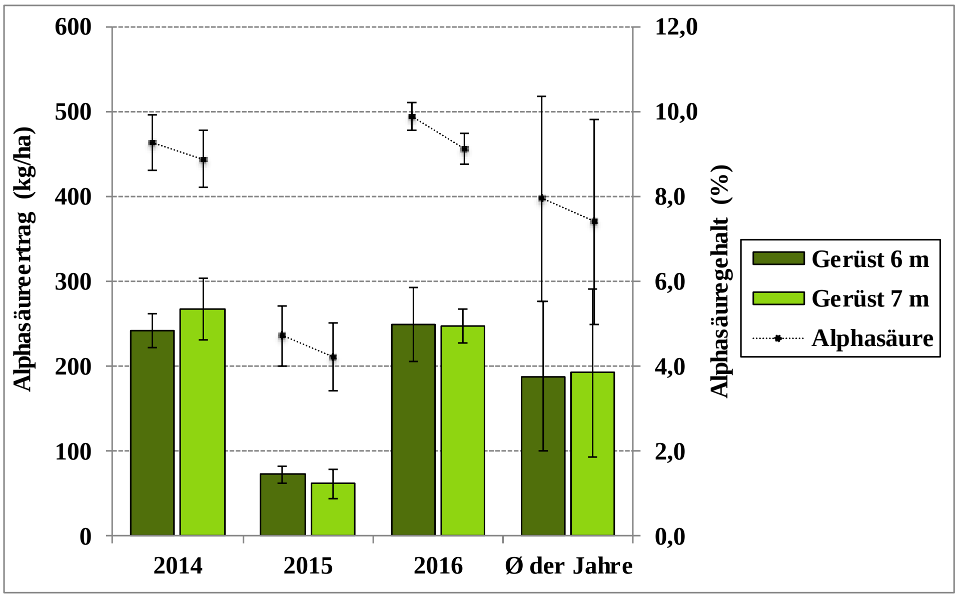


Fig. 5.6: Impact of trellis height on alpha acids yield and content from Perle

Alpha acids content (%) and alpha acids yield (kg/ha) from aroma variety Perle (n = 24); 6 mtr and 7 mtr trellis heights compared. Intraspecific testing of significant differences in alpha acids yield and content, using multifactorial analysis of variance, and identification (p<0.05, p<0.01** and p<0.001***).*

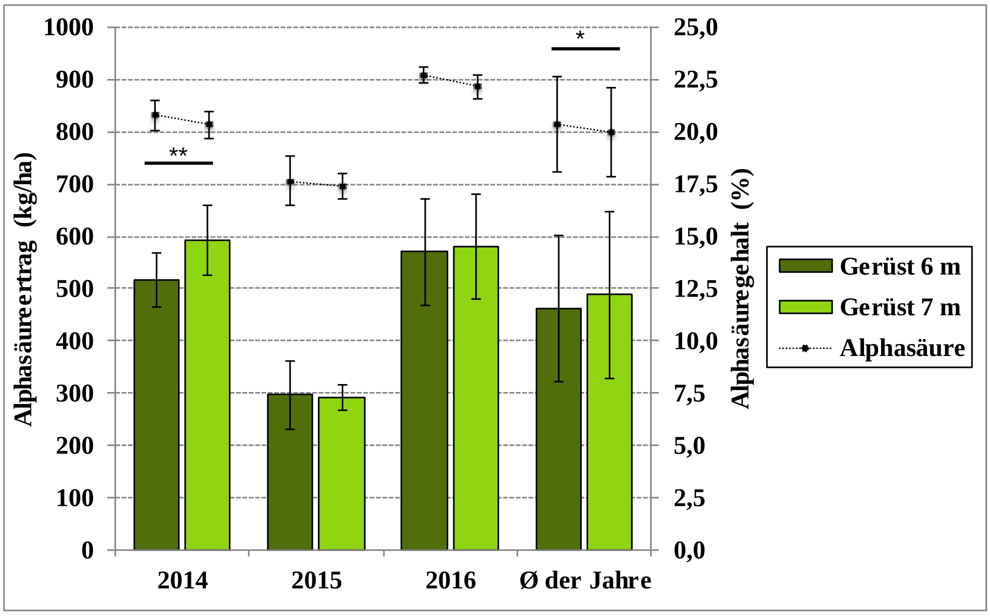


Fig. 5.7: Impact of trellis height on alpha acids yield and content from Polaris

Alpha acids content (%) and alpha acids yield (kg/ha) from high alpha variety Polaris (n = 24); 6 mtr and 7 mtr trellis heights compared. Intraspecific testing of significant differences in alpha acids content and yield, using multifactorial analysis of variance, and identification (p<0.05, p<0.01** and p<0.001***).*

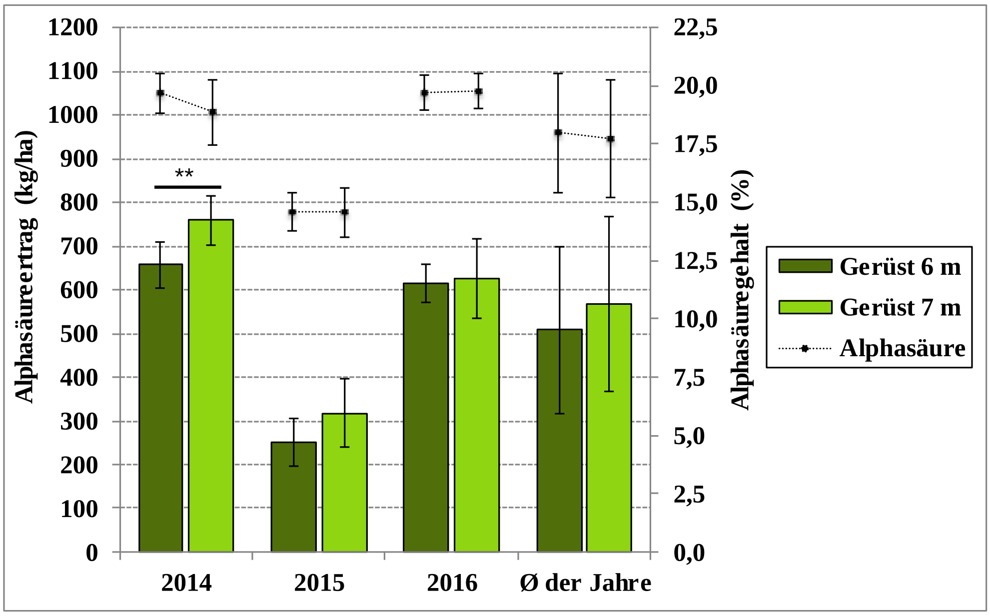


Fig. 5.8: Impact of trellis height on alpha acids yield and content from Herkules

Alpha acids content (%) and alpha acids yield (kg/ha) from high alpha variety Herkules (n = 24); 6 mtr and 7 mtr trellis heights compared. Intraspecific testing of significant differences in alpha acids yield and content, using multifactorial analysis of variance, and identification (p<0.05, p<0.01** and p<0.001***).*

The minor differences in alpha acids content for all varieties were negligible. Only in 2014 is there statistical evidence of higher alpha acids yields in the 7 metre system with *Herkules* and *Polaris*. Due to the fluctuating yields and differences in results from alpha acids analyses from replication to replication within a variant, no statistical differences from variant to variant could be established, since the divergence within the variants is too great.

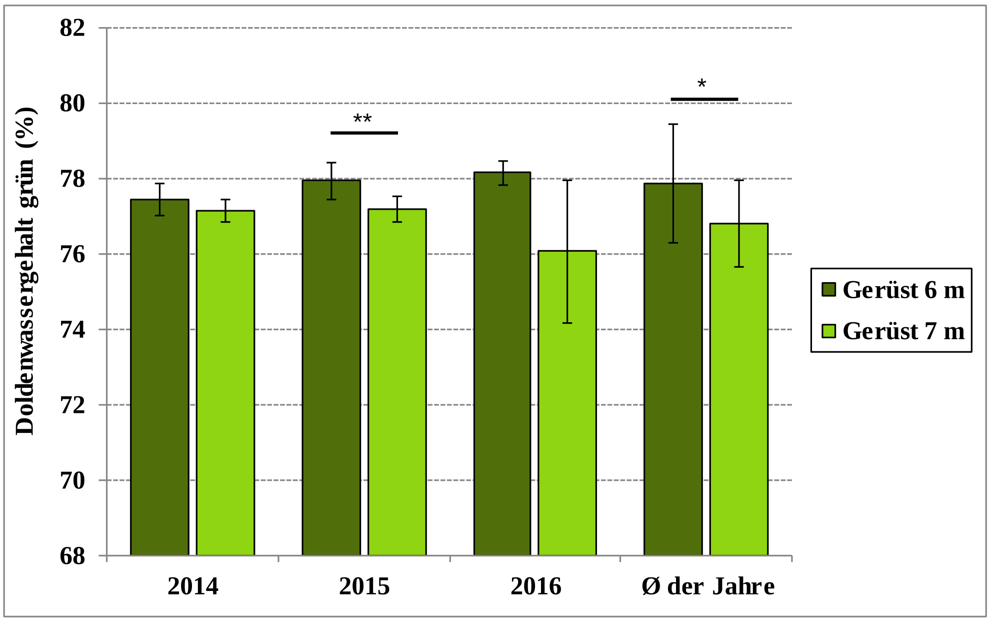


Fig. 5.9: Impact of trellis height on cone moisture content on same harvest date in Perle

Cone moisture content - green (%) in aroma variety Perle (n = 24); 6 mtr and 7 mtr trellis heights compared. Intraspecific testing of significant differences in cone moisture content using multifactorial analysis of variance, and identification (p<0.05, p<0.01** and p<0.001***).*

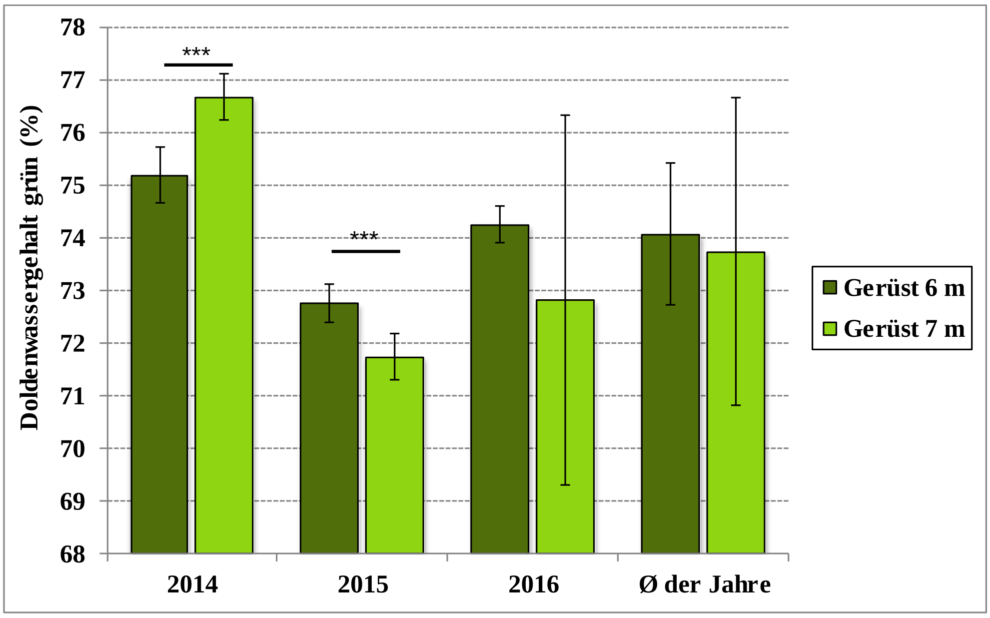


Fig. 5.10: Impact of trellis height on cone moisture content on same harvest date in Polaris

Cone moisture content - green (%) in high alpha variety Polaris (n = 24); 6 mtr and 7 mtr trellis heights compared. Intraspecific testing of significant differences in cone moisture content, using multifactorial analysis of variance, and identification (p<0.05, p<0.01** and p<0.001***).*

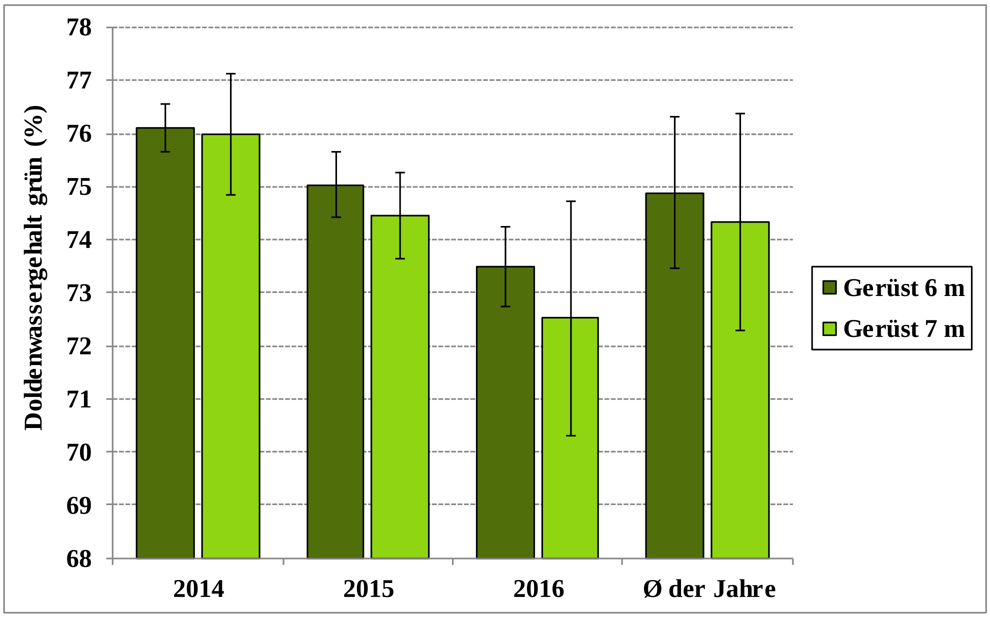


Fig. 5.11: Impact of trellis height on cone moisture content on same harvest date in Herkules

Cone moisture content - green (%) in high alpha variety Herkules (n = 24); 6 mtr and 7 mtr trellis heights compared. Intraspecific testing of significant differences in cone moisture content, using multifactorial analysis of variance, and identification (p<0.05, p<0.01** and p<0.001***).*

Reducing the trellis height to 6 metres resulted in a higher moisture content measured in the green cones in all the hop varieties, in almost all years of testing and on average for the years of testing, with the exception of the result measured in *Polaris* in 2014. However, in this particular case an error in the analysis cannot be ruled out. On the whole, the charts confirm the results from the previous trials which point to the conclusion that optimum harvest maturity is reached at a later date in the 6 metre systems. It is, therefore, to be recommended for agricultural practice that healthy crops of the same variety in the 6 metre systems should be harvested last.

As far as evaluations and assessments of the cone samples with regard to cone development and incidence of disease go, for all cultivars and all years no differences could be discerned between the trellis heights.

The findings so far should be taken into account when setting up hop yards in locations with very good yields, since optimum yield potential can only be realized in the 7 metre systems. However, when establishing new trellis systems in locations exposed to gale-force winds, and especially on sites producing lower yields, the greater stability of the lower trellises can make up for the disadvantage of any potential yield losses.

5.4 Testing an Alternative Method of Training Hops on the Two Varieties *Perle* and *Herkules* While Looking into Self-training, Plant Growth, Yield and Quality

Project lead: J. Portner

Project staff: R. Obster (bachelor thesis)

Collaboration: M. Huber, T. Goldbrunner (Moser Company)

Duration: 2016

Objective

The cultivation of hop as a speciality crop is one of the most labour-intensive agricultural practices, and every now and then efforts should be made to explore whether it might be possible to lighten the burden where certain individual stages of production are concerned, or even to do away with them altogether. This thinking was the subject of a bachelor thesis realized in collaboration with the Hochschule Weihenstephan-Triesdorf, which examined whether the time requirement for the most time-consuming jobs in hop growing, namely training and stripping the hop shoots, could perhaps be reduced or even eliminated by devising an alternative to the present system. The idea was to profit from the merits of a low-trellis system, the principal advantage of which is self-training, by transposing them to a high-trellis system. To do this, designated strips which utilized an alternative system (a wall of foliage) were integrated into a typical 7 metre trellis system, and then compared with a traditional training system (V-shaped training wire). This took place in randomized blocks at a location where *Perle* and *Herkules* are grown, the two most important hop types in terms of acreage. The aim was not only to test whether self-training could be successful, but also to find out what impact this system would have on yield performance, plant growth, and quality.

Fig. 5.12: The alternative training system in Perle at the beginning of August

Method

The soil at the testing site, near the commune of Volkenschwand, was homogeneous silty loam; the site covered an area of 4.14 hectares and was planted to hops of the type *Perle* (2 hectares) and *Herkules* (2.14 hectares). In each of these two cultivars, four trial strips using the traditional V-shaped training system, and four strips using the alternative system were set up (each in replicates).

To make sure that testing took place under real world conditions, the individual strips consisted of three rows each, but only the hops harvested from the central hill (Bifang) were used for the tests. Each strip was equivalent in length to the distance between two poles and contained 14 hop plants.

For the purposes of the trial using the alternative system, a few minor alterations to the trellis system were necessary, as the plants needed to climb up a vertical string arranged in a kind of web. However, also with this trial system, there were only two strings per plant, so that a kind of V-shape, but turned by 90°, was formed. The training string was affixed near the plant to a wire running about 45-50 cm above the cutting level. From there, the string, which was endless, was taken upwards to the barbed wire, threaded into a metal hook there and then passed down again where it changed direction once more to create a narrow V-pattern of training string along the row.

Fig. 5.13: Attaching the strings to the trellis in the alternative training system

In the conventionally managed strips, standard training of three shoots to each climbing wire was done at the time usual for this operation (Tab. 5.3). In the strips using the alternative system, no training was done initially because the shoots were expected to grow towards the climbing elements of their own accord, without help. However, it soon became clear that the distance between the ground and the bottom of the training string was too high, and self-training was not possible in either hop type. Consequently, the shoots had to be trained by hand, in the same way as with the traditional method, in order to close any gaps in the crop and prevent major yield losses. It was only possible to do this several days after the training work in the conventional strips, to allow the shoots to grow long enough to be wound round the training string, the bottom end of which was approximately 48 cm off the ground.

Tab. 5.3: Training dates for the two hop varieties using the different systems

	Herkules	Perle
V-type training method	12.05.2016	06.05.2016
Alternative training method	17.05.2016	17.05.2016

Results were collected by measuring the height of the developing crop every week, and also via various assessments and targeted harvesting. To establish yield, the middle row of each strip in 4 replicates was harvested and the green weight determined.

In order to calculate the dry hop weight and determine alpha acids content, a sample was taken from each replicate and then dried and analysed at Hüll. The cone volume was also ascertained by counting exactly 500 dry cones per strip and establishing their volume using a measuring beaker.

Result

As already explained, the self-training project failed because it was found that the average gap of 48 cm between the level of the shoots and the bottom wire was too big. Most of the shoots lost their stability and flopped sideways before they were able to reach the string (Fig. 5.14).

Fig. 5.14: Perle plants as part of the alternative training system just before the stripping and training stage, 17.05.2016

Focused on creating the best starting conditions for the alternative training system, the decision was taken, in spite of this setback, to abandon self-training and to attach the shoots to the string in the same way as in the traditional system. The original plan had been to reduce the amount of training work needed for the alternative variants, but this did not happen. In fact, the opposite was the result; on average, an increase of more than 15% in the hours of work required was recorded, as against the traditional system. The reason was that the shoots could only be trained after they had reached a certain height, but, by the time they actually reached the required height, many shoots had become tangled up with other shoots, or they were still too short to wind round the string. They then had to be very carefully wound round other shoots that had already been trained round the string. This required quite a bit of dexterity and slowed the speed of the training operation as a result.

The time recorded for the job of setting up the training elements showed that attaching the training string did not take any longer than installing and affixing the wire for the traditional system. If the alternative system could be perfected, and self-training could be made to work, it could save hop planters a lot of time every spring. However, success in that quarter would only be relevant if the system proved to measure up to the conventional system in terms of yield and hop quality.

This explains why the trial continued even after self-training failed; results for the alternative training system with respect to yield and quality etc. were still needed.

In the case of *Herkules*, there was hardly any discernible divergence between the two systems with respect to the way that the plants developed (Fig. 5.15). With *Perle*, on the other hand, growth in the strips using the alternative training method lagged behind that in the conventional strips up until the end of July (Fig. 5.16), probably because it was not possible to carry out training until 11 days later than in the conventional strips. As a consequence, the hop plant expended a great deal of energy on maintaining a large number of shoots. In addition, there was no help with climbing available for quite some time – something that would have had a positive impact on growth. With *Herkules*, the difference between the training dates was about half that number of days and, here, the divergence was minimal to hardly noticeable.

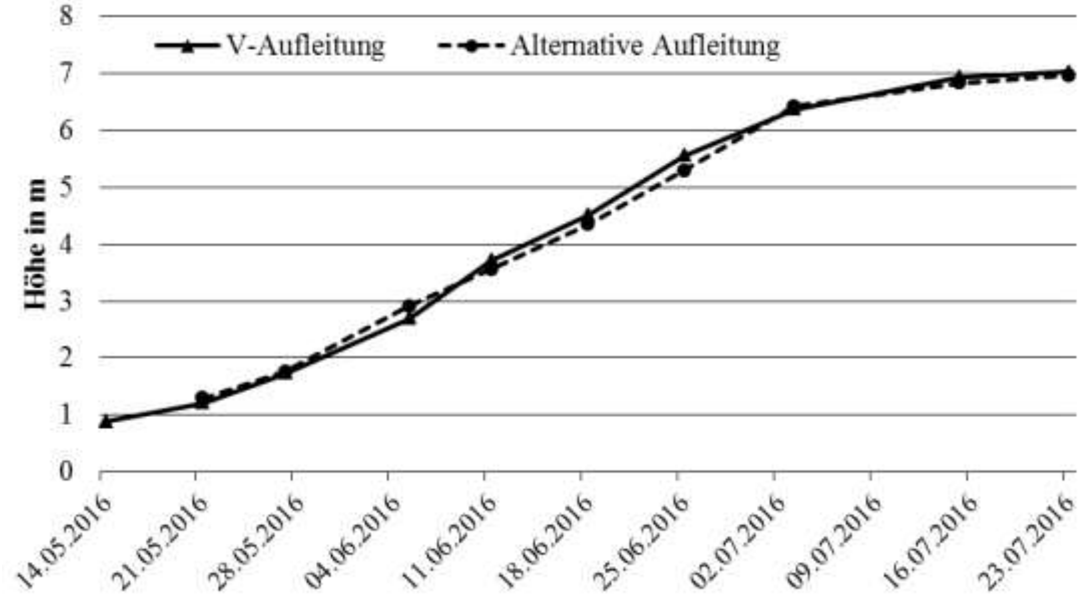


Fig. 5.15: Herkules - growth pattern of hop plants showing the two different training systems

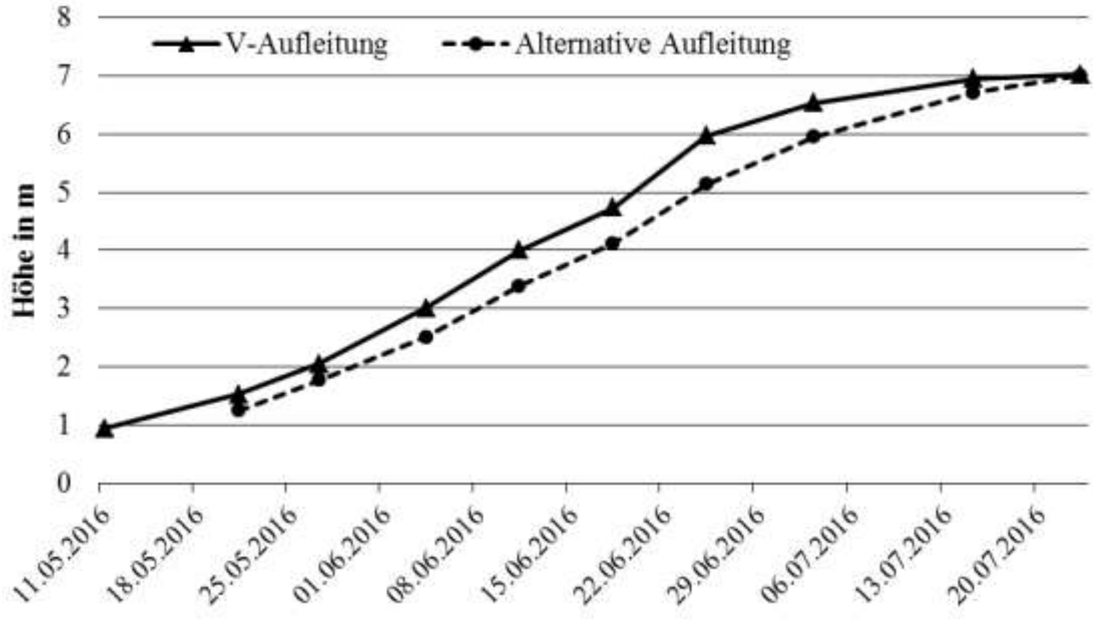


Fig. 5.16: Perle - growth pattern of hop plants showing the two different training systems

The question is: did the divergence in plant growth later affect yield performance? The results for *Perle* using the alternative training system were indeed significantly lower, with respect to both yield (kg/ per hectare) and alpha acids levels (kg/per hectare), than those from the V-type system. In contrast, in the high alpha type hop *Herkules*, the differences in cone yield and bitter compounds yield were far smaller. Thus, the big yield differentials from the trial in *Perle* could be put down, at least in some measure, to the delayed training in the alternative system.

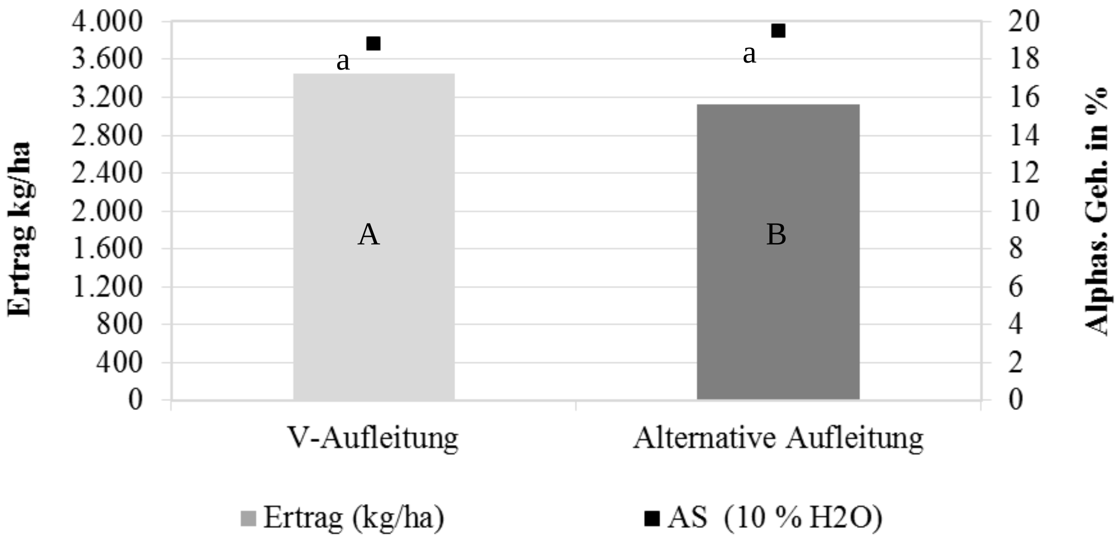


Fig. 5.17: Herkules - yields and alpha acids content according to training system

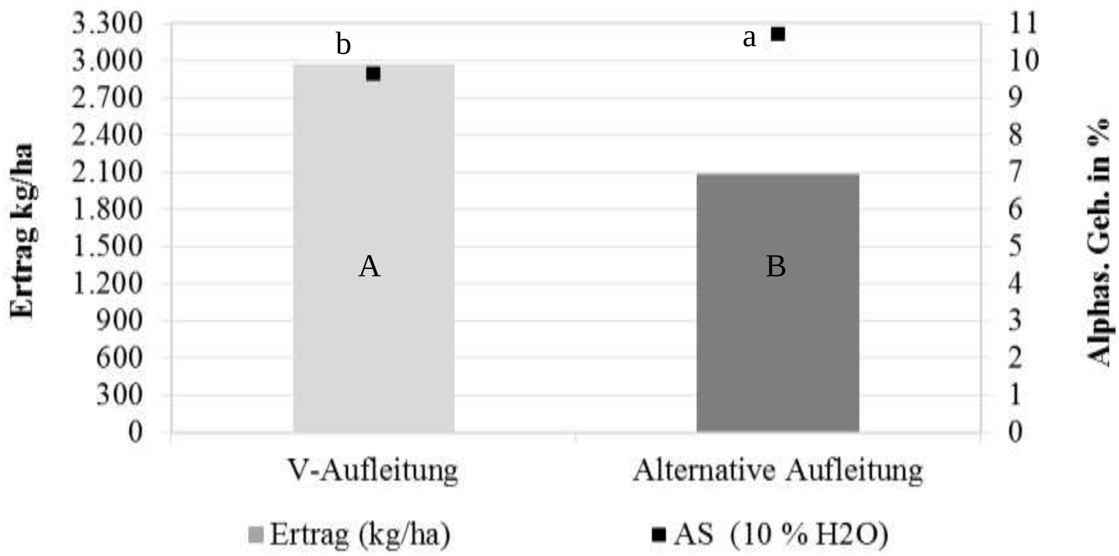


Fig. 5.18: Perle – yields and alpha acids content according to training system

The poor yield for the alternative system with aroma hop *Perle* was mirrored in the cone volume measured (Fig. 5.19). The cone volume was much greater in the alternative system. The theory is that when the plant bears fewer cones (yield), the cones are naturally always bigger, therefore, the smaller number of cone clusters in the aroma hop led in the alternative system to a 30% greater cone volume than in the conventional system. In the case of Herkules, however, no difference in cone volumes could be detected between the two systems.

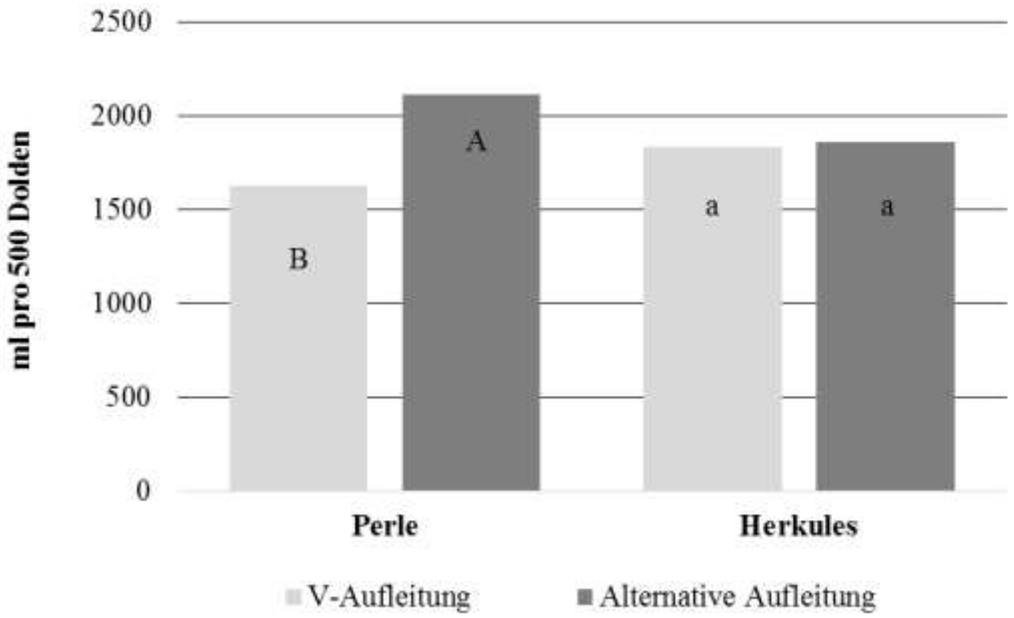


Fig. 5.19: Cone volume per 500 cones of both varieties according to training system

As far as alpha acids content goes, the values for both cultivars tended to be lower with the V-type training method than with the alternative version. The reason for this is unclear. It is possible that a higher yield has some kind of diluting effect.

Outlook

Training systems offering an alternative to the traditional high-trellis V-type system can only be viewed as promising if they can deliver a reduction in costs or benefits to labour management economics, a precondition being that any advantages are not cancelled out by reduced yields or lower market profits.

It was not possible to achieve either of these goals with this trial. Cost savings in future would only be feasible, if the training elements were cheaper than the metal wire, or easier to install. It is conceivable that training netting designed to remain in the field, similar to the trelliswork used with low-level trellises, could be used. Hop cultivation in which the bines grow together to form a kind of wall of foliage would pose entirely new technical challenges, for example, with regard to plant protection and harvesting. It is difficult to imagine that suitable solutions can be found at present.

From the perspective of labour management economics, it would be a big improvement if the hop shoots could be persuaded to train themselves up the training support and would mean that the hours of work could be reduced by a quarter. The trial has shown that this can only work if the shoot has just a short way to go to reach the training elements.

However, even if the training elements were lowered in the same way as in low-trellis systems, and self-training then became possible, there would still be further problems.

As soon as the taut wire is positioned lower, new pruning and crowning equipment that is capable of working underneath the wire would be needed. If pruning and crowning were no longer carried out, phytosanitary problems would arise and, in the medium term, the hop plant would be impaired.

Nevertheless, even if we leave aside all these issues plus conversion costs for a moment, the reduced yields from the alternative training system are still not economically viable. In view of this year's test yields and the necessary prerequisites, it must be concluded that there is little prospect of the alternative system tested in this trial becoming established.

5.5 Testing Different Harvest Dates on Flavor Hops *Mandarina Bavaria*, *Hallertau Blanc* und *Polaris*

Project staff: J. Münsterer, Dr. K. Kammhuber, A. Lutz

Duration: 2014 – 2016

Objective

Brewing trials and beer tastings confirm how unique the aromas and flavours of the Hüll special flavor hops are. It stands to reason then that the top priority in producing flavor hops is to achieve the optimum aroma profile which characterizes each variety. Since the timing of the harvest has both a quantitative and a qualitative effect on the aroma profile of a hop, different harvest dates were tested in the above cultivars to establish the best timing for achieving optimum results with respect to individual criteria such as yield, aroma, outward appearance and internal quality.

Method

During the trials involving flavor hops, *Mandarina Bavaria*, *Hallertau Blanc* and *Polaris*, 20 bines in four replications were removed twice weekly from commercial field crops on 5 different harvest dates (T1-T5) and harvested at Hüll. The middle date, T3, corresponded to the recommended beginning of maturity for harvesting in the respective year. Thus, in each case, the first date, T1, was one week earlier, and the last date, T5, one week later than the recommended harvest date. No change was made to the layout of the randomized plots during the 3 years in which they were harvested, since the aim was to demonstrate how far yield and quality were affected if harvest always took place too soon.

Result

The yields were determined for each plot replication on the dates fixed for harvest. In 2014, the first year of the test, no differences in yield were found between early and late harvested hops. In the second year, and in the third year especially, monitoring during the growing season showed that it was easy to tell which plots were those that were harvested early. The bines in these plots were not as well developed, i.e. were much weaker in appearance. In 2015, *Mandarina Bavaria* suffered hail damage, so no yield could be established. Even so, the plots where early harvesting had taken place on the first date, T1, in 2014, were easily distinguishable from the others before the 2016 harvest because of the poorer development of the bines.

The diagram below shows yields in the third year of the trial, 2016. Right up to harvest, reserves are stored in the rootstock. The later harvest takes place and the longer this storage period lasts, the more vigorous the crops become and the greater their yield stability. Early harvest timing led in all cultivars to significant yield losses in the years following.

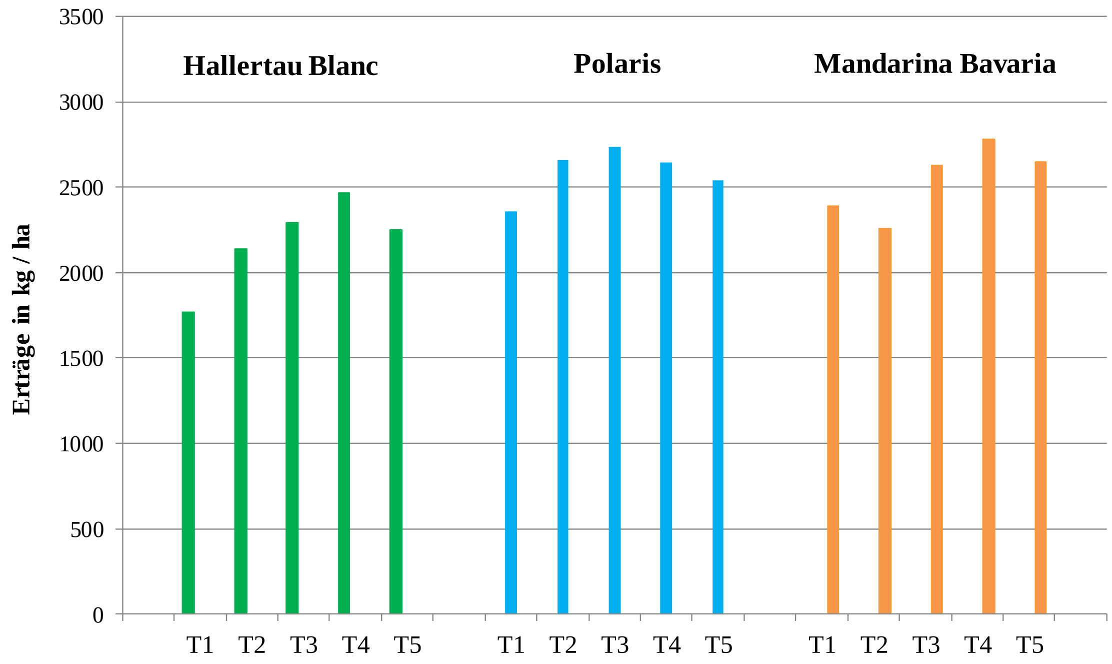


Fig. 5.20: Yields from cultivars Hallertau Blanc, Polaris and Mandarina Bavaria in the third year of the trial, by harvest date

Since the harvest timing in flavor varieties is important primarily for its influence on the aroma active compounds, all hop samples were analysed in the laboratory to determine their total oil content and oil composition. The next graph shows total oil content in *Hallertau Blanc*, *Polaris* and *Mandarina Bavaria* in the test years and clearly illustrates how total oil content increases with advancing maturity of the hop.

Differences in levels of oil content from year to year are also evident. The oil composition also changes, depending on the harvest date; for example, there was a far greater rise in myrcene content than in the other oil components. Harvest timing had a far greater impact on oil content and oil composition than on alpha acids content.

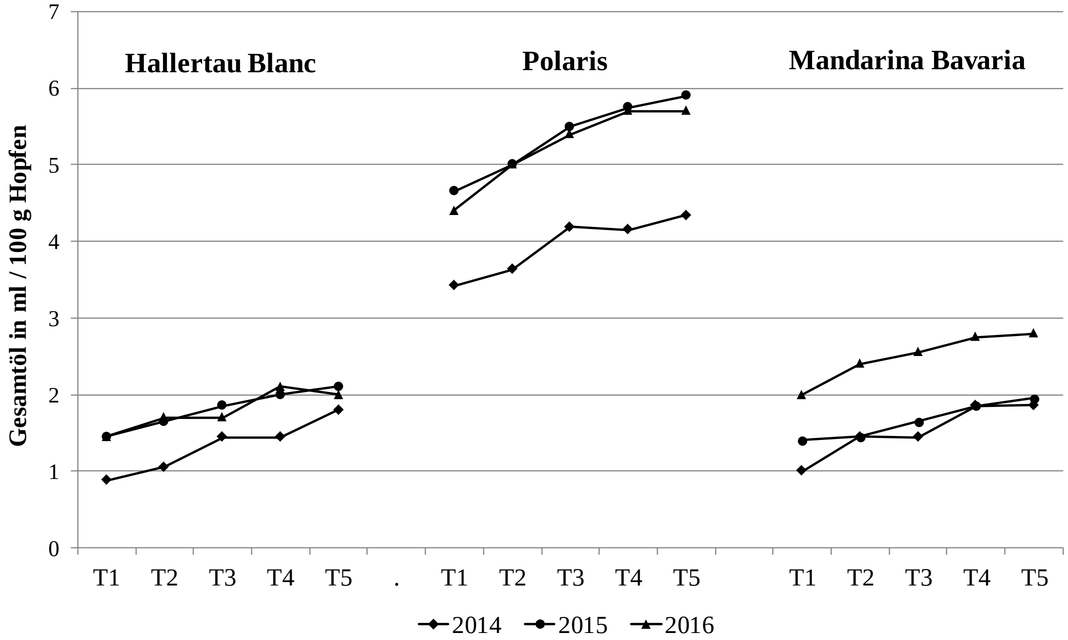


Fig. 5.21: Total oil content of cultivars Hallertau Blanc, Polaris and Mandarina Bavaria in the three test years, by harvest date

Tab. 5.4: Monitoring of plot samples for colour, sheen and aroma assessment from Hallertau Blanc (HC), Polaris (PA) and Mandarina Bavaria (MB), in 2016

HC	**External quality**	**Aroma**
Harvest date	Colour and sheen(1-15)	Aroma points (1-30)
T1 = 05.09.	13	25
T2 = 08.09.	**14**	26
T3 = 12.09.	12	**27**
T4 = 15.09.	12	26
T5 = 19.09.	11	24

PA	**External quality**	**Aroma**
Harvest date	Colour and sheen(1-15)	Aroma points (1-30)
T1 = 05.09.	**12**	24
T2 = 08.09.	9	**25**
T3 = 12.09.	8	24
T4 = 15.09.	8	23
T5 = 19.09.	7	21

MB	**External quality**	**Aroma**
Harvest date	Colour and sheen(1-15)	Aroma points (1-30)
T1 = 12.09.	11	24
T2 = 17.09.	13	25
T3 = 19.09.	**14**	25
T4 = 24.09.	13	**27**
T5 = 26.09.	12	26

The findings from the monitoring of external quality and aroma demonstrate that the point at which optimum external quality was reached was always ahead of the date for the best aroma profile. In hops that were harvested later, the variety-typical aroma was increasingly spoilt by onion- and garlic-type signatures, due to the increase in sulphur compounds. This was especially noticeable in *Polaris*, which has a higher proportion of sulphur compounds anyway.

Conclusiona for routine agricultural practice

Harvest timing has a big influence on yield and the typical aroma and flavour profiles of flavor hops. In terms of optimizing yields and maintaining plant health and vitality, late harvest dates would be preferable. However, in the case of *Polaris*, but also in *Hallertau Blanc*, external quality and aroma are distinctly impaired with advancing maturity, and harvesting at too late a date should be avoided in these cultivars. Flavor hops are expected to comply with high quality standards; in this context, the requirements of the brewers must be taken into account and harvest timing coordinated with contract partners to ensure that the varietal range continues to expand in Germany and that the new flavor hops are here to stay!

5.6 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 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 2016.

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

Dry matter and alpha acids monitoring

In the period 16.08. – 27.09.2016 – spaced out across the Hallertau region – a trained bine from each of 3 aroma varieties and 3 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 the dry matter content and alpha acids content 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 uploaded 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.

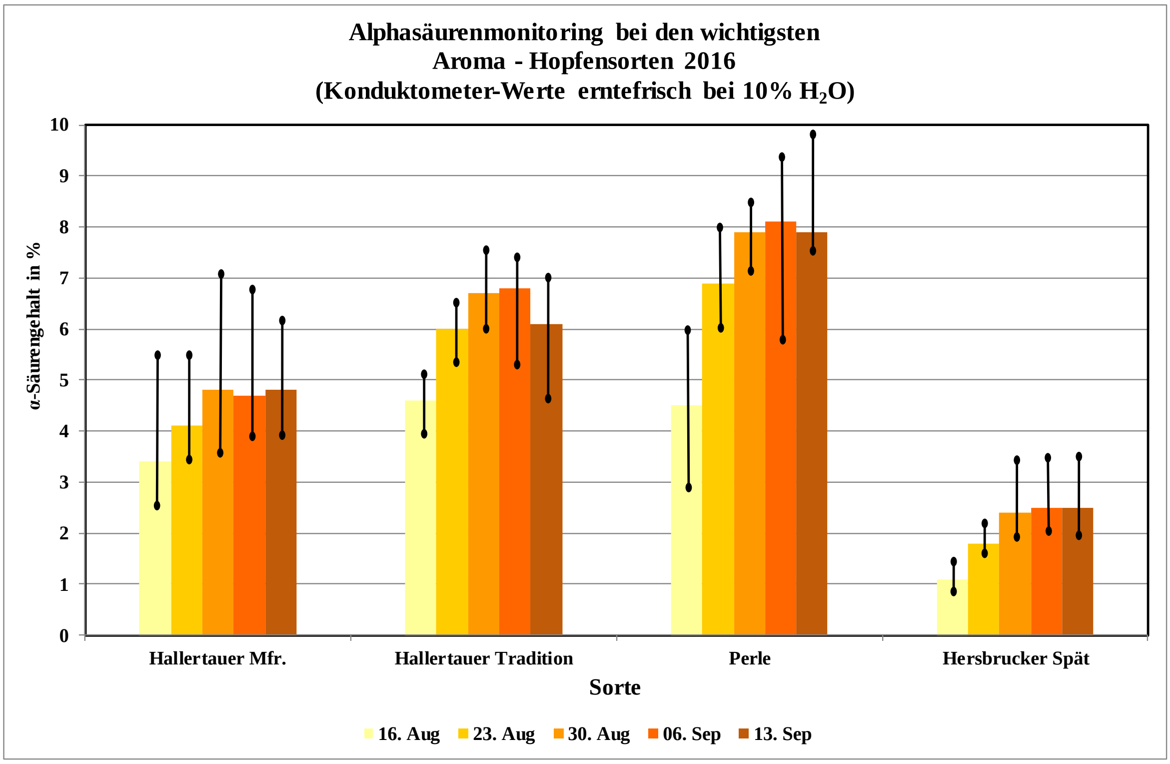


Fig. 5.22: Alpha acids monitoring in the major aroma varieties in 2016

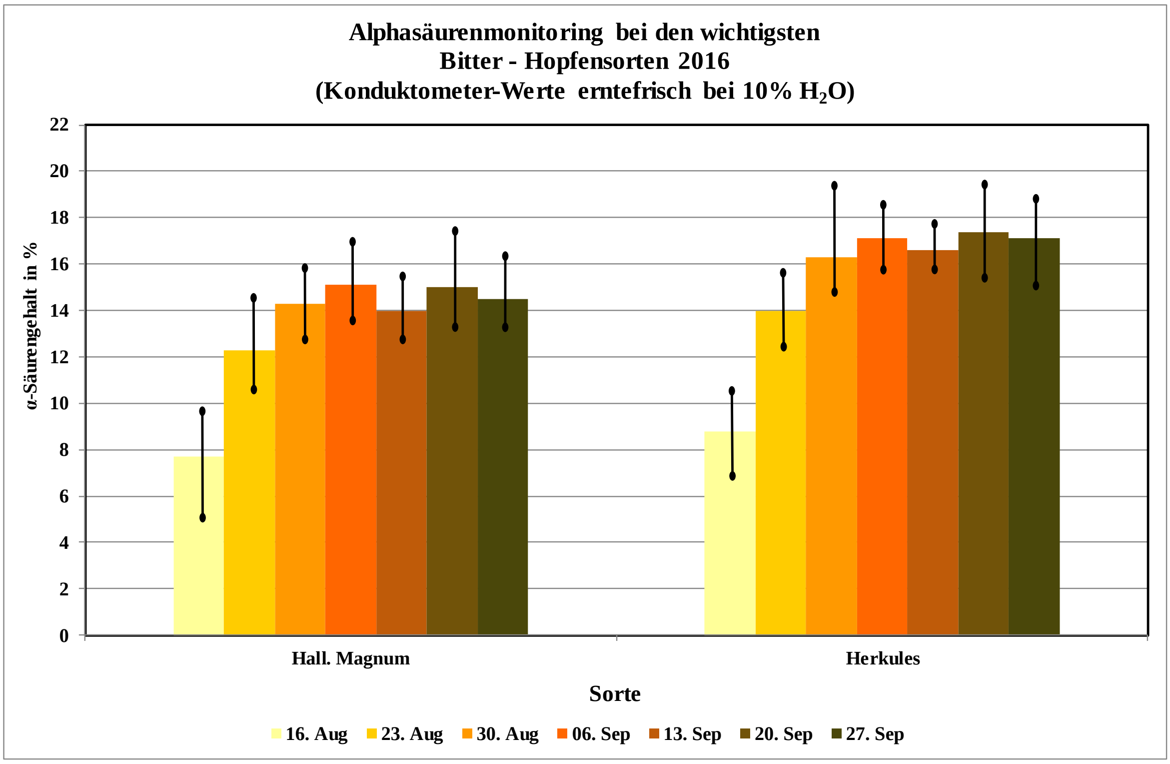


Fig. 5.23: Alpha acids monitoring in the high alpha varieties in 2016

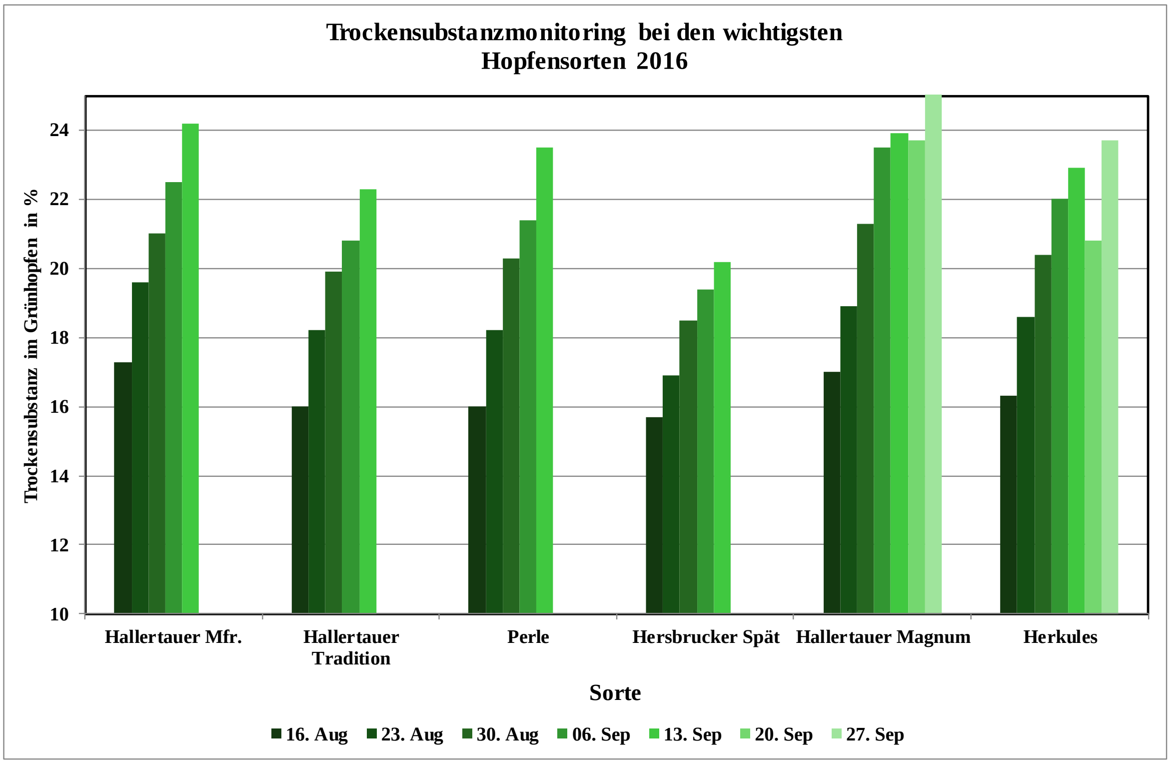


Fig. 5.24: Dry matter monitoring in the major hop varieties in 2016

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 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 110 of the anticipated 600 data sets were submitted in 2016, this meant that stratification and an evaluation were once again not possible.

5.6.2 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 June 6 to August 8, 2016, assessments were carried out at weekly intervals on 10 different dates in 30 representative hop yards (different varieties) in the Hallertau region (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.

5.6.3 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 (*Hop Analysis Working Group),* 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 analysis is organized, conducted and evaluated by the Bayerische Landesanstalt für Landwirtschaft in its capacity as a neutral body.

The role of the Hopfenring 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.

5.7 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 Cultivation, 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 are 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'Ring*).

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

5.7.1 Written Informationen

- The *Green Pamphlet* Hop (das *Grüne Heft* Hopfen) for 2016 – 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 2 350 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 30 faxes via the Hopfenring multiple recipient fax (2016: 50 faxes in the Hallertau region + 3 for Spalt and 1 additional fax for Hersbruck with 1 023 participants).
- In the context of the Nmin soil audit, 2 797 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 8 monthly issues of the *Hopfen Rundschau.*

5.7.2 Internet and intranet

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

5.7.3 Telephone advisory and information services

- The downy mildew warning service was set up for the period May 10 to September 5, 2016, by AG Hopfenbau/ Produktionstechnik (*WG Hop Cultivation/ Production Techniques*) in Wolnzach, in collaboration with AG Pflanzenschutz (*WG Plant Protection*) at Hüll and updated 81 times, for access on request, either via answerphone (on 08442/9257-60 and -61), or via the internet.
- The specialists from AG Hopfenbau/Produktionstechnik 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 the ground.

5.7.4 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
- 20 specialist lectures
- 3 guided tours of trial sites for hop growers and the hop industry
- 5 conferences, trade events or seminars

5.7.5 Basic and continuing training courses

- Setting assignments for 7 and examining 5 work projects as part of a master's certificate (vocational)
- 11 instruction sessions at the Landwirtschaftsschule (*Agricultural College*) Pfaffenhofen for students studying hop cultivation
- 1-day course in the summer term at the Pfaffenhofen Agricultural College
- 1 informational event for vocational school students from Pfaffenhofen
- 6 meetings of the study group *Hop Management*

6 Plant Protection Management in Hop

LD Wolfgang Sichelstiel, Dipl.-Ing. agr.

6.1 Pests and Diseases in Hop

6.1.1 Aphids

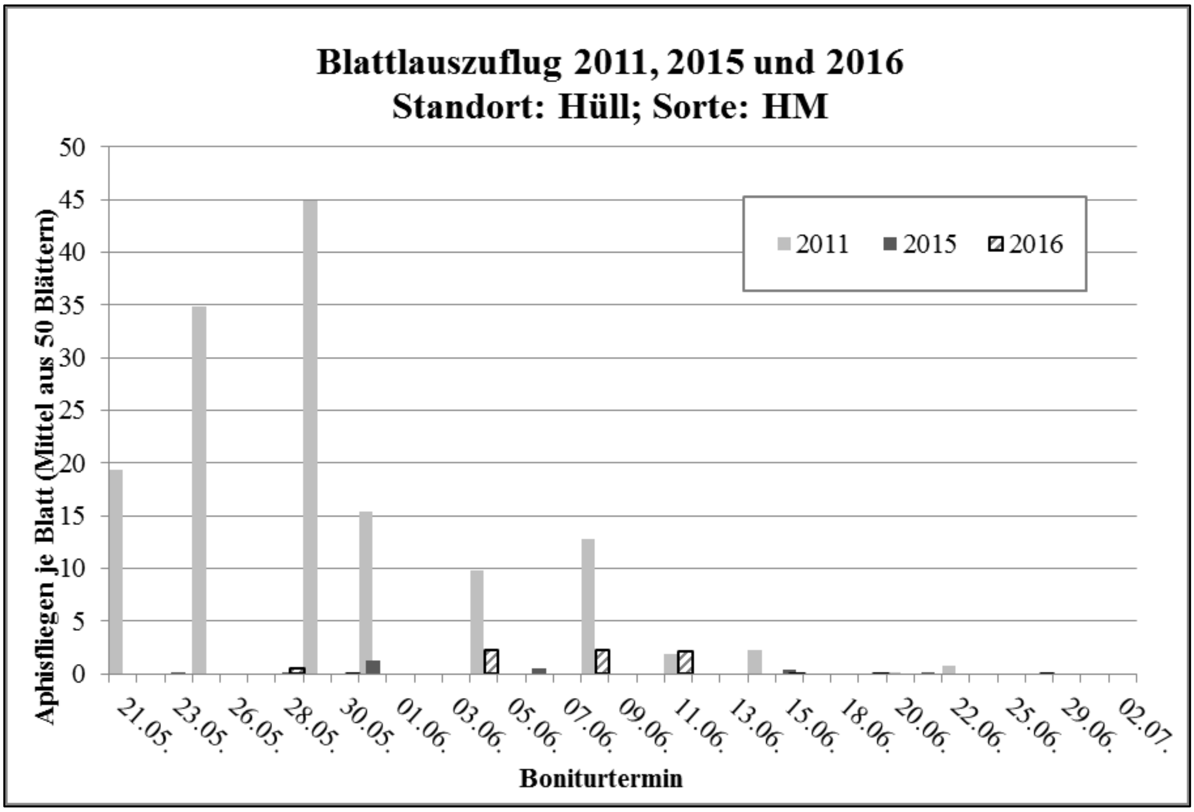


Fig. 6.1: Aphid migration at Hüll in 2016

Tab. 6.1: Monitoring of aphid migration and infestation at 30 locations in the Bavarian hop growing regions

Date	Aphid migration	Aphids per leaf		
	Ø	Ø	min	max.
06.06.	0.89	3.90	0.00	31.00
13.06.	0.30	2.70	0.00	38.00
20.06.	0.05	2.08	0.02	14.50
27.06.	0.01	2.80	0.00	39.00
04.07.	0.00	2.75	0.00	39.10
11.07.	-	1.30	0.00	24.00
18.07.	-	0.70	0.00	12.00
25.07.	-	0.20	0.00	4.20
01.08.	-	0.10	0.00	1.40
08.08.	-	0.09	0.00	1.94
	Main treatment dates 07.07. – 10.07. and 19.07. – 30.07. 5 locations left untreated			

Hop aphid migration began at the end of May and, although occurrence was slightly higher than last year, it remained at a moderately low level; but actual infestation was more severe and more widespread than in the four previous years. Only 21 crops in the 30 hop yards under observation as part of the monitoring programme were aphid-free by the end of the inspection period. Treatment was carried out in 24 hop yards, and in one yard spraying was done twice. In contrast, aphid treatment had been deemed unnecessary in 70-80% of the yards under observation in the years 2013 to 2015.

6.1.2 The two-spotted spider mite

Tab. 6.2: Monitoring of infestation by the two-spotted spider mite (eggs, adults and index) in 30 locations in the Bavarian hop growing regions

Date	Eggs	Spiders	Spider mite index per leaf		
	Ø	Ø	Ø	min.	max.
06.06.	0.43	0.28	0.07	0.00	0.40
13.06.	0.56	0.63	0.17	0.00	0.70
20.06.	1.15	1.23	0.23	0.00	1.00
27.06.	0.92	0.88	0.20	0.00	0.80
04.07.	1.76	1.17	0.21	0.00	0.75
11.07.	0.63	1.16	0.18	0.00	0.65
18.07.	0.56	1.37	0.14	0.00	0.85
25.07.	0.13	0.40	0.07	0.00	0.40
01.08.	0.12	0.19	0.05	0.00	0.20
08.08.	0.18	0.24	0.05	0.00	0.30
	Main treatment dates 21.06. – 23.06. and 06.07 - 12.07. No locations left untreated				

Conditions in 2016 allowed the two-spotted spider mite to appear earlier than in the previous year and levels of infestation were heavier and more widespread. On the first monitoring date, June 6, the spider mite was already present in eleven of the thirty crops under inspection, and, in the following two weeks, infestation spread to two thirds of the monitored areas. Treatment was carried out in eleven yards in the last week of June. By the end of July, all monitored areas had been sprayed at least once. Ten areas had to be sprayed twice to control the spider mite, and, in one case, three treatments were necessary.

6.1.3 Downy mildew

Downy mildew infection pressure reached very high levels from mid-May onward. The zoosporangia counts recorded by the downy mildew warning service exceeded the treatment threshold for susceptible cultivars over longer periods during the season and, at times, even rose above the threshold for tolerant hops. In the second half of May and the first half of June, infection pressure was especially severe. Almost daily rainfall, high humidity and moderate temperatures provided the fungus with ideal growth and infection conditions. During the same period, there was also a late outbreak of primary infection on side shoots. Infection pressure eased off slightly at the end of June/beginning of July but increased again around 12 July, following a period of continuous rain, and then remained at a high level throughout the season. Consequently, the warning service issued a total of six spray alerts for all cultivars and eight spray alerts for susceptible and late hops.

Tab. 6.3: Warning service for downy mildew and powdery mildew in 2016

Fax-No.	Date	Primary downey mildew alert	Sray alert			Powdery mildew
			Suscept. cultivars	All cultivars	Late cultivars	
13	07.04.	xx				
16	10.05.	xx				
19	27.05.	x		x		susceptible
20	06.06.	x		x		susceptible
25	17.06.			x		susceptible
28	06.07.					susceptible
31	18.07.					susceptible
32	20.07.			x		susceptible
34	29.07.			x		
35	08.08.		x		x	
37	17.08			x		susceptible
39	30.08.		x		x	susceptible & late
Number of spray alerts			2	6	2	8

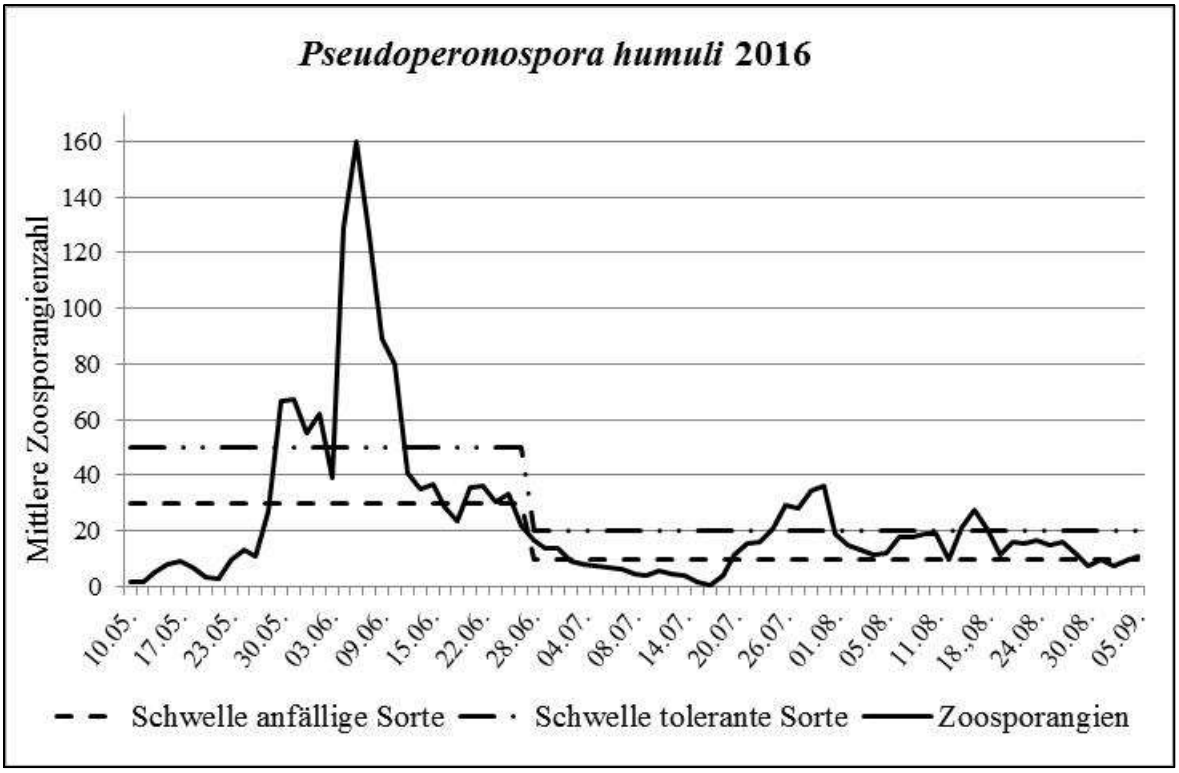


Fig. 6.2: Downy mildew warning service 2016 – average zoosporangia migration at 5 locations in the Hallertau

6.2 Two Forecasting Models for Powdery Mildew Management in Hop Now Included in the ISIP System; Comparison of the Different Forecasting Results 2014 - 2016

Two weather-based forecasting models for predicting infection by powdery mildew were devised in the period 2003 to 2009 at the Hop Research Center at Hüll. The aim was to show, based on weather parameters, how an attack progresses, and to draft recommendations for spray dates. One model was a provisional system developed by B. Engelhard, based on empirical data; the other was a weather-based model devised by S. Schlagenhaufer, using scientific data. The two models were made available on the ISIP platform for decision-making tools in plant cultivation (Informationssystem Integrierte Pflanzenproduktion e.V - *Information System for Integrated Plant Production*). The ISIP platform uses a one square kilometre grid to make precision forecasts. Weather parameters are extrapolated for each location with the aid of data from neighbouring weather stations and rain radar.

Both models aim to provide a precision prediction, specific to the day, of any risk of powdery mildew, with a view to optimizing deployment of plant protection agents. In this context, it is absolutely crucial that conditions favourable to infection are recognized in order to prevent primary infection and to halt spreading and new occurrences of infection. Inspections and monitoring of the stands provide information as to the accuracy of the models.

Parameters for the two forecasting models are calculated every day with the help of the ISIP platform, thus providing information on local levels of attack by powdery mildew. The provisional Engelhard model defines 'critical conditions for infection' by the half-day. These conditions are: rainfall, global radiation, temperature and temperature differential. If these favourable infection conditions are present on five half-days in a row, a spray alert is issued for susceptible cultivars; after six half-days an alert for all cultivars follows.

The Schlagenhaufer model uses an algorithm based on a 3-day infection value, utilizing severity of attack and incubation period to predict attacks and juxtapose them with threshold deadlines. At the start of the season, threshold values are very low but rise steadily from 20 May to 20 June. As of 20 June, the threshold value depends on whether the crop is free of infection, or powdery mildew is present. The evaluation provides an advance warning the moment 75% of the threshold value is reached, followed by a further warning at 110% of the current threshold value.

In 2014 to 2016, the data from these models were analysed and compared at 7 locations over the period mid-April to mid-September. In contrast to the situation in 2015, powdery mildew infection pressure in 2014 and 2016 was high throughout the entire season. By making a direct comparison, it was possible to see the differences between the two models and to give the reasons for the divergence in sensitivity.

Three situations in 2016, by way of example:

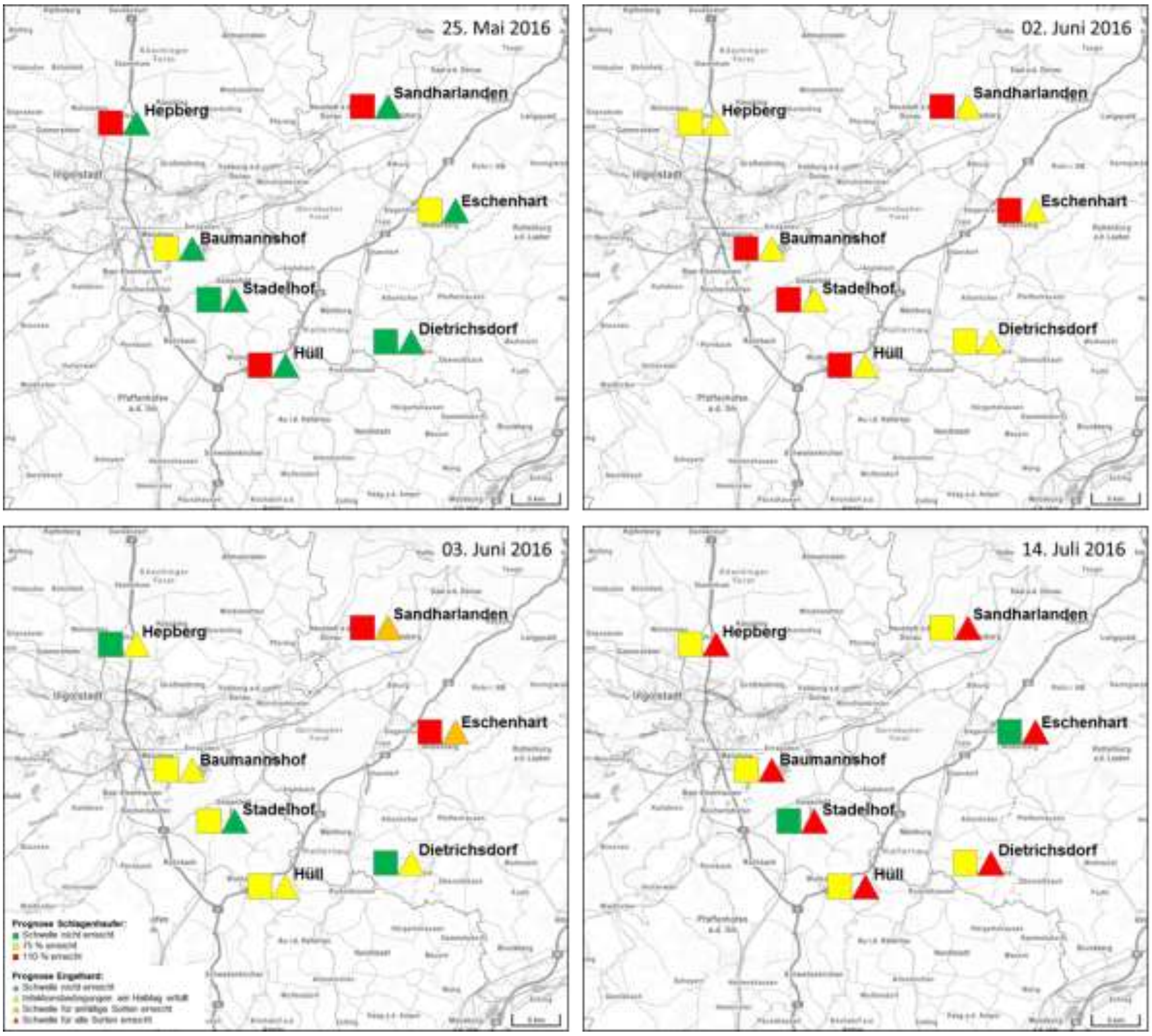


Fig. 6.3: The day's evaluation of each forecasting model in 3 different situations: on 25 May, 2/3 June, 14 July 2016

25.05.16: The Schlagenhaufer model (square) issued a warning in three locations, whereas the Engelhard model (triangle) did not issue a warning in any of the locations. Owing to the low threshold at the beginning of the season, the Schlagenhaufer model is more sensitive, and small-scale climatic differences are registered.

02./03.06.16: At the beginning of June, the weather conditions were conducive to infection over a period of several days. According to the Schlagenhaufer model, the 110% limit of the current threshold value was exceeded in five of the seven locations monitored. The Engelhard system, however, triggered a warning for susceptible cultivars in only two places. This may have happened because several half-days were counted together. If four half-days with conditions for infection are followed by a fifth day (in this case 3 June), on which the criteria are not met, the system reverts to counting the critical half-days starting at 0 again. It seems that the Engelhard model is not sensitive enough in exceptional cases like this.

14.07.16: The Schlagenhaufer forecasting model seems to have difficulty in dealing with extreme amounts of rainfall (70 mm in 2 days). In none of the locations was a warning issued – whereas the Engelhard model issued a warning for all cultivars in all seven locations.

Comparison of the two models is to continue in the next few years, alongside inspections for infection in commercially run hop yards in order to evaluate the models in the field.

7 Ecological Issues in Hop Farming

Dr. Florian Weihrauch. Dipl.-Biol.

A new Working Group AG Ökologische Fragen des Hopfenbaus (*WG Ecological issues in Hop Cultivation*) was set up on 1 August 2016 for the specific purpose of establishing a knowledge base and carrying out practical research into the ecologically sound production of hops. This includes diagnosing, observing and monitoring levels of infestation by pests inflicting damage on hops and their biological antagonists, in the context of progressive climate change and the consequent impact on biocenoses. At the same time, the intention is to develop and evaluate biological and other environmentally friendly means of plant protection. The Working Group relies primarily on attracting funding for its research into ecological issues in hop cultivation.

7.1 Spider Mite Trial at Oberulrain 2016

Immediately following on from completion of the research project entitled *Deployment and establishment of predator mites for sustainable spider mite control in hop as a special agricultural crop,* in the spring of 2016 (*p.18f),* the trial was continued at the site in Oberulrain for reasons of self-interest. It was managed in 10 plots (4 where predator mites were deployed, 4 as untreated controls, and 2 treated according to commercial practice). The same area was so badly infested with spider mites in 2015 that no harvest was possible, due to severe copper browning, and compensation had to be paid for the whole area as a consequence. The objective of the continuing trial was to find out, amongst other things, what impact a total loss due to spider mite infestation in one year would have on levels of infestation in the next year.

The predator mites were introduced into the 4 relevant plots in the yard on 12 May, on cut sections of grapevine taken from a vineyard near Neustadt an der Weinstraße (314 sections from first-year vine growth in 4 plots, i.e. they were applied to 2/3 of the hop plants). From the beginning of July through to harvest at the beginning of September, development of the spider mite population was monitored in all trial plots. (Fig. 7.1). The monitoring also covered predator mites and their eggs. On 12 September, a test harvest was also carried out in the trial plots.

The results deliver impressive evidence that severe spider mite damage does not necessarily cause even greater problems in the following year – as is often thought to be the case in commercially managed farms. In fact, it seems that the opposite occurs; during this trial, the spider mite populations completely collapsed in all the plots at the beginning of August– it made no difference whether they had been left untreated, or predator mites had been deployed, or they had twice been sprayed with acaricides. The already large numbers of spider mites in the untreated trial plots (on average 50 individuals and more per leaf) throughout July meant that slight yield losses of 3.5 dt/ha were recorded in three out of four plots; however, the yields of at least 24 dt/ha were still very good, and neither quality (alpha acids) nor cone cluster density were adversely affected by the pest infestation in the early part of the summer (Fig. 7.2). This phenomenon could perhaps be put down to induced systemic resistance (ISR), something which will be examined more closely in the next few years.

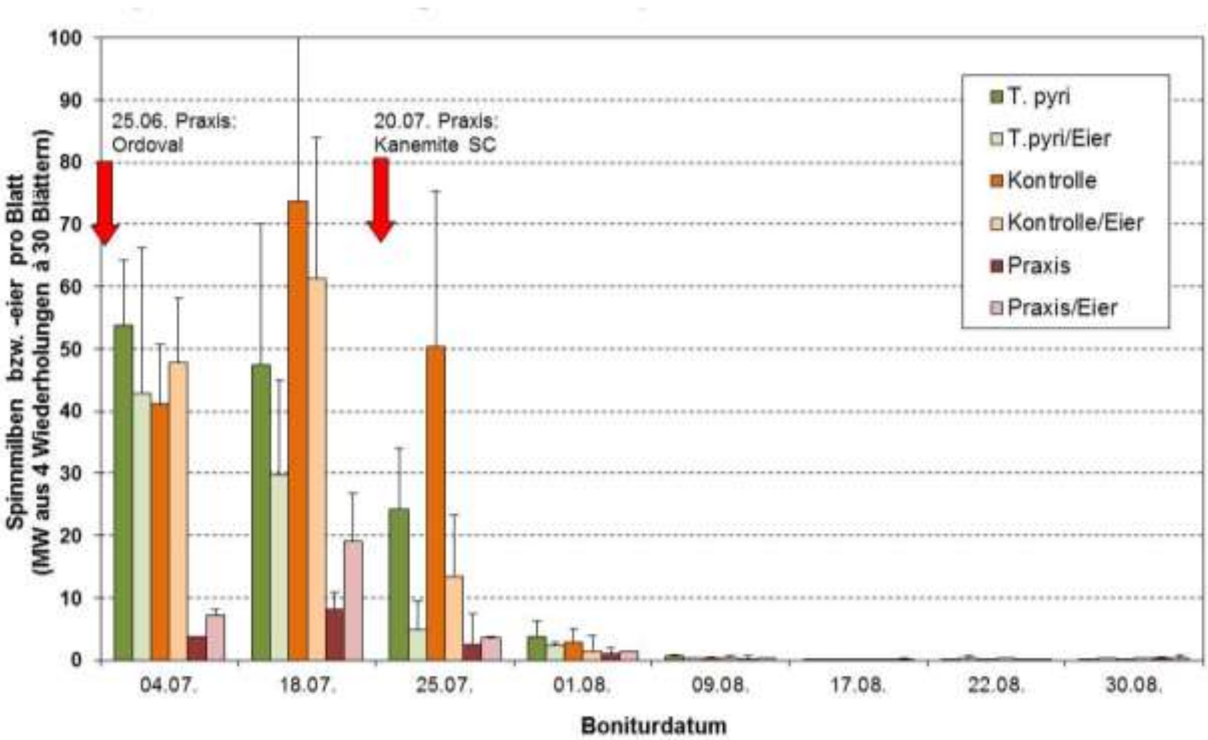


Fig. 7.1: Development of the spider mite population (imagoes and eggs monitored separately) in individual trial plots in 2016 at Oberulrain. In the previous year, 2015, the entire plot suffered a total loss due to extreme copper browning

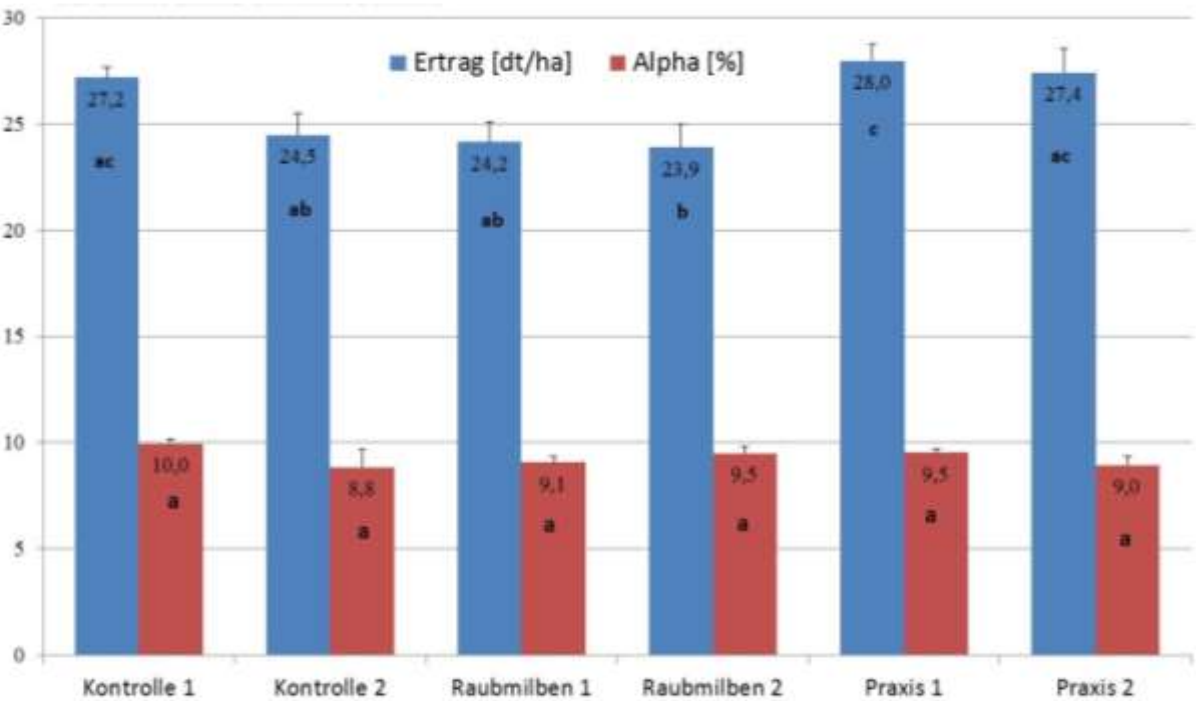


Fig. 7.2: Results of the trial harvest at Oberulrain on 12.09.2016

8 Hop Quality and Analytics

ORR Dr. Klaus Kammhuber. Dipl.-Chemiker

8.1 General Information

Working Group IPZ 5d carries out all analytical testing in the IPZ Hops Department needed 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 substances of value; in order of importance, these are the bitter compounds, the essential oils, and the polyphenols. Until now, the alpha acids have been considered to be the key element contributing to hop quality because they are a determinant for 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 even 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 is generally considered to constitute the soul of a beer. It certainly fulfils multiple roles in this context (Fig. 8.1).

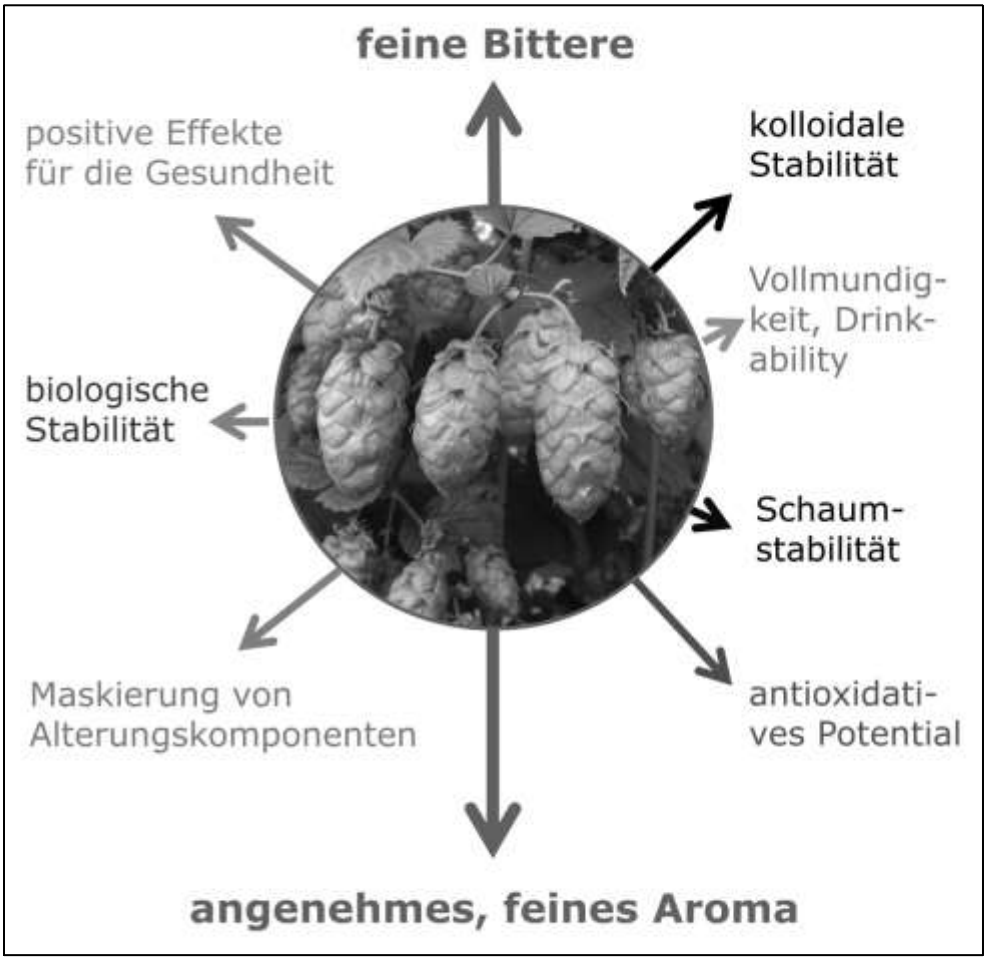


Fig. 8.1: The effect of hops in beer

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 aromas, sometimes not even typical of hops, and these are grouped under the term *Special Flavor Hops*. 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 to the finished beer in the storage tanks, usually on the basis of their oil content. The alcohol content of the beer acts as a solubilizing agent, and predominantly polar substances are dissolved out of the hops. Alpha acids enter the solution 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 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 production is used for 2% of world beer production. In the United States, the acreage devoted to hop increased from 12 670 hectares in 2010 to 21 672 hectares in 2016. 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. 8.2). 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.

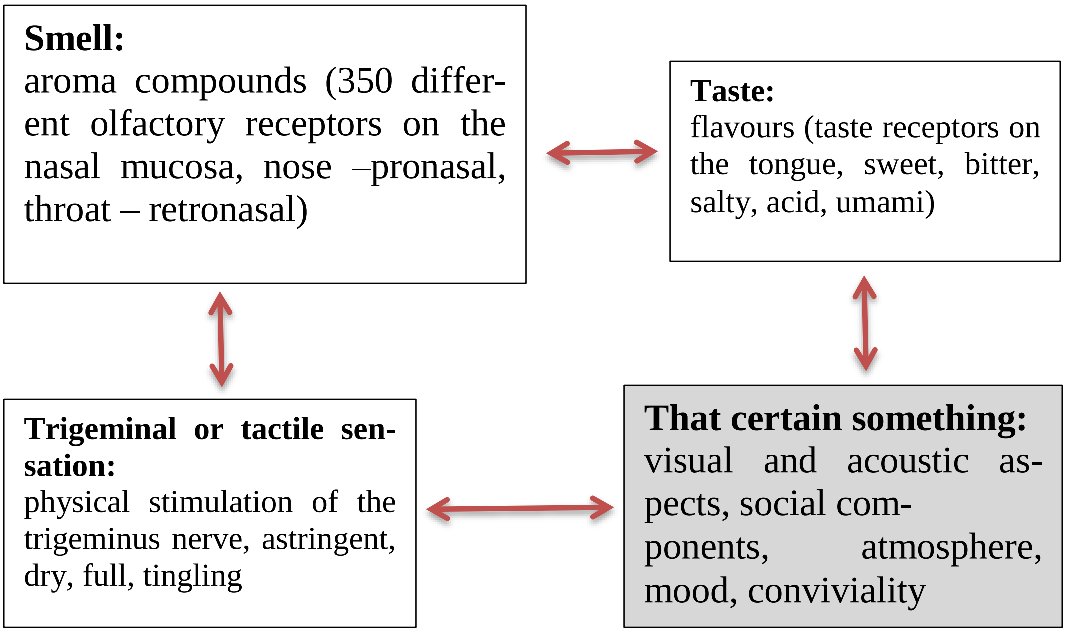


Fig. 8.2: Eating and drinking - a holistic experience of sensual pleasure

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 accounts for 95% of hop output, making it the biggest consumer of hops at present and set to remain so in the future (Fig. 8.3).

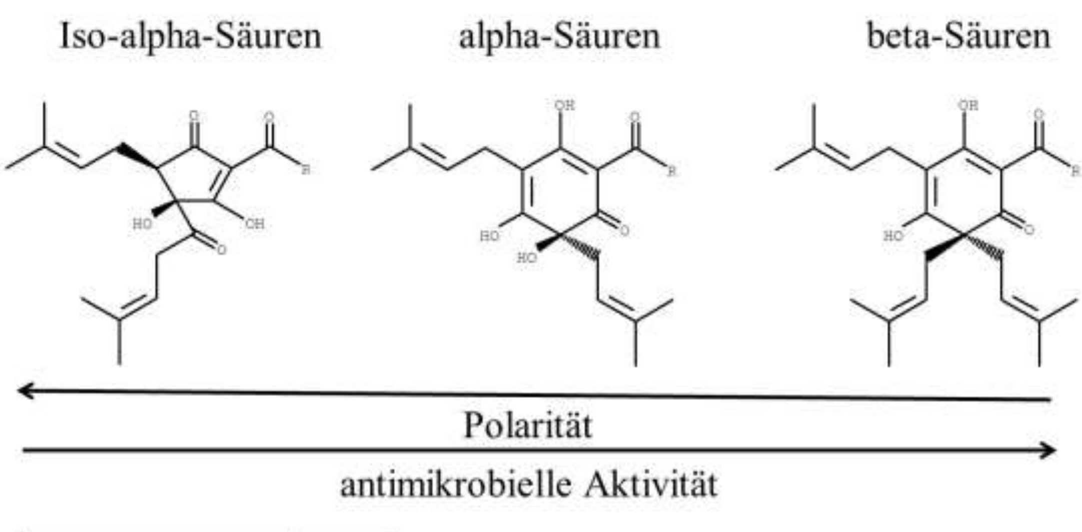
Fig. 8.3: Uses of hop

The requirements of the brewing industry and the hop 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 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. 8.4).



$R=CH_2CH(CH_3)_2$	n-
$R= CH(CH_3)_2$	Co-
$R= CH(CH_3)CH_2CH_3$	Ad-
$R= CH_2CH_2CH(CH_3)_2$	Prä-
$R= CH_2CH_3$	Post-

Fig. 8.4: Order of antimicrobial activity: iso-α acids, α acids and ß acids

The more non-polar a molecule is, the higher the degree 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. 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 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 approx. 20%. There is actually a breeding line that produces only β acids and no α acids.

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 one of the principal components 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. 8.5), the most promising discovery being that it works in treating cancer.

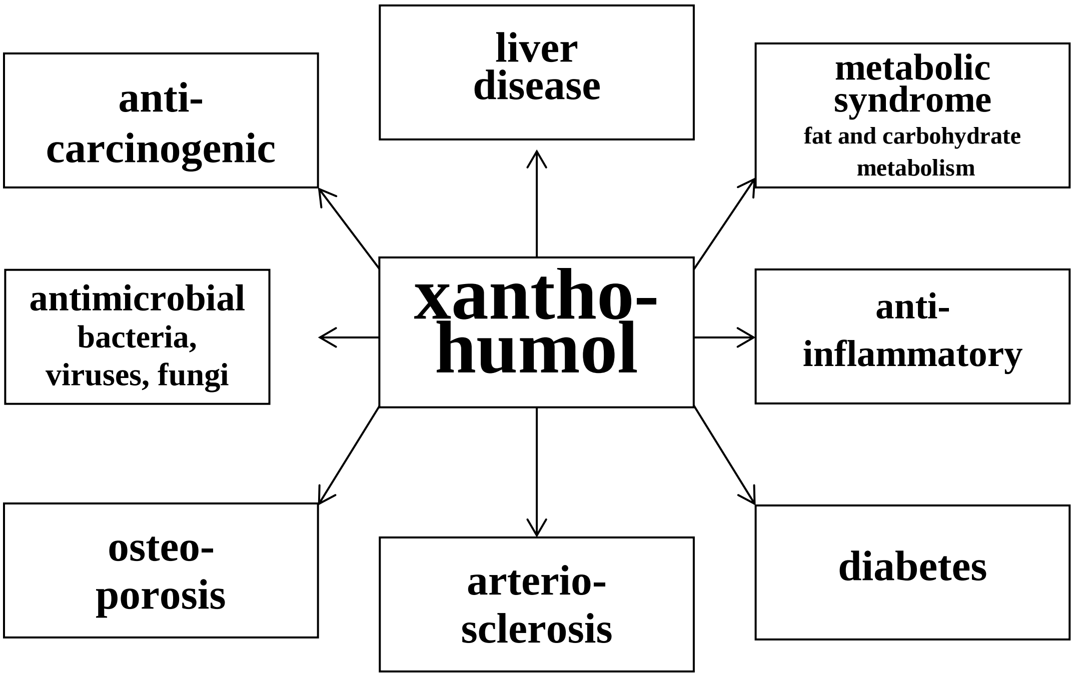


Fig. 8.5: Xanthohumol can help treat almost anything

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 Range (2015 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. The new gas chromatography/mass spectrometry system was used for the first time for the crop harvested in 2015.

Tab. 8.1 shows the results for the 2015 harvest. It can be used as an aid to identifying unknown hop varieties.

Tab. 8.1: World hop range (2015 crop)

Cultivar	Myrcene	2-M.-iso-butyrate	Sub. 14 b	Sub. 15	Linalool	Aromadendrene	Undecanone	Humulene	Farnesene	γ-Muurolene	ß-Selinene	α-Selinene	ß,γ-Cadinene	Selinadien	Geraniol	α acids	ß acids	ß/a	Cohumulone	Colupulone
Admiral	3157	789	1	183	98	0	22	430	8	17	3	5	38	0	1	12.5	3.9	0.31	45.6	67.3
Agnus	906	81	0	33	20	0	1	136	0	17	2	8	36	0	2	8.1	3.9	0.48	26.8	50.7
Ahil	4247	894	105	39	50	0	24	466	122	16	6	10	35	0	9	7.2	4.0	0.55	28.1	54.8
Alliance	1708	187	0	13	49	0	14	412	8	17	3	3	37	0	0	3.8	1.8	0.47	26.1	44.8
Alpharoma	3574	886	117	112	34	0	43	642	45	21	0	6	43	0	2	6.3	2.0	0.32	24.3	52.4
Apolon	4496	536	164	78	73	0	8	466	134	18	8	15	33	0	5	7.9	4.0	0.51	19.2	43.4
Aquila	3349	247	0	434	52	41	47	57	2	29	50	96	28	143	9	4.4	3.4	0.77	52.6	60.9
Ariana	2196	419	200	332	27	0	37	450	0	19	11	21	17	0	1	8.1	4.9	0.60	37.5	55.5
Aromat	1975	7	1	17	41	0	35	628	72	22	3	4	44	0	0	1.7	3.4	2.05	27.7	43.7
Atlas	4216	1013	115	58	50	0	3	443	147	15	6	11	32	0	17	9.0	3.7	0.41	34.6	57.9
Aurora	3066	489	7	324	101	0	65	408	65	13	3	3	34	0	2	8.4	3.3	0.40	23.6	50.0
Backa	3828	869	0	157	67	0	16	560	49	18	2	3	37	0	0	6.9	3.5	0.52	43.2	64.1
Belgisch Spalter	1997	333	0	77	43	7	19	328	0	16	15	32	27	55	0	1.6	1.3	0.80	17.4	37.4
Blisk	2574	585	70	23	43	0	4	471	129	20	5	8	40	0	5	5.9	3.0	0.51	35.0	58.2
Bobek	3971	413	39	462	167	0	75	461	68	16	3	4	36	0	4	3.6	4.3	1.18	26.0	47.4
Bor	1825	194	0	142	25	0	18	468	0	13	3	3	32	0	1	5.8	2.6	0.45	26.1	50.2
Bramling Cross	2752	248	0	17	52	0	16	586	0	15	3	5	33	0	0	3.1	3.3	1.09	41.7	51.8
Braustern	1602	276	0	220	26	0	14	339	0	12	2	3	30	0	0	4.4	2.2	0.51	25.8	53.3
Brewers Gold	2172	609	61	97	43	0	10	335	0	17	9	15	33	0	7	7.4	4.1	0.55	32.9	57.2
Brewers Stand	9610	1275	190	321	139	28	43	169	0	89	51	94	163	150	11	10.1	3.3	0.33	18.6	40.3
Buket	2184	388	1	230	90	0	65	394	43	18	3	3	39	0	1	8.2	3.9	0.47	21.6	50.7
Bullion	2102	900	141	48	59	0	10	420	0	27	9	15	47	0	3	6.3	4.6	0.72	39.2	55.8
Callista	2110	299	112	17	104	0	34	429	0	25	24	44	44	2	1	2.1	5.1	2.46	15.3	35.9
Cascade	3281	314	50	77	32	0	9	477	46	19	10	19	19	0	5	3.6	4.2	1.18	33.8	49.9
Chang bei 1	3417	89	11	18	94	0	51	547	39	22	15	27	39	38	1	2.0	3.2	1.61	24.5	41.8
Chang bei 2	3201	2	11	16	97	0	50	525	41	21	13	24	35	36	1	2.2	3.0	1.37	21.9	40.6

Cultivar	Myrcene	2-M.-isobutyrate	Sub. 14 b	Sub. 15	Linalool	Aromadendrene	Undecanone	Humulene	Farnesene	γ-Muurolene	ß-Selinene	α-Selinene	ß,γ-Cadinene	Selinadien	Geraniol	α acids	ß acids	ß/a	Cohumulone	Colupulone
College Cluster	2313	648	145	98	33	0	15	392	0	21	7	12	38	3	3	5.5	2.1	0.38	25.0	32.6
Columbus	1896	396	58	119	20	0	2	257	0	44	10	16	40	0	1	14.5	5.4	0.38	31.9	54.4
Crystal	2241	17	5	27	47	28	22	439	0	21	17	41	30	76	0	0.8	4.0	5.24	6.9	39.1
Density	2574	174	2	17	49	0	15	566	0	15	2	3	34	0	0	3.1	3.0	0.98	39.0	52.0
Early Choice	1678	200	0	33	8	0	13	537	0	14	0	56	33	0	0	1.2	0.8	0.67	40.9	58.6
Eastwell Golding	1948	131	1	43	42	0	16	444	0	14	2	3	32	0	0	3.1	1.8	0.58	29.2	47.5
Emerald	1075	163	7	54	16	0	21	406	0	14	2	3	32	0	0	3.2	3.2	0.99	32.5	49.0
Eroica	2993	940	133	599	2	0	18	405	0	14	6	11	27	0	1	10.1	6.8	0.67	41.4	59.4
Estera	1350	131	0	16	45	0	8	408	26	14	2	3	31	0	0	2.0	1.7	0.84	30.6	48.9
First Gold	3091	742	1	114	79	0	25	456	13	17	49	103	39	0	1	6.8	2.8	0.42	27.4	55.0
Fuggle	4262	287	2	35	36	0	10	546	32	15	3	3	35	0	0	2.3	2.0	0.88	27.1	40.0
Galena	2195	391	160	494	3	0	16	326	0	14	9	17	30	0	1	9.3	7.7	0.82	40.2	60.4
Ging Dao Do Hua	3945	1368	0	35	63	0	34	558	1	50	35	60	90	0	8	3.8	3.3	0.88	44.3	55.6
Glacier	2445	224	11	25	71	0	28	516	0	21	1	4	43	0	2	3.3	6.2	1.89	12.2	37.8
Golden Star	3689	1320	0	24	41	0	28	602	0	42	29	52	81	0	4	3.3	2.5	0.75	47.7	61.8
Granit	2195	202	8	43	19	0	44	486	0	14	1	10	30	0	1	5.8	3.8	0.66	24.8	46.6
Green Bullet	4624	281	52	68	23	0	31	703	0	17	1	3	36	0	0	5.7	3.6	0.64	34.3	55.9
Hall. Blanc	12583	1861	585	273	185	0	37	182	2	22	329	719	26	29	8	9.2	5.0	0.54	21.7	37.2
Hall. Gold	2317	241	34	45	72	0	29	440	0	15	2	3	33	0	0	6.7	3.8	0.56	19.2	45.4
Hall. Magum	2716	319	117	167	18	0	17	479	0	17	2	4	37	0	1	14.3	6.4	0.45	22.5	46.2
Hall. Merkur	2707	348	83	60	60	0	11	445	0	18	3	4	39	0	0	12.8	4.6	0.36	16.9	36.9
Hallertauer Mfr.	1014	131	0	4	54	0	22	427	0	22	3	4	43	0	0	0.9	2.6	2.93	17.3	35.8
Hall. Taurus	4897	78	40	120	104	0	29	598	0	15	27	75	37	0	1	12.3	3.7	0.30	22.9	47.1
Hall. Tradition	2790	261	12	30	94	0	24	491	0	17	3	3	37	0	0	6.0	3.5	0.59	26.8	49.1
Harmony	6455	1	0	97	63	0	20	563	0	17	39	79	40	4	1	5.2	4.3	0.83	22.9	36.2
Herald	3011	640	4	435	35	0	72	349	4	12	13	27	30	0	5	11.1	4.1	0.37	31.9	62.5
Herkules	2556	526	308	363	24	0	19	421	0	15	3	4	36	0	2	15.8	4.6	0.29	30.7	45.7

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
Hersbr. Pure	3134	340	14	71	100	22	47	452	92	18	13	34	30	1	1	1.9	1.3	0.67	21.3	40.6
Hersbr. Spät	2708	183	7	69	87	44	19	433	0	26	24	47	35	75	1	1.5	4.2	2.70	2.4	38.2
Huell Melon	6254	1780	12	546	54	1	56	133	230	42	172	351	73	14	11	7.2	9.8	1.37	29.0	47.4
Hüller Anfang	1007	158	8	4	45	0	17	427	0	23	3	4	43	0	0	1.7	4.1	2.38	15.6	39.0
Hüller Aroma	1917	192	3	8	68	0	23	532	0	23	3	4	45	0	0	2.5	2.3	0.95	28.2	48.6
Hüller Bitter	4760	939	151	57	101	19	21	394	0	82	33	58	138	101	2	6.0	3.6	0.60	24.8	49.2
Hüller Fortschritt	1740	91	7	8	61	0	20	485	0	19	3	4	38	0	0	1.5	3.6	2.48	33.0	44.2
Hüller Start	1158	42	0	8	21	0	25	522	0	22	3	4	42	0	0	0.8	3.3	4.47	22.3	42.5
Kazbek	2010	519	49	191	35	8	15	345	0	20	14	25	33	28	3	4.6	3.7	0.81	44.7	58.1
Kirin 1	3137	1067	0	22	45	0	27	528	1	42	30	54	78	0	6	3.7	3.2	0.88	53.4	61.8
Kirin 2	3352	1215	0	29	45	0	27	535	1	47	34	60	89	0	6	3.5	3.1	0.88	49.7	60.0
Kitamidori	1154	29	24	185	8	0	11	364	29	19	1	4	39	0	1	7.0	4.0	0.57	23.5	43.6
Kumir	2238	210	1	159	70	0	18	402	15	16	3	4	37	0	1	7.9	3.9	0.49	16.0	42.1
Late Cluster	6792	1054	133	241	121	26	43	94	1	95	50	101	177	2	19	7.8	3.7	0.47	22.0	40.0
Lubelski	3205	0	0	17	61	0	34	650	109	21	3	4	42	0	0	2.3	4.2	1.84	25.9	42.2
Mandarina Bavaria	3482	598	39	257	38	0	27	527	22	28	19	95	55	4	9	7.7	7.3	0.95	32.5	50.2
Marynka	3139	563	2	254	34	0	15	244	122	11	4	9	26	0	8	8.8	3.4	0.38	20.7	47.2
Mt. Hood	1112	193	38	35	36	0	10	254	0	20	1	4	38	0	1	2.1	3.4	1.62	22.1	41.6
Neoplanta	2956	365	0	214	65	0	35	429	40	14	2	3	32	1	1	6.9	3.4	0.49	26.9	51.1
Neptun	3740	327	141	47	38	0	3	457	0	19	2	3	45	0	0	13.1	4.6	0.35	19.1	34.6
Northern Brewer	2122	302	0	199	30	0	16	396	0	13	0	3	31	0	0	4.8	2.8	0.59	27.9	48.1
Nugget	1671	399	7	111	37	0	17	303	0	12	5	9	26	0	0	9.7	3.6	0.37	25.2	50.1
NZ Hallertauer	2251	425	0	100	42	4	19	391	36	18	14	28	29	34	1	1.7	3.4	2.02	46.6	56.7
Olympic	1678	411	6	162	37	0	12	297	0	12	5	9	27	0	0	9.5	3.7	0.39	25.7	52.0
Opal	3252	314	41	164	104	0	22	419	5	17	1	3	37	0	1	5.8	3.2	0.55	13.7	30.7
Orion	1804	379	8	51	51	0	20	314	0	17	2	3	39	1	0	7.3	3.2	0.44	27.6	55.1
Outeniqua	2177	4	12	11	5	0	45	560	0	25	40	74	46	0	1	8.9	4.2	0.47	27.7	49.8

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
PCU 280	1940	268	0	83	17	0	10	388	0	12	5	8	30	1	1	5.8	2.5	0.43	26.4	52.2
Perle	1169	213	0	97	15	0	10	328	0	13	2	3	31	0	0	4.3	2.5	0.57	33.7	60.4
Phoenix	1157	405	0	27	12	0	12	373	5	16	33	71	39	0	0	7.2	3.1	0.43	21.1	42.5
Pilgrim	3393	808	2	548	43	0	70	441	0	15	39	84	37	3	6	7.1	3.1	0.44	38.7	60.7
Pilot	4661	870	6	403	153	0	82	139	0	18	143	316	41	13	2	5.8	2.3	0.39	37.6	65.1
Pioneer	2879	858	5	613	33	0	107	382	0	14	15	30	32	0	4	6.8	2.4	0.36	32.8	67.9
Polaris	1378	117	64	209	13	0	12	239	0	16	2	3	37	0	1	14.9	4.0	0.26	21.7	37.9
Premiant	1622	188	2	137	57	0	18	296	9	15	2	4	36	0	1	7.2	3.2	0.45	21.4	43.2
Pride of Ringwood	2159	171	11	22	8	0	40	55	0	19	59	112	34	0	1	8.6	4.8	0.56	31.1	57.2
Progress	12344	1810	265	339	182	35	58	77	0	110	61	115	200	188	16	10.2	3.4	0.33	19.5	39.1
Relax	1869	27	18	26	12	0	40	426	4	21	3	4	36	0	2	0.2	6.2	32.9	33.4	24.1
Rubin	2092	296	95	151	33	0	10	300	0	18	37	75	38	3	5	9.4	3.0	0.31	29.0	49.1
Saazer	2301	1	0	38	39	0	35	418	119	18	1	4	36	0	0	2.2	3.3	1.52	22.2	37.9
Saphir	1742	16	4	94	50	6	72	312	0	16	4	21	30	0	1	1.9	2.6	1.40	12.9	38.4
Serebrianker	1323	79	0	13	56	0	15	353	3	27	1	30	48	0	1	1.1	4.2	3.82	15.6	38.0
Sladek	1655	171	0	115	62	0	21	384	11	16	3	4	37	0	1	7.3	3.3	0.45	19.6	43.2
Smaragd	3342	70	24	110	92	0	20	548	7	17	1	3	36	0	2	2.6	2.8	1.07	9.9	38.5
Southern Promise	1637	29	28	65	2	0	57	502	3	20	10	18	35	33	0	7.7	3.8	0.49	28.6	53.3
Southern Star	2550	111	23	21	9	0	44	670	46	25	5	6	44	3	1	8.8	4.5	0.51	32.9	58.0
Spalter	2685	5	0	16	66	0	43	703	98	22	3	4	44	0	1	1.8	4.9	2.77	29.9	43.2
Spalter	2553	0	0	66	48	0	34	451	138	17	2	3	35	0	1	1.9	3.4	1.81	24.3	40.6
Spalter Select	4967	338	28	34	173	30	61	554	127	23	19	39	36	65	1	2.1	2.6	1.21	10.9	40.0
Sterling	1724	466	8	150	36	0	13	310	0	12	2	9	26	0	0	9.5	3.7	0.39	26.3	49.4
Strisselspalter	1699	13	19	57	50	31	27	316	3	20	18	36	31	1	0	2.7	4.2	1.55	15.1	33.3
Südafrika	1891	5	3	13	3	0	18	566	0	26	48	87	47	0	1	3.5	3.8	1.06	30.8	49.8
Super Alpha	3919	719	113	105	70	0	33	644	0	17	1	3	37	0	1	5.8	3.3	0.57	33.0	58.4
Talisman	1441	210	0	153	23	0	10	305	0	14	3	4	33	0	0	5.8	3.4	0.58	25.9	52.0

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	2975	2	0	19	69	0	57	738	100	23	4	6	45	0	1	1.6	3.0	1.84	36.1	44.6
Vojvodina	2769	345	0	116	23	0	22	466	3	14	2	3	32	0	1	3.6	2.3	0.66	31.6	49.9
WFG	3347	39	3	19	61	1	34	667	94	25	5	9	49	7	1	2.1	3.9	1.89	25.9	42.0
Willamette	1295	227	0	57	37	0	4	265	34	15	3	5	35	0	1	2.5	2.3	0.93	32.3	53.7
Wye Challenger	2306	476	6	109	59	0	29	373	6	15	25	53	34	2	0	3.6	3.0	0.83	28.6	46.7
Wye Northdown	1653	221	0	26	49	0	5	311	2	15	2	3	33	0	0	4.2	4.2	0.99	25.1	47.8
Wye Target	2567	500	2	88	82	0	33	343	0	33	7	10	66	13	2	9.7	3.8	0.39	31.8	61.0
Wye Viking	3632	384	3	269	48	0	47	437	130	15	0	39	35	0	1	7.0	4.4	0.64	21.1	40.8
Yeoman	1706	379	40	60	27	0	19	342	3	12	15	41	31	0	2	8.8	4.0	0.45	24.0	42.7
Zatecki	1582	214	0	42	47	0	10	425	25	13	3	6	31	0	0	1.1	1.9	1.67	24.8	46.9
Zenith	3034	245	1	136	87	0	24	477	2	14	39	86	35	0	1	5.6	2.9	0.51	22.7	55.4
Zeus	1986	394	66	120	21	0	2	262	0	40	9	14	83	0	1	15.7	5.3	0.34	32.9	55.3
Zitic	1510	3	0	25	18	0	20	433	5	15	3	4	34	0	1	2.9	2.9	0.99	27.9	49.1

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

Using the new gas chromatography/mass spectrometry system, 143 substances were identified with the help of mass spectra and also based on standards (Tab. 8.2). According to the literature, hop essential oil consists of 300 to 400 individual substances. However, the substances identified here almost certainly represent 99% of the oil components in hop in quantitative terms.

The new system of analysis makes it possible to characterize hop varieties in greater depth and detail. Completely new substances were also discovered, which, so far, have never been mentioned in the literature, e.g. perrilene, bergamotene, santalol etc.

Aroma analytics is carried out in order 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. Key substances exist but an aroma must also be seen holistically. There are synergies between the aroma substances; sometimes their effect is enhanced, at other times they cancel each other out. As is the case with bittering agents, the matrix effects of the beer also play a part.

Important aroma substances in order of significance are: linalool, geraniol, α terpineol, citronellol.

Tab. 8.2: Identified aroma substances

Substance	RT	Substance	RT	Substance	RT	Substance	RT
2-Methyl-4-pentanon	10.36	cis-ß-Ocimen	25.00	α-Cubeben	40.50	Cedren	55.58
3-Methyl-2-pentanon	10.58	Methyl-heptanoat	25.55	Ylangen	42.24	Methyl-7.8-octadecadienoat	55.70
α-Pinen	10.85	p-Cymen	26.55	Citronellal	42.32	Viridifloren	55.84
α-Thujen	11.02	α–Terpineol	27.40	alpha-Copaen	42.85	Methyl-geraniat	55.94
2-Methyl-3-buten-2-ol	11.48	2-Methybutyl-2-methylbutjat	27.42	Pelargonsäuremethylester	43.08	2-Dodecanon 1	56.40
Campfen	12.44	Oenanthsäure-methylester	28.05	2-Decanon	43.20	Valencen	56.75
Dimethyldisulfid	13.05	Tridecan	28.45	ß-Citral	43.84	Epizonaren	56.85
Propionsäure-isobutylester	13.15	Amylisovalerat	28.64	Farnesol	43.84	α-Copaen	57.05
Hexanal	13.44	2-Octen-4-on	29.05	S-Methyl-thioheptanoat	44.00	ß-Selinen	57.27
Isobutyl-isobutjat	13.62	Acetol	29.58	ß-Bourbonen	44.60	Zingiberen	57.39
ß-Pinen	14.10	3-Methyl-2-buten-1-ol	30.68	2-Nonanol	44.90	α-Selinen	57.56
Isobutanol	14.40	int. Standard	31.60	Benzaldehyd	45.29	Citral	58.06
Isoamylacetat	15.40	2-Pentensäure-3-ethylmethylester	31.80	α-Gurjunen 1	45.34	α-Gurjunen 2	58.07
3-Penten-2-on	16.45	Methyl-2.4-dimethylheptanoat	31.92	Methyl-4-nonenoat	45.40	α-Farnesen	59.00
S-Methyl-thioisobutjat	16.60	6-Methyl-5-hepten-2-on	32.05	Isobuttersäure-octylester	46.40	Geranylacetat	59.46
Mjcen	18.00	Methyl-6-methylheptanoat	32.25	Linalool	46.70	ß-Cadinen	59.50
Buttersäure-2-methyl-isobutylester	19.20	1-Hexanol	33.00	Geranylvinylether	46.88	y-Cadinen	59.63
α-Terpinen	19.35	S-Methyl-thiohexanoat (Isomer)	33.00	2-Undecanon	46.94	3.7-Selinadien	59.86
Hexansäure-methylester	20.00	Hopfenether	34.07	ß-Cedren	48.35	Curcumen	60.55
Propionsäure-()-methylbutylester	20.20	Isocyclocitral	34.55	2-Methyl-3-pentanol	48.60	Methylsalicylat	60.79
2.3-Dimethyl-3-buten-2-ol	20.38	Essigsäure-heptylester	34.70	Isobuttersäure	48.75	α-Cadinen	61.01
3-Methylbuthyl-isobutjat	20.48	Dimethyltrisulfid	35.15	alpha-Bergamoten	49.10	α-Muurolen	61.61
Limonen	20.58	4-Mercapto-4-methyl-2-pentanon	35.40	ß-Cubeben	49.50	3.6-Dodecadiensäure-	61.96
2-Metylbutyl-isobutjat	20.70	3-Hexenol	35.45	ß-Caryophyllen	49.90	Tridecanon	62.67

Substance	RT	Substance	RT	Substance	RT	Substance	RT
Prenal	21.40	2-Nonanon	35.75	ß-Caryophyllen_int	49.90	Geranyl-isobutjat	62.84
ß-Phellandren	21.40	Caprylsäuremethylester	35.90	Undecanon	50.03	Elixen	63.92
2-Methylbutanol	21.74	Nonanal	36.10	Aromadendren	50.45	Calamenen	64.20
S-Methyl-thio-2-methylbutjat	22.47	allo-Ocimen	36.21	5.5-Dimethylfuranon	50.74	Geraniol	64.95
S-Methyl-thio-isovalerat	23.12	S-Methyl-thiohexanoat	36.70	4-Decensäuremethylester	51.74	Tetradecanon	69.49
Pentylfuran	23.41	Citronellol	36.85	Methylgeranat	52.10	α-Calacoren	69.51
trans-ß-Ocimen	23.60	Perrilen	38.07	Undecansäure-methylester	53.23	2-Pentadecanon	71.60
Hexansäure-ethylester	23.75	Caprylsäure-ethylester	39.20	2-Dodecanon 2	53.51	Heptansäure	72.00
Propionsäureisopentylester	24.20	Propionsäure-heptylester	39.50	ß-Farnesen	54.13	Caryophyllenoxid 1	73.00
γ-Terpinen	24.35	Isobuttersäure-heptylester	39.60	Humulen	54.35	ß-Santalol	74.50
Methylisoheptanoat	24.40	Pelargonsäure-methylester	39.86	4.7-Selinadien	54.70	Humulen-2-epoxid	75.52
2-Methyl-1-penten-3-ol	24.65	1-Octen-3-ol	40.14	γ-Muurolen	55.45		

8.5.2 Analysis of sulphur compounds

Sulphur compounds are present only in trace amounts in the essential oils contained in hop. However, they have significance in terms of sensory impressions because of their very low odour detection thresholds. Particularly in special flavor hops they play a key role. Generally speaking, the sulphur compounds in hop can be subdivided into three groups:

- alkyl sulphides and polysulphides
- thioesters
- polyfunctional thiols

Sulphur compounds can be measured highly selectively with a flame photometric detector; when sulphur atoms burn, they emit light with a wavelength of 394 nm (Fig. 8.6).

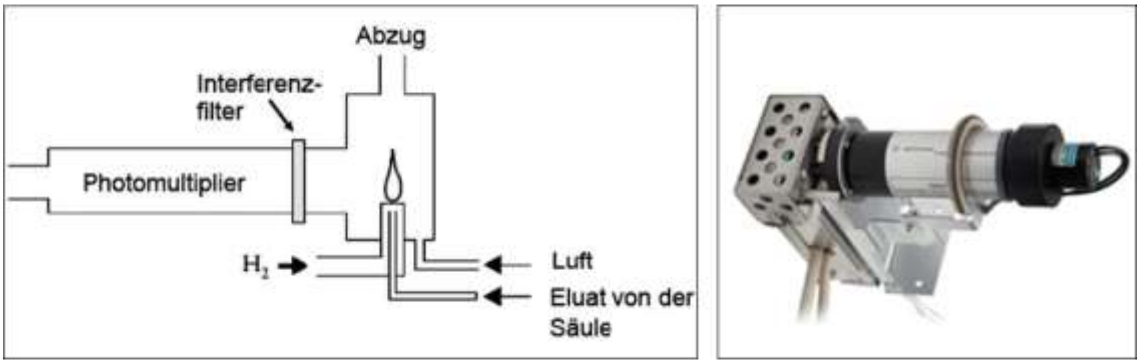


Fig. 8.6: Principle of a flame photometric detector

Fig. 8.7 shows a chromatogram of cultivar Polaris

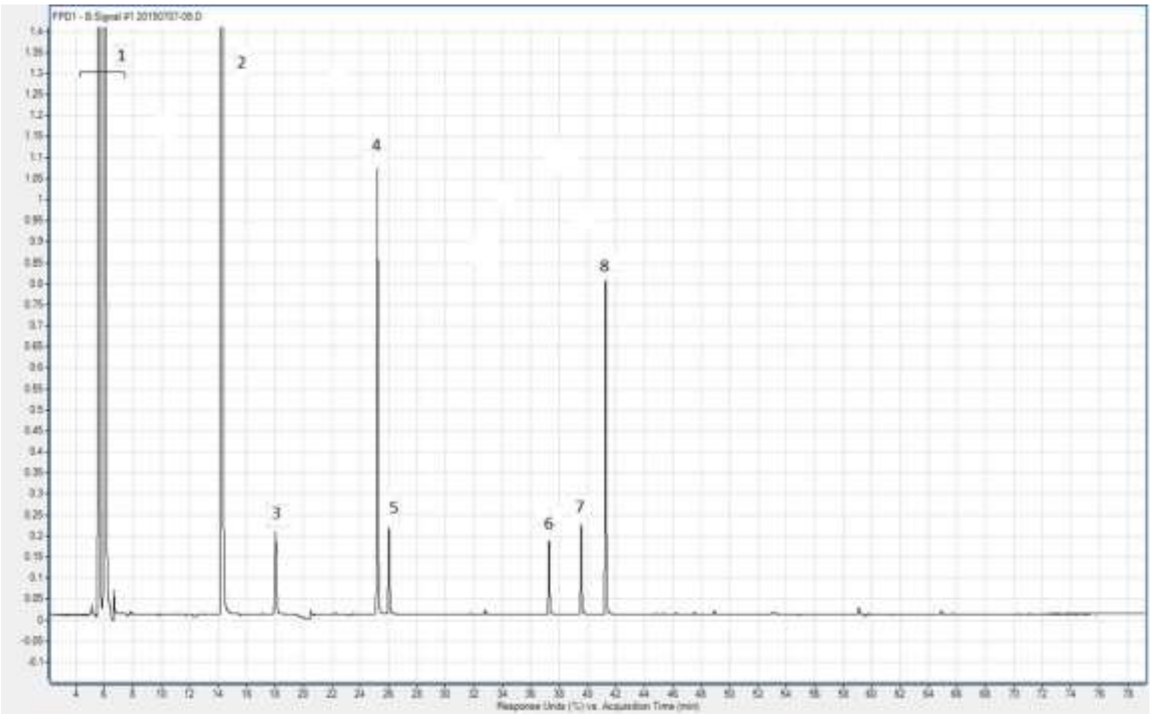


Fig. 8.7: Sulphur compounds in cultivar Polaris

It is plain to see that hop does not have very many sulphur compounds. They were clearly identified with the help of pure substances and comparison with the mass spectra. (Tab. 8.3).

Tab. 8.3: Main sulphur compounds in hop

1)	H_2S, Methyl mercaptan, dimethyl sulphide
2)	Dimethyl disulphide
3)	S-Methyl thio isobutyrate
4)	S-Methyl thio-2-methyl butyrate
5)	S-Methyl thio isovalerate
6)	S-Methyl thio hexanoate (isomer), probably S-Methyl thio-4-methyl pentanoate
7)	Dimethyl trisulphide
8)	S-Methyl thio hexanoate

When the chromatogram is shown at a higher sensitivity (Fig. 8.8). it is possible to see that there are still a few smaller spikes, but it will be difficult to identify them because they can no longer be detected in the mass spectrometer.

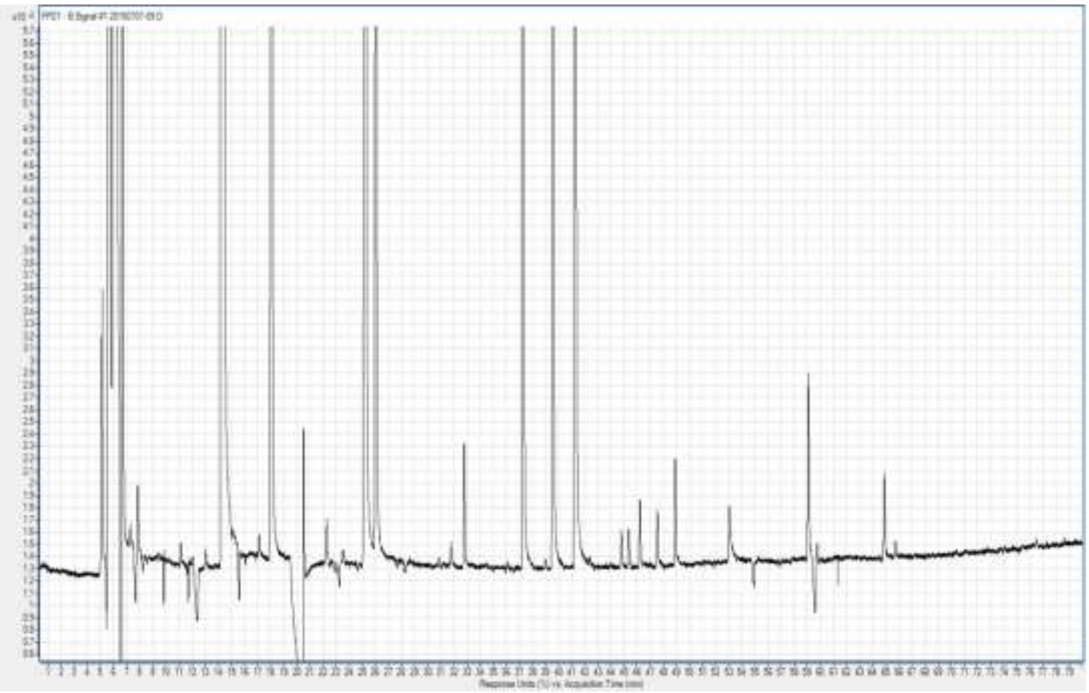


Fig. 8.8: Sulphur compounds in cultivar Polaris (higher resolution)

The very small spikes are concentrated in the ppb range and it is doubtful whether these minor sulphur compounds contribute anything to sensory impressions.

A flame photometric detector is not really suitable for quantitive evaluations because it does not produce linear signals.

8.5.2.1 Alkyl sulphides and polysulphides

Alkyl sulphides and polysulphides arise during the decomposition of proteins (sulphur-containing amino acids such as methionine and cysteine). They have a sulphurous cabbage-like smell reminiscent of boiled vegetables and are regarded as being on the negative side; hop should contain only slight amounts.

Fig. 8.9 shows how alkyl sulphides are formed.

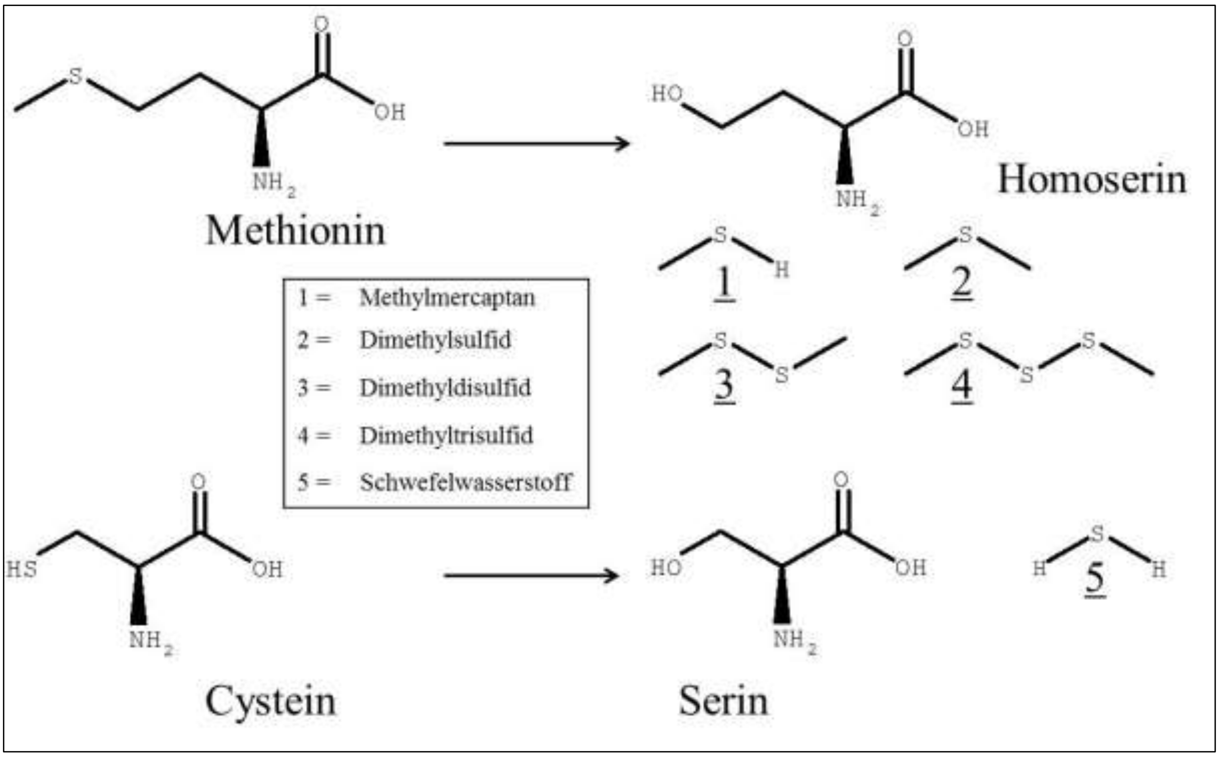


Fig. 8.9: Formation of alkyl sulphides

Tab. 8.4: Alkyl sulphides and polysulphides in hop

Compound	Odour threshold ppb	Olfactory impression
Hydrogen sulphide	20 - 100	rotten eggs
Methyl mercaptan	20	rotting vegetables, unpleasant
Dimethyl sulphide	25 – 60	boiled vegetables, oniony, rubber
Dimethyl disulphide	3 – 50	boiled vegetables, oniony, sulphurous
Dimethyl trisulphide	0.1	boiled vegetables, oniony, sulphurous
Dimethyl tetrasulphide	0.2	boiled vegetables, oniony, sulphurous

8.5.2.2 Thioesters

The thioesters S-Methyl thio isobutyrate, S-Methyl thio-2-methyl butyrate and S-Methyl thio isovalerate are very similar to the lateral chains of alpha acids. They probably arise via the biosynthetic pathway of the alpha acids (Fig. 8.10).

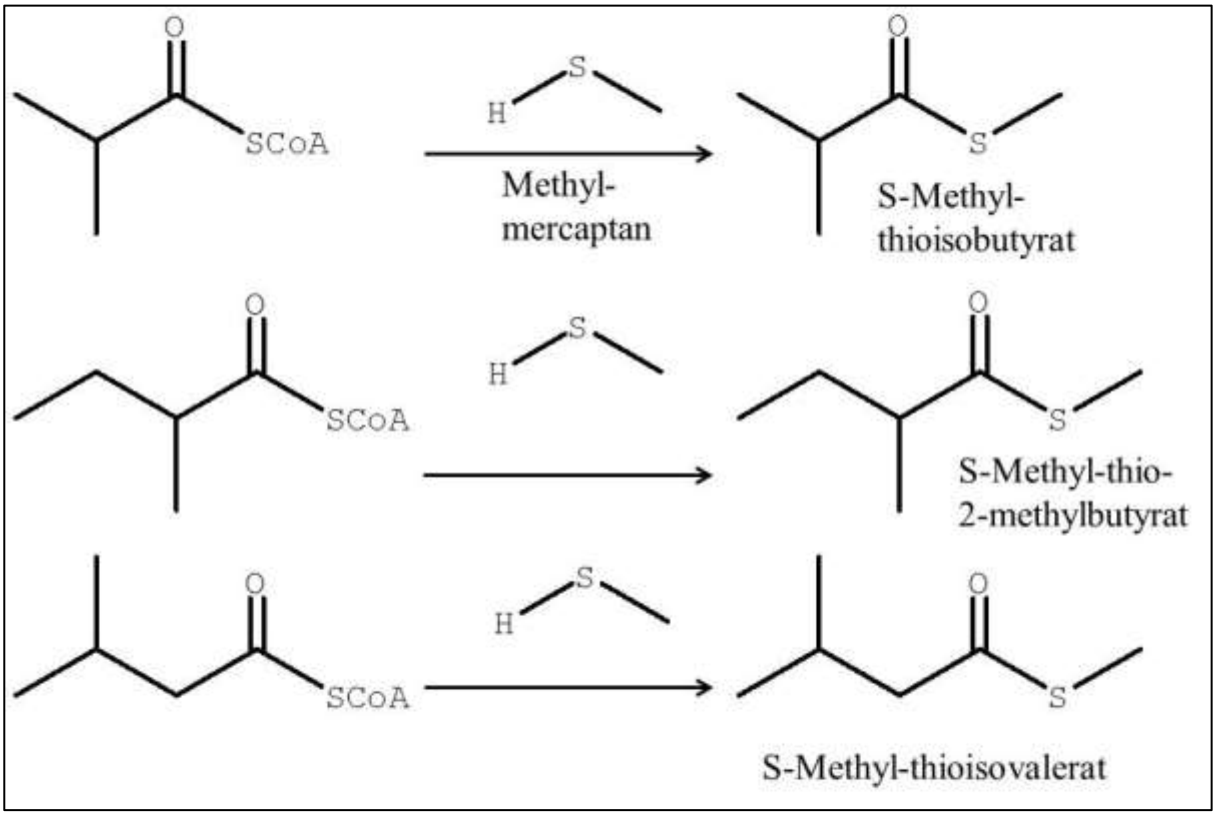


Fig. 8.10: How thioesters are formed

S-Methyl thio hexanoate and S-Methyl thio-4-methyl pentanoate are probably produced by fatty acid metabolism.

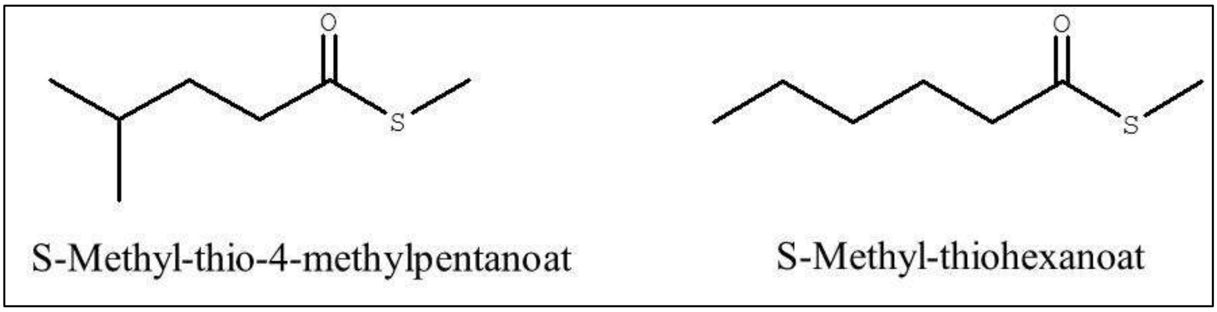


Fig. 8.11: S-Methyl thio hexanoate and S-Methyl thio-4-methyl pentanoate

Tab. 8.5: Thioesters in Hop

Compound	Aroma threshold ppb	Olfactory impression
S-Methyl thio isobutyrate	4 - 40	cheesy, boiled vegetables
S-Methyl thio-2-methyl butyrate	1	soapy, boiled vegetables
S-Methyl thio isovalerate	50	cheesy, boiled vegetables
S-Methyl thio-4-methyl pentanoate	15	musty, boiled vegetables
S-Methyl thio hexanoate	0.3 -1	soapy, boiled vegetables

Thioesters are also regarded as having a negative effect. According to A. Suggett, M. Moir and J.C. Seaton in the *Proceedings of the European Brewery Convention Congress*, Berlin (West) 1979, 79-89, hops with high levels of thioesters are not suitable for "flavour hopping".

Levels and composition of thioesters are definitely specific to each hop cultivar. *Polaris* has a particulary high thioester content (S-Methyl thio hexanoate in particular) and this is probably the reason why this cultivar is not suitable for dry hopping.

8.5.2.3 Polyfunctional thiols

Hop contains only very small quantities (ppb) of polyfunctional thiols. However, they have extremely low odour detection thresholds and thus contribute to the aroma of the hop (Fig. 8.12).

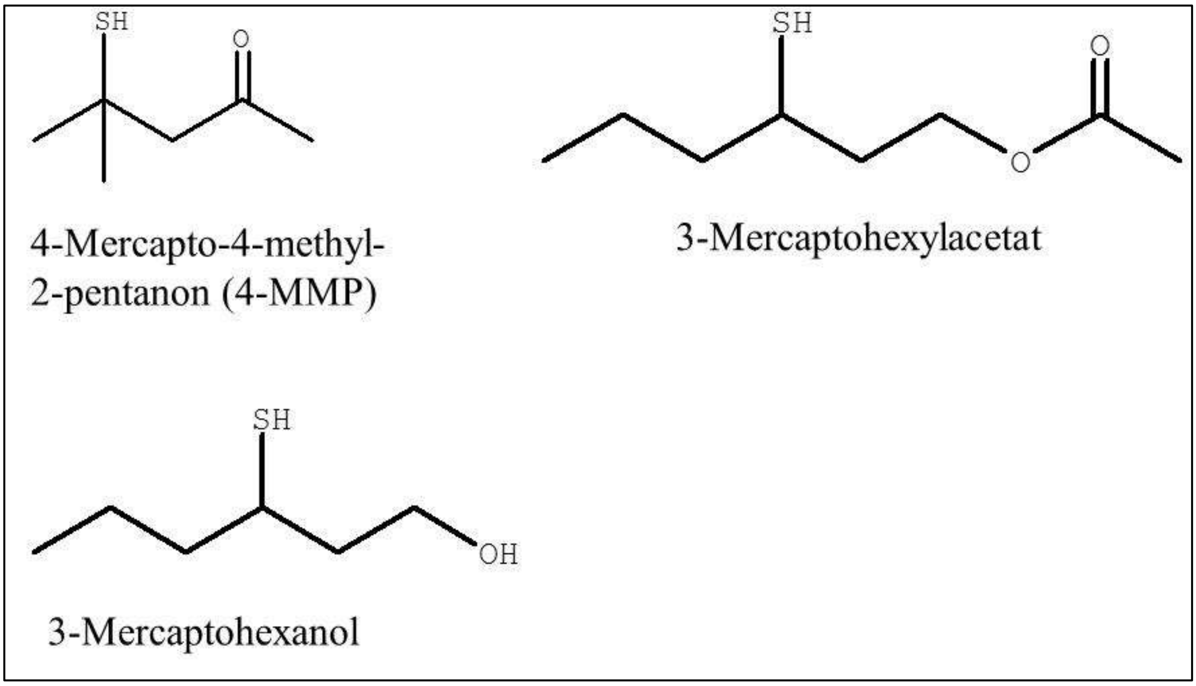


Fig. 8.12: Important polyfunctional thiols in hop

Tab. 8.6: Polyfunctional thiols in hop

Compound	Aroma threshold ppb	Ofactory impression
4-Mercapto-4-methyl-2-pentanone	0.8	blackcurrant, box tree
3-Mercapto hexanol	4.2	blackcurrant, passion fruit
3-Mercapto hexyl acetate	60	grapefruit, passion fruit

Polyfunctional thiols arise via glutathione and are stored as S-cysteine conjugates in the cell vacuoles (Fig. 8.13). They can be released during alcoholic fermentation. According to the literature, 10%-20% of the polyfunctional thiols in hop are bound to cysteine.

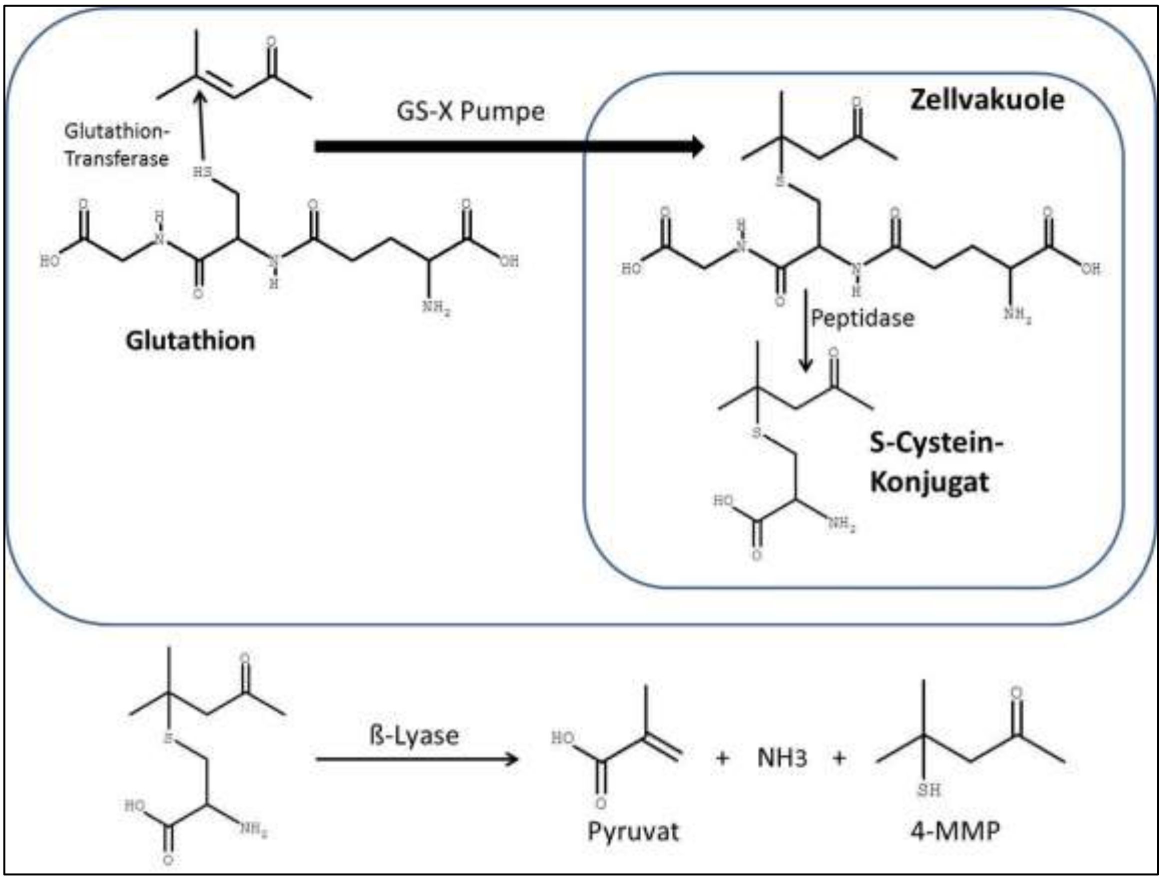


Fig. 8.13: Biosynthesis model for 4-Mercapto-4-methyl-2-pentanone (M. Wüst (2003)), Chemie in unserer Zeit, 37, 8-17

The substance 4-MMP has one of the most intensive smells in existence. As a pure substance, it has the pungent smell of cat urine. In very low concentrations (ppb), however, it is responsible for the aroma typical of blackcurrant (cassis, ribes nigrum). 4-MMP is typical of cultivar *Cascade*.

All three polyfunctional thiols described here are found in the new special flavor hops from Hüll. Work on quantitative measurement is in progress.

8.6 Jakob Münsterer Drying Project

As part of the Jakob Münsterer project, extensive tests were carried out in order to establish whether drying has an impact on component compounds. The bittering agents do not change at all during drying. Within the essential oils, it was found that myrcene and hexanal were significantly reduced. Myrcene is also found in the condensation from hop kilns. Hexanal is also known as grass aldehyde (Fig. 8.14) and is responsible for the smell typical of green grass.

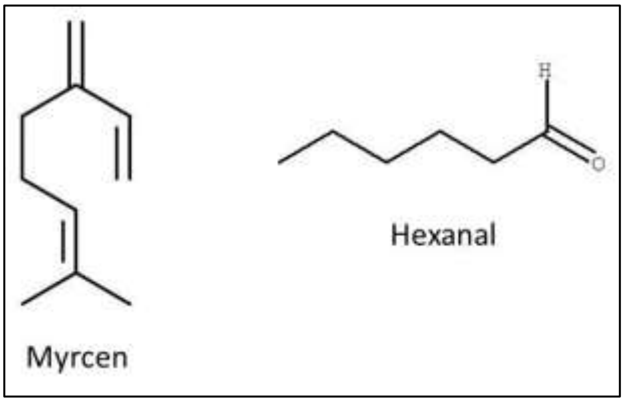


Fig. 8.14: Myrcene and hexanal

The substance 5.5 dimethyl-(5H)-2-furanone increases significantly. It arises during oxidation of β acids (Fig. 8.15).

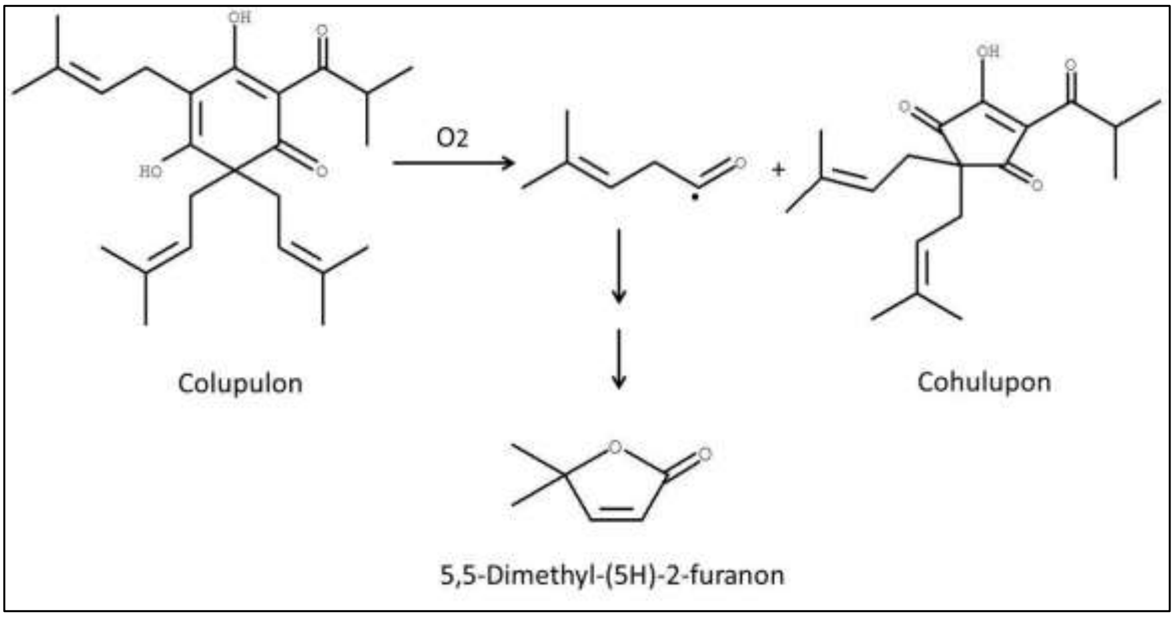


Fig. 8.15: How hulupone and 5.5 dimethyl-(5H)-2-furanone are formed

More work will be done with the aim of carrying our quantitative measurements to determine to what extent myrcene and hexanal decrease: when hop is still green, through freeze drying and during the conventional drying process.

8.7 Multi-laboratory Ring Analysis of the 2016 Crop

Since 2000, hop supply contracts have included a supplementary agreement regarding 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 Hop Analytics Working Group 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 2016, 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 2016, the following labs participated in the ring analysis:

- Hallertauer Hopfenveredelungsgesellschaft (HHV), Au/Hallertau plant
- HV, Wolnzach
- Hopfenveredlung St. Johann GmbH & Co. KG. St, Johann
- Hallertauer Hopfenveredelungsgesellschaft (HHV), Mainburg plant
- Hallertauer Hopfenverwertungsgenossenschaft (HVG), Mainburg
- Agrolab GmbH, Oberhummel
- Bavarian State Research Center for Agriculture, Hops Department, Hüll

The ring analysis began in 2016 on September 13 and finished on November 11, with most of the hop batches having been analysed during this time. Altogether, ring analyses were performed nine times (9 weeks). The sample material was very kindly provided by Mr. Hörmannsperger (Hopfenring Hallertau). The samples were each 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 2016, a total of 34 samples were analysed.

The evaluation findings were passed on to the individual labs as soon as possible. Fig. 8.16 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.

Nr. 10: HPE (28.09.2016)

Labor	KW		mittel	s	cvr
1	8,84	8,78	8,81	0,042	0,5
2	8,75	8,78	8,77	0,021	0,2
3	8,74	8,70	8,72	0,028	0,3
4	8,68	8,63	8,66	0,035	0,4
5	8,79	8,82	8,81	0,021	0,2
6	8,84	8,82	8,83	0,014	0,2
7	8,75	8,90	8,83	0,106	1,2

mean	8,77
sr	0,048
sL	0,055
sR	0,073
vkr	0,55
vkR	0,83
r	0,13
R	0,20
Min	8,63
Max	8,90

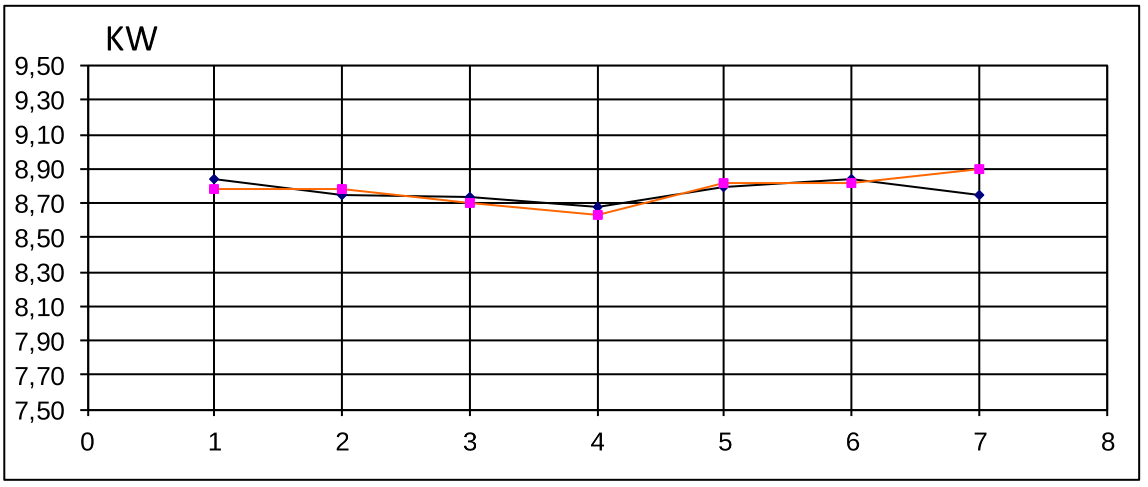


Fig. 8.16: Evaluation of a ring analysis

The outliers in 2016 are shown in Tab. 8.7.

Tab. 8.7: 2016 outliers

	Cochran		Grubbs	
Sample	α = 0.01	α = 0.05	α = 0.01	α = 0.05
12	0	0	0	5
Total:	**0**	**0**	**0**	**1**

As of 2013, there are now 5 alpha classes and new tolerance limits. Tab. 8.8 shows the new alpha acids classes and the outliers in 2016.

Tab. 8.8: Updated alpha acids classes and tolerance limits; outliers in 2016

	< 5.0 % α acids	5.0 % - 80 % α acids	8.1 % - 11.0 % α acids	11.1 % - 14 % α acids	> 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 2016	1	2	0	0	2

In 2016, the permitted tolerance limits were overrun in five cases; one was a sample with an alpha acids content below 5.0%, two were samples with between 5% and 8%, and two were samples with over 14%.

Fig. 8.17 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.

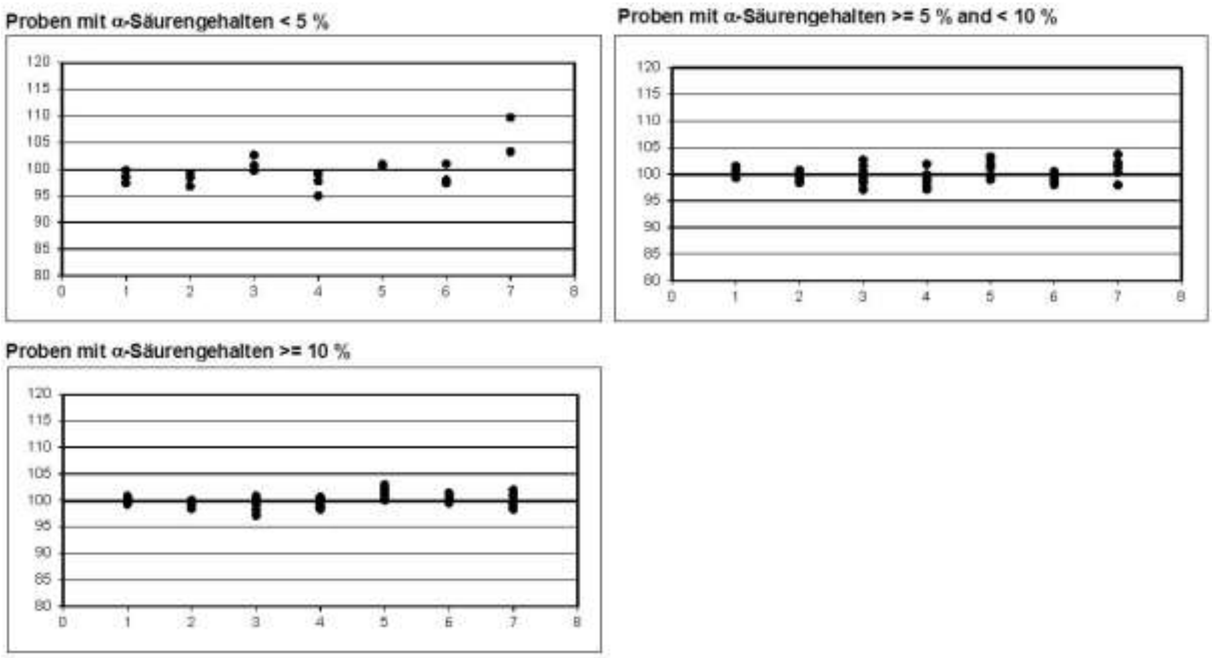


Fig. 8.17: Test results of the laboratories relative to the mean

The Hüll lab is number 5.

8.7.1 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 analysis 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. 8.9 shows the results for 2016. Two reliability checks were not validated.

Tab. 8.9: Analysis reliability checks in 2016

Sample designation	Initial test laboratory	Initial test	reliability check			Mean value	Result validated
			1	2	3		
HT 23624	Agrolab	6.5	6.0	6.0	6.0	6.00	no
HA 23621	Agrolab	5.7	5.1	5.1	5.1	5.10	no
PE 23594	Agrolab	8.9	8.4	8.4	8.5	8.43	yes
KW 38 HHM	HHV AU	13.5	13.6	13.7	13.7	13.67	yes
KW 38 HHS	HHV AU	17.8	17.6	17.7	17.9	17.73	yes
KW 38 HNB	HHV AU	11.4	11.3	11.5	11.6	11.47	yes
HHT KW 39	HVG Mainburg	6.8	6.8	6.9	7.0	6.90	yes
HNB KW 39	HVG Mainburg	10.4	10.4	10.5	10.6	10.50	yes
HPE KW 39	HVG Mainburg	9.1	9.0	9.2	9.3	9.17	yes
QK 2467 HHM	HV Wolnzach	14.2	13.9	13.9	14.2	14.00	yes
QK 2454 HHS 1	HV Wolnzach	16.1	16.3	16.5	16.6	16.47	yes
QK 2456 HHS 2	HV Wolnzach	18.4	18.4	18.6	18.6	18.53	yes
PE 28096	Agrolab	8.5	8.2	8.2	8.3	8.23	yes
HM 28072	Agrolab	13.0	12.8	12.9	12.9	12.87	yes
HS 29614	Agrolab	17.8	17.9	18.1	18.3	18.10	yes
KW 42 HHS 2	HHV AU	16.7	16.8	16.8	16.9	16.83	yes
KW 42 HHM	HHV AU	14.8	14.8	14.8	14.9	14.83	yes
KW 42 HHS 1	HHV AU	13.5	13.3	13.5	13.9	13.57	yes
KW 43 27903	HVG Mainburg	18.1	18.2	18.3	18.3	18.27	yes
KW 43 27903	HVG Mainburg	5.9	6.0	6.0	6.1	6.03	yes
KW 43 27903	HVG Mainburg	13.5	13.4	13.5	13.5	13.47	yes
QK 4718 HNB	HV Wolnzach	9.4	9.3	9.3	9.3	9.30	yes
QK 4724 HHM	HV Wolnzach	12.2	12.1	12.2	12.2	12.17	yes
QK 4733 HHS	HV Wolnzach	15.4	15.3	15.4	15.5	15.40	yes

8.8 Expansion of the NIRS Calibration Model

Work has been in progress since 2000 on developing an NIR spectroscopy method for hop bitter compounds, in what was originally a collaborative project with the AHA Hop Analytics Working Group. However, in 2008, the AHA labs withdrew from the project and Hüll continued to develop calibration alone. Every year, ring analysis samples have been added, as well as conductometric and HPLC values. Meanwhile, the calibration of bitter compounds has become very good and is perfectly suitable as a screening method in breeding work. Fig. 8.18 shows the conductometric and NIRS values in comparison (ring analysis 2015). The differences upward and downward balance each other out. Water is a good absorber in the NIR range and is therefore easily quantifiable via NIRS.

The Gesellschaft für Hopfenforschung *(Society of Hop Research)* has now approved the purchase of new equipment.

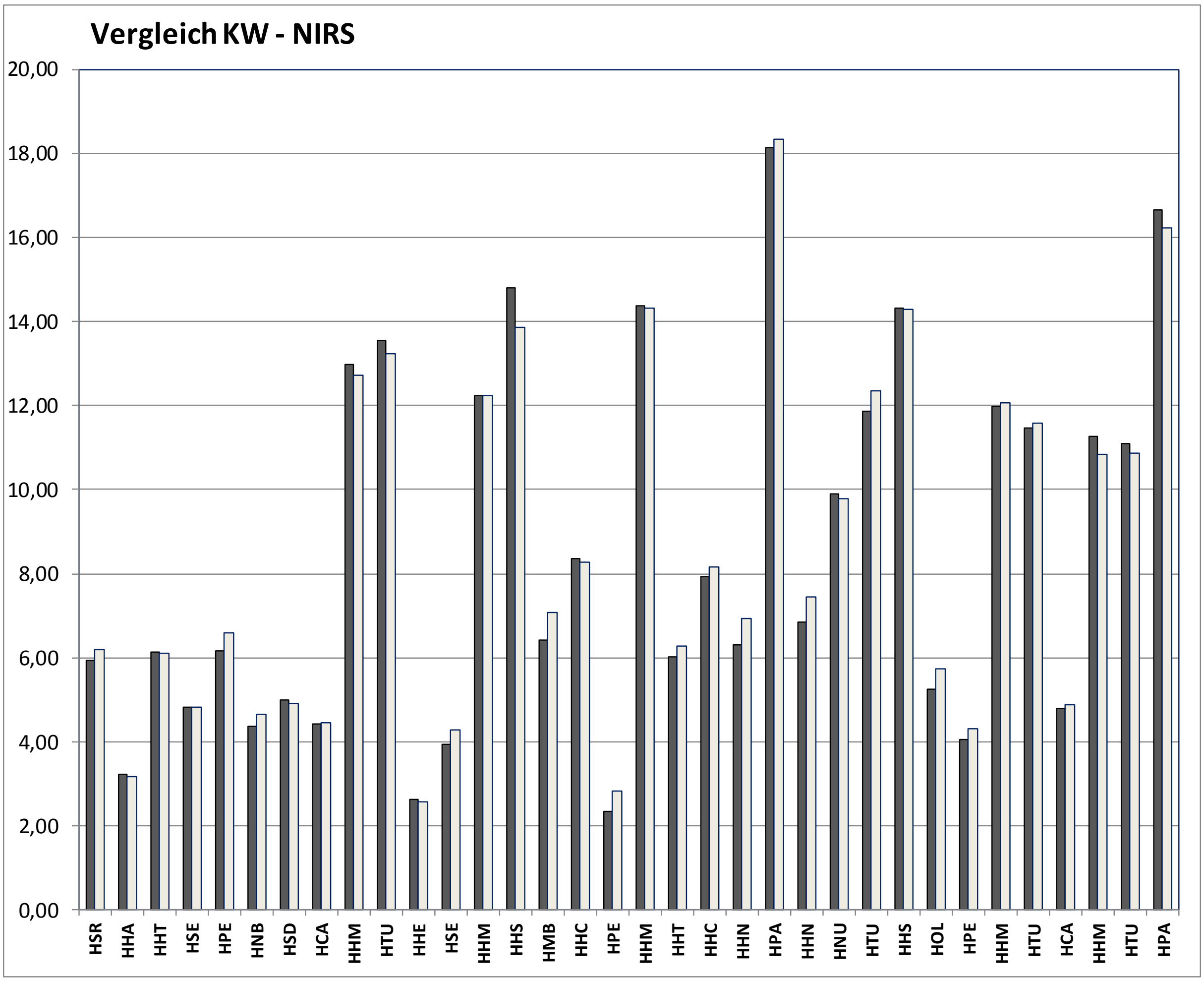


Fig. 8.18: Conductometric and NIRS values compared (ring analysis 2015)

8.9 Analyses for WG IPZ 3d „Medicinal and Aromatic Plants“

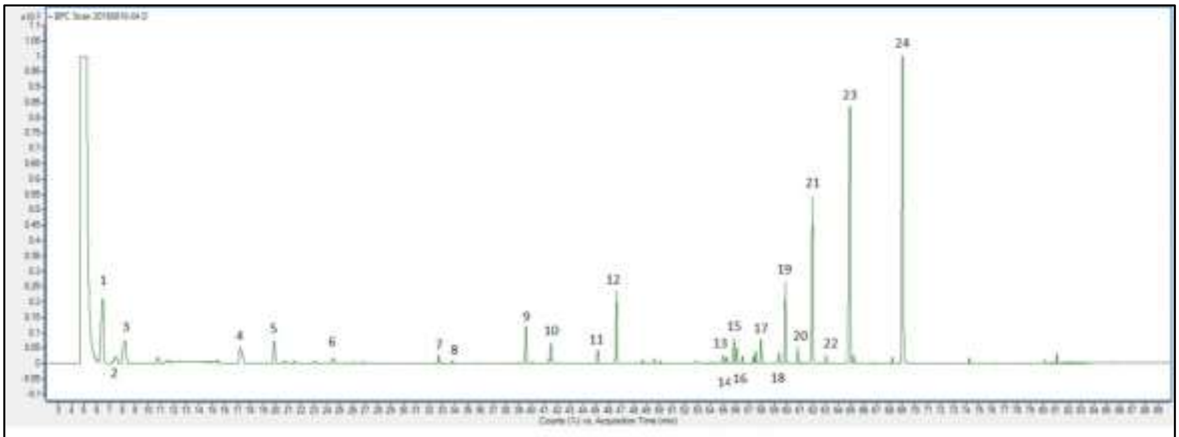
The following special analyses were performed on behalf of IPZ 3d Medicinal and Aromatic Plants:

Saposhnikovia divaricata
Prim-O-glucosylcimifugin and 5-O- methylvisamminosid: 15 duplicate determinations

Salvia miltiorrhiza
Tanshinone IIA and salvianolic acid B: 15 duplicate determinations

Rose oils

The components of 11 rose oils were determined**.** The composition of rose essential oils is far simpler than that of hop essential oils. The main components are citronellol, nerol, geraniol and phenyl ethanol**.** Fig. 8.19 shows a typical rose oil chromatogram and the identified spikes.



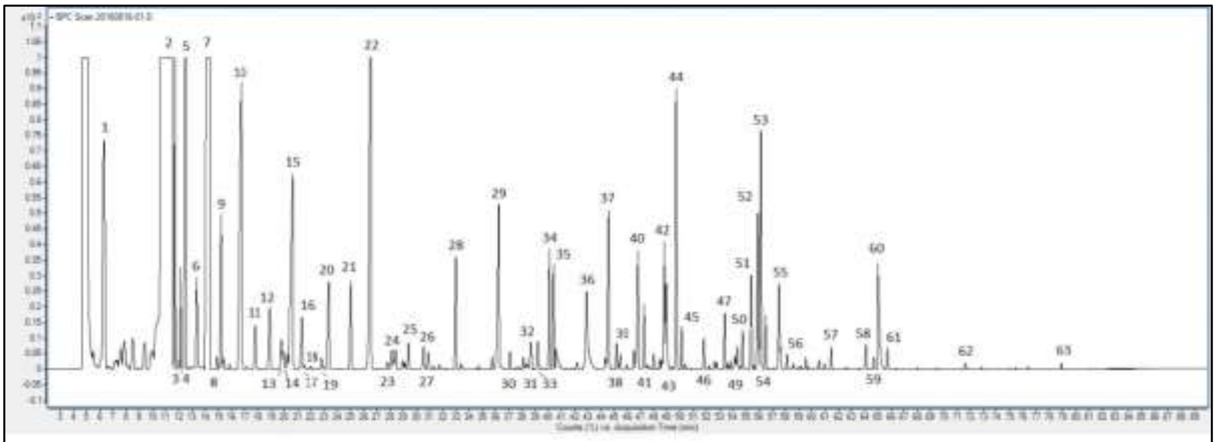
1 =	Acetone	13 =	ß-Citral
2 =	Methanol	14 =	γ-Muurolene
3 =	Ethanol	15 =	α-Terpineol
4 =	Myrcene	16 =	endo-Borneol
5 =	2,3-Dehydro-1,3-cinneol	17 =	α-Citral
6 =	3-Carene	18 =	Farnesol acetate
7, 8 =	Rose oxide	19 =	Citronellol
9, 10 =	Ethyl 2-(5-methyl-5-vinyltetra hydrofuran-2-yl) propane-2-yl carbonate	20 =	p-Mentha-1,5-dien-8-ol
		21 =	cis-Geraniol (Nerol)
11 =	Benzaldehyde	22 =	Acetic acid phenyl ethyl ester
12 =	Linalool	23 =	trans-Geraniol
		24 =	Phenyl ethanol

Fig. 8.19: Rose oil chromatogram and the substances identified

Stone pine essential oils

Four stone pine oils were analysed and their components identified using GC/MS.

Fig. 8.20 shows a typical chromatogram with the substances that were identified. Stone pine oil is far more complex in composition. The main components are alpha and beta pinene.



1 =	Acetone	23 =	Octanol acetate	44 =	Isothymol-methyl-ether
2 =	α-Pinene	24 =	Octanol	45 =	(-)-Terpinene-4-ol
3 =	Toluol	25 =	Isopropyl hydroperoxide	46 =	(-)-4-Terpineol
4 =	Camphene (3R, 4S)	26 =	6-(1-Hydroxy-1-methyl ethyl)-	47 =	Myrtenal
5 =	Camphene (3S, 4R)		3-methyl-2-cyclohexene-1-ol	48 =	L-Pinocarvenol
6 =	Hexanal	27 =	n-Heptyl-formate	49 =	Crypton
7 =	ß-Pinene	28 =	Hexanol	50 =	cis-Verbenol
8 =	ß-Phellandrene	29 =	Fenchone	51 =	γ-Muurolene
9 =	2,4(10)-Thujadien	30 =	3-Octene-2-on	52 =	α-Terpineol
10 =	3-Carene	31 =	cis-ß-Dihydroterpinol	53 =	endo-Borneol
11 =	α-Pinene	32 =	(E)-2-Octene-1-al	54 =	Berbenone
12 =	m-Cymene	33 =	3, 4-Dimethyl styrol	55 =	α-Muurolene
13 =	2-Heptanone	34 =	Amyl-vinyl-carbinol	56 =	(-)-Carvone
14 =	Heptanal	35 =	1-Heptanol	57 =	Myrtenol
15 =	Limonene	36 =	α-Campholenal	58 =	cis-Carveol
16 =	ß-Phellandrene	37 =	(+)-2-Bornanone	59 =	p-Cymene-8-ol
17 =	Cinneol	38 =	Benzaldehyde	60 =	Hexanoic acid
18 =	p-Mentha-1,3,8-trien	39 =	p-Ethylanisol	61 =	Benzyl acetone
19 =	n-Hexyl formate	40 =	ß-Maalien	62 =	Heptanoic acid
20 =	n-Pentylfuran	41 =	Octanol	63 =	Cinnamic acid ethyl ester
21 =	n-Pentanol	42 =	(-)-Bornyl-acetate		
22 =	p-Cymene	43 =	Fenchol		

Fig. 8.20: Stone pine oil chromatogram and the substances identified

8.10 Verification of Varietal Authenticity 2016

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

Varietal verifications fort he food control authorities (Landratsämter - *rural district administration offices*)	39
Number not accepted	0

9 Publications and Specialist Information

9.1 Overview of PR Activities

	Number		Number
Practice-relevant information and scientific papers	43	Guided tours	50
LfL publications	2	Exhibitions and posters	9
Press releases	-	Basic and continuing training courses	23
Radio and TV broadcasts	6	Diploma, bachelor and master theses	2
Conferences, trade events and seminars	7	Participation in working groups	29
Lectures and talks	98	Foreign guests	292

9.2 Publications

9.2.1 Practice-relevant information and scientific papers

Fuß. S. (2016): Pflanzenstandsbericht April 2016. Hopfen-Rundschau. 67. Jahrgang; Nr. 5. Hrsg.: Verband Deutscher Hopfenpflanzer e.V.. 173

Fuß. S. (2016): Pflanzenstandsbericht August 2016. Hopfen-Rundschau. 67. Jahrgang; Nr. 9. Hrsg.: Verband Deutscher Hopfenpflanzer e.V.. 339

Fuß. S. (2016): Pflanzenstandsbericht Juli 2016. Hopfen-Rundschau. 67. Jahrgang; Nr. 8. Hrsg.: Verband Deutscher Hopfenpflanzer e.V.. 308

Fuß. S. (2016): Pflanzenstandsbericht Juni 2016. Hopfen-Rundschau. 67. Jahrgang; Nr. 7. Hrsg.: Verband Deutscher Hopfenpflanzer e.V.. 255

Fuß. S. (2016): Pflanzenstandsbericht Mai 2016. Hopfen-Rundschau. 67. Jahrgang; Nr. 6. Hrsg.: Verband Deutscher Hopfenpflanzer e.V.. 214

Hanke. S.. Schüll. F.; Seigner. E.; Lutz. A. (2016): Development of a Tasting Scheme and a New Systematic Evaluation Program for new German Breeding Lines by example of the New German varieties Callista (CI) and Ariana (AN). BrewingScience - Monatsschrift für Brauwissenschaft. 69. Hrsg.: Fachverlag Hans Carl . 94 - 102

Jereb. M.. Weihrauch. F. (2016): Einsatz und Etablierung von Raubmilben zur nachhaltigen Spinnmilbenkontrolle in der Sonderkultur Hopfen. Hrsg.: LfL. 1 - 61

Jereb. M.. Weihrauch. F. (2016): Use and establishment of predatory mites for sustainable control of two-spotted spide mite (Tetranychus urticae) in hop. DGaaE-Nachrichten. 30 (1). Hrsg.: Deutsche Gesellschaft für allgemeine und angewandte Entomologie. 17 - 17

Kammhuber. K. (2016): Der Einfluss des Erntezeitpunkts auf das Aroma des Hopfens. Flyer Hopfenrundfahrt 2016. Hrsg.: Hopfenpflanzerverband e. V.. 2

Kammhuber. K. (2016): Der Einfluss des Erntezeitpunkts auf das Aroma des Hopfens. Hopfen-Rundschau. 09. Hrsg.: Verband Deutscher Hopfenpflanzer e.V.. 333

Kammhuber. K. (2016): Resultse von Kontroll- und Nachuntersuchungen für Alphaverträge des Jahres 2015. Hopfen-Rundschau. 08. Hrsg.: Hopfenpflanzerverband e. V.. 310 - 312

Kammhuber. K. (2016): Untersuchungen zur Biogenese des Gesamtölgehalts. Hopfen-Rundschau. 07. Hrsg.: Hopfenpflanzerverband. 259 - 260

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9.2.2 LfL Publications

Name	WG	LfL publications	Title
Hops Department IPZ	IPZ 5	LfL Information	Annual Report 2015 – Special Crop: Hop
Portner, J.	IPZ 5a	LfL Information	Hop 2016 – Green Pamphlet

9.2.3 Radio and TV broadcasts

Broadcast date	People	Title	Series	Channel
16.02.2016	Kammhuber, K. Lutz, A.	Beer that tastes of passion fruit or mandarin oranges?	Zeitfragen	Deutschland-radio
06.03.2016	Lutz, A.	Beer – A world history	Terra X	ZDF
11.04.2016	Lutz, A.	The beer rebels	Bayern erleben	BR
08.07.2016	Lutz, A.	Marktgemeinde Wolnzach - the place where the hops come from	Abendschau	BR
17.09.2016	Lutz, A.	The keepers of the hops – what will tomorrow's beer taste like?	W wie Wissen	ARD
30.12.2016	Lutz, A.	Big Brew – Germany and its beers	n24 Doku	n24

9.3 Conferences. Talks and Lectures. Guided Tours. Exhibitions

9.3.1 LfL Events

Organized by	Subject/Title	Attendees	Date/ Venue
Münsterer, J. IPZ 5a	Workshop on irrigation - organization and implementation	Hop growers (12 attendees)	Hüll 16.02.2016
Münsterer, J. IPZ 5a	Workshop on hop drying - organization and implementation	Hop growers (25 attendees)	Hüll 16.02.2016
Münsterer, J. IPZ 5a	Effects of different measures to protect against erosion using a rain simulator - field day	Hop growers (150 attendees)	Dietrichsdorf 27.05.2016
Ismann, D. Kneidl, J. Lutz, A. Seigner, E. IPZ 5c	Hop Advisory Board – working group meeting	Hops and brewing industries, TUM Brewing Department (25 attendees)	Hüll 06.09.2016
Ismann, D. Kneidl, J. Lutz, A. Seigner, E. IPZ 5c	Hop Advisory Board – working group meeting	Hops and brewing industries (24 attendees)	Hüll 10.10.2016

9.3.2 External Events

Organized by	Subject/ Title	Venue/Date	Involved
TUM Experimental Brewery; LS Brewing and Beverage Technology	Beer tasting - new breeding lines	Freising 26.04.2016	Lutz, A. IPZ 5c
StMELF, LWG	Regional Horticultural Show	Bayreuth 21.-27.07.2016	Portner, J. Fischer, E. Lutz, M. IPZ 5a
Hop Growers' Association	Plant protection symposium – demonstration of equipment technology to reduce accidental drifting	Buch 26.08.2016	Portner, J. IPZ 5a

9.3.3 Talks and lectures

Speakers	Subject/Title	Organizers/ Target Group	Venue/ Date
Doleschel, P. Graf, T. Portner, J.	Address: "Hop irrigation – a challenge"	HVG Hop Producer Group, hop growers and members of HVG e.G.	Wolnzach, 23.02.2016
Doleschel, P.	*Bavarian Beer* - How does the LfL support the value chain?	LfL, brewers, malters, hop producers, the hops trade, advisors, farmers, politicians, association representatives	München, 17.03.2016

Speakers	Subject/Title	Organizers/ Target Group	Venue/ Date
Doleschel, P. Kammhuber, K. Portner, J. Seigner, E. Sichelstiel, W. Weihrauch, F.	LfL hop research and advisory activities in Bavaria in 2015	Members of the Society of Hop Research	Wolnzach, 05.04.2016
Doleschel, P.	Climate change and the challenges associated with it facing hop research in Bavaria	Society of Hop Research, Science and Technology Advisory Committee of the Society of Hop Research	Aldersbach, 10.05.2016
Doleschel, P. Seigner, E.	Plant breeding – a key component in facing climate change	LfL, and LfL Science and Technology Advisory Committee	Freising, 06.07.2016
Jereb, M.	Deployment and establishment of predator mites for sustainable spider mite control in hop as a speciality crop	Bioland, organic hop farmers and organic farming advisory service	Kloster Plankstetten, 02.02.2016
Jereb, M. Weihrauch, F.	Deployment and establishment of predator mites for sustainable management of spider mites in hop farming: background and findings after three years'work on the project	Society of Hop Research, Science and Technology Advisory Committee of the Society of Hop Research	Aldersbach, 10.05.2016
Kammhuber, K.	Determination of alpha acids content for alpha contracts – quality assurance methods	LfL + AELF Abensberg, hop growers	Biburg, 25.01.2016
Kammhuber, K.	Determination of alpha acids content for alpha contracts – quality assurance methods	LfL + AELF Pfaffenhofen, hop growers	Lindach, 26.01.2016
Kammhuber, K.	Determination of alpha acids content for alpha contracts – quality assurance methods	LfL + AELF Abensberg, hop growers	Mainburg, 27.01.2016
Kammhuber, K.	Determination of alpha acids content for alpha contracts – quality assurance methods	LfL + AELF Erding, hop growers	Osseltshausen, 28.01.2016
Kammhuber, K.	Determination of alpha acids content for alpha contracts – quality assurance methods	LfL + AELF Landshut, hop growers	Oberhatzkofen, 29.01.2016
Kammhuber, K.	Determination of alpha acids content for alpha contracts – quality assurance methods	LfL + AELF Roth, hop growers	Hedersdorf (Hersbruck), 01.02.2016
Kammhuber. K.	Determination of alpha acids content for alpha contracts – quality assurance methods	LfL + AELF Roth, hop growers	Spalt, 01.02.2016

Speakers	Subject/Title	Organizers/ Target Group	Venue/ Date
Kammhuber, K.	Determination of alpha acids content for alpha contracts – quality assurance methods	LfL + AELF Pfaffenhofen, hop growers	Niederlauterbach, 03.02.2016
Kammhuber, K.	Determination of alpha acids content for alpha contracts – quality assurance methods	LfL + AELF Abensberg, hop growers	Marching, 05.02.2016
Kammhuber, K.	Current status of analytical aroma testing in the laboratory at Hüll	Society of Hop Research (GfH), representatives from the hops industry, brewers, hop scientists	Aldersbach, 10.05.2016
Kammhuber, K.	The impact harvest timing has on aroma in hop	Hop Growers'Association, rural district of Pfaffen-hofen, representatives from the brewing industry, trade, ministries, authorities and politics	Hüll, 25.08.2016
Kammhuber, K.	'Analytical characterization of the new "Huell Special Flavor-Hops" and the influence of the date of harvest on the amount as well as on the composition of the essential oils'	Society of Hop Research (GfH), members of the Ad-visory Board of the GfH (brewing industry)	Nürnberg, Messe, 08.11.2016
Lutz, A., Seigner, E.	The two new Hüll Special Flavor hops	Jura Hops Promotion Socie-ty, hop growers	Hiendorf, 18.01.2016
Lutz, A., Seigner, E.	Hüll Special Flavor hops – what we we know so far	LfL, IPZ 5 and agencies for food, agriculture and forest-ry, hop growers	Biburg, 25.01.2016
Lutz, A., Seigner, E.	Hüll Special Flavor hops – what we know so far	LfL, IPZ 5 and agencies for food, agriculture and forest-ry, hop growers	Lindach, 26.01.2016
Lutz, A., Seigner, E.	Hüll Special Flavor hops – what we know so far	LfL, IPZ 5 and agencies for food, agriculture and forest-ry, hop growers	Mainburg, 27.01.2016
Lutz, A., Seig-ner, E.	Hüll Special Flavor hops – what we know so far	LfL, IPZ 5 and agencies for food, agriculture and forest-ry, hop growers	Osseltshausen, 28.01.2016
Lutz, A. Seigner, E.	Hüll Special Flavor hops – what we know so far	LfL, IPZ 5 and agencies for food, agriculture and forest-ry, hop growers	Oberhatzkofen, 29.01.2016
Lutz, A. Seigner, E.	Hüll Special Flavor hops – what we know so far	LfL, IPZ 5 and agencies for food, agriculture and forest-ry, hop growers	Hedersdorf, 01.02.2016

Speakers	Subject/Title	Organizers/ Target Group	Venue/ Date
Lutz, A., Seigner, E.	Hüll Special Flavor hops – what we know so far	LfL, IPZ 5 and agencies for food, agriculture and forestry, hop growers	Spalt, 01.02.2016
Lutz, A. Seigner, E.	Hüll Special Flavor hops – what we know so far	LfL, IPZ 5 and agencies for food, agriculture and forestry, hop growers	Niederlauterbach, 03.02.2016
Lutz, A. Seigner, E.	Hüll Special Flavor hops – what we know so far	LfL, IPZ 5 and agencies for food, agriculture and forestry, hop growers	Marching, 05.02.2016
Lutz, A. Seigner, E.	Hüll Special Flavor hops – what we know so far	BayWa AG Tettnang, Tettnang hop growers	Tettnang, 16.02.2016
Lutz, A. Seigner, E.	Large-scale growing trial with traditional Hüll breeding lines 89/02/25 and 96/01/24	Ministry for Rural Affairs and Consumer Protection, Tettnang Hop Growers' Association und Ministry for Rural affairs and Consumer Protection	Stuttgart, 18.02.2016
Lutz, A.	Large-scale growing trial with two old breeding lines	HVG, Hop Sales Cooperative, hop growers	Wolnzach, 31.03.2016
Lutz, A. Seigner, E.	The two new Hüll Special Flavor hops	Hop Sales Cooperative HVG, HVG board of directors and members of the supervisory board	Wolnzach, 31.03.2016
Lutz, A. Seigner, E.	Introducing the new Hüll Special Flavor cultivars Callista and Ariana	Society of Hop Research, hops and brewing industries	Aldersbach, 10.05.2016
Lutz, A. Seigner, E.	Row planting trial with highly promising LfL breeding lines in the Elbe/Saale region	Elbe-Saale Hop Growers' Association, hop growers from the Elbe/Saale region, representatives from Elbe-Saale ministries, the brewing industry	Stobra, 08.07.2016
Lutz, A.	New Special Flavor cultivars Ariana und Callista	Young Hop Growers' Group, hop growers	Eichelberg, 02.08.2016
Lutz, A.	New Special Flavor cultivars Ariana und Callista	VLF Freising, hop growers	Eichelberg, 03.08.2016
Lutz, A.	New Special Flavor cultivars Ariana und Callista	VLF Kelheim, hop growers	Eichelberg, 04.08.2016
Lutz, A.	Wilt disease problems in hop growing	IGN Hop Marketing, hop growers, Hops Syndicate Niederlauterbach	Niederlauterbach, 29.08.2016
Lutz, A.	Hop varieties and aroma monitoring	Altweihenstephan Brewers' Federation, student brewers	Freising, 07.11.2016

Speakers	Subject/Title	Organizers/ Target Group	Venue/ Date
Lutz, A., Seigner, E.	Marker-assisted breeding for hop	Universität Hohenheim, project partners of Hohenheim university and the Max-Planck-Institut	Stuttgart, 15.11.2016
Lutz, A., Seigner, E.	What we know to date about Special Flavor breeding line 2011/02/04	Society of Hop Research and GfH board of directors	Hüll, 22.11.2016
Lutz, A., Seigner, E.	Decision on bringing forward large-scale brewing trials with breeding lines 89/2/25 and 96/1/24, now undergoing field trials in large-scale plots	Society of Hop Research, GfH board of directors	Hüll, 22.11.2016
Münsterer, J.	New results from research into hop drying	Hop traders Joh. Barth & Sohn, Mainburg, the hop trade	Mainburg, 04.02.2016
Münsterer, J.	LfL information on how to make sure the N_{min} audit is carried out correctly	Hopfenring e.V., Wolnzach	Wolnzach, 05.02.2016
Münsterer, J.	Optimizing hop drying	Young Hop Growers' Group, hop growers	Hüll, 02.08.2016
Münsterer, J.	Optimizing hop drying	VLF Freising, hop growers	Hüll, 03.08.2016
Münsterer, J.	Optimizing hop drying	VLF Kelheim, hop growers	Hüll, 04.08.2016
Münsterer, J.	Presenting research results with respect to preserving quality in hop drying	Association of German Hop Growers, hop growers	Hüll, 25.08.2016
Münsterer, J.	Rotary distributors – what they can and cannot do	Hop Study Group	Haunsbach, 21.12.2016
Portner, J.	Sustainable hop production – economic aspects	Landhandel	Hebrontshausen, 21.01.2016
Portner, J.	Sustainable hop production – economic aspects	Hop growers	Biburg, 25.01.2016
Portner, J.	Sustainable hop production – economic aspects	LfL, hop growers	Lindach, 26.01.2016
Portner, J.	Sustainable hop production – economic aspects	LfL, hop growers	Mainburg, 27.01.2016
Portner, J.	Sustainable hop production – economic aspects	LfL, hop growers	Osseltshausen, 28.01.2016
Portner, J.	Sustainable hop production – economic aspects	LfL, hop growers	Oberhatzkofen, 29.01.2016

Speakers	Subject/Title	Organizers/ Target Group	Venue/ Date
Portner, J.	Sustainable hop production – economic aspects	LfL, hop growers	Hedersdorf, 01.02.2016
Portner, J.	Sustainable hop production – economic aspects	LfL, hop growers	Spalt, 01.02.2016
Portner, J.	Sustainable hop production – economic aspects	LfL, hop growers	Niederlauterbach, 03.02.2016
Portner, J.	Sustainable hop production – economic aspects	LfL+AELF AB, hop grow- ers	Marching, 05.02.2016
Portner, J.	Sustainable hop production – economic aspects	BayWa, BayWa staff	Wolnzach, 26.02.2016
Portner, J.	Professional review on the subject of hop 2016	City of Moosburg a.d. Isar, prizewinners and guests of the Moosburg hops and bar- ley show	Moosburg a.d. Isar, 15.09.2016
Portner, J.	Hop - jewel in the crown of the Hallertau	kus PAK, tour guides in the rural district of Pfaffenhofen	Reichertshofen, 17.11.2016
Seigner, E. Lutz, A.	Hop Breeding Research	LfL, students of St. Catherine University, Minnesota, USA	Hüll, 15.01.2016
Seigner, E. Lutz, A.	Crossbreeding with Tettnanger landrace	Ministry for Rural Affairs and Consumer Protection, hops experts from Tettnang Hop Growers' Association and Ministry for Rural Af- fairs, Baden-Württemberg	Stuttgart, 18.02.2016
Seigner, E.	Meristem culture and cryotherapy for eliminating pathogens	gD und hD Hopfen	Hüll, 07.06.2016
Seigner, E.	Faster availability of virus-free hops through improved tissue culture	Scientific Station for Brew- ing in Munich, brewing and hops industries	München, 09.06.2016
Seigner, E. Lutz, A.	Breeding robust high alpha varieties for the Elbe/Saale region	Elbe-Saale Hop Growers' Association, hop growers from the Elbe/Saale region, representatives from the Elbe/Saale ministries, the brewing industry	Stobra, 08.07.2016
Seigner, E.	Marker-assisted breeding in hop	StMELF, StMELF	München, 29.07.2016
Seigner, E. Lutz, A.	Crossbreeding with Tettnanger landrace	HVG Hop Sales Coopera- tive, HVG supervisory board	Wolnzach, 17.08.2016

Speakers	Subject/Title	Organizers/ Target Group	Venue/ Date
Seigner, E. Lutz, A.	Marker assisted breeding in hop	German Brewers' Federation, agricultural commission of the German Brewers' Federation	Hüll, 01.09.2016
Seigner, E. Lutz, A.	Outlook for development and production of healthy quality hops	German Brewers' Federation, agricultural commission of the German Brewers' Federation	Hüll, 01.09.2016
Seigner, E. Lutz, A.	'The new Huell Special Flavor Hops - Great Performance in Hop Yards and Beers'	Society of Hop Research, members of the GfH Advisory Board (brewing industry)	Nürnberg, 08.11.2016
Seigner, E. Kammhuber, K. Lutz, A.	Marker assisted breeding for hop	Universität Hohenheim, project partners of Hohenheim university and the Max-Planck-Institut	Stuttgart, 15.11.2016
Sichelstiel, W.	Authorization status of plant protection agents for hop 2016	Beiselen, Landhandel	Hebrontshausen, 21.01.2016
Sichelstiel, W. Wörner, L.	Authorization status of plant protection agents for hop 2016	LfL, hop growers	Biburg, 25.01.2016
Sichelstiel, W. Wörner, L.	Authorization status of plant protection agents for hop 2016	LfL, hop growers	Lindach, 26.01.2016
Sichelstiel, W. Wörner, L.	Authorization status of plant protection agents for hop 2016	LfL, hop growers	Mainburg, 27.01.2016
Sichelstiel, W. Wörner, L.	Authorization status of plant protection agents for hop 2016	LfL, hop growers	Osseltshausen, 28.01.2016
Sichelstiel, W. Wörner, L.	Authorization status of plant protection agents for hop 2016	LfL, hop growers	Oberhatzkofen, 29.01.2016
Sichelstiel, W. Wörner, L.	Authorization status of plant protection agents for hop 2016	LfL, hop growers	Hedersdorf (Hersbruck), 01.02.2016
Sichelstiel, W. Wörner, L.	Authorization status of plant protection agents for hop 2016	LfL, hop growers	Spalt, 01.02.2016
Sichelstiel, W. Wörner, L.	Authorization status of plant protection agents for hop 2016	LfL, hop growers	Niederlauterbach, 03.02.2016
Sichelstiel, W., Wörner, L.	Authorization status of plant protection agents for hop 2016	LfL + AELF AB, hop growers	Marching, 05.02.2016
Sichelstiel, W.	Plant protection agents for hop cultivation in Germany – authorization and current situation	IHPS Zalec, Slovenian hop growers, hop traders, specialist bodies	Lasko, 10.02.2016
Sichelstiel, W.	'Hop production in Germany'	JKI, attendees of workshop on hop viroids	Freising, 10.02.2016

Speakers	Subject/Title	Organizers/ Target Group	Venue/ Date
Sichelstiel, W.	Experience with and recommendations for use of Vorox F in hop stripping	BayWa, Landhandel	Wolnzach, 26.02.2016
Sichelstiel, W.	Authorization status of plant protection agents for hop 2016	BayWa, Landhandel	Wolnzach, 26.02.2016
Sichelstiel, W.	Field test - hop stripping	Young Hop Growers' Group, hop growers	Eichelberg, 02.08.2016
Sichelstiel, W.	Field test - hop stripping	VLF Freising, hop growers	Eichelberg, 03.08.2016
Sichelstiel, W.	Field test - hop stripping	VLF Kelheim, hop growers	Eichelberg, 04.08.2016
Sichelstiel, W.	Problems of plant protection and possible solutions for hop cultivation	Association of German Hop Growers, regulatory bodies of the plant protection agent manufacturers, hop growers	Buch, 26.08.2016
Weihrauch, F.	Externally funded projects in 2015 with respect to hop cultivation at Hüll	Bioland, organic hop farmers and organic farming advisory service	Kloster Plankstetten, 02.02.2016
Weihrauch, F.	'The arthropod fauna of hop cones, with specific consideration of the Neuroptera'	TUM, international scientists	Freising, 01.09.2016
Weihrauch, F.,	Managing the hop flea beetle *Psylliodes attenuatus* in organic hop growing: what are the options?	JKI, Plant Protection Service Sachsen-Anhalt & DPG, scientists and plant protection advisors from German Federal agencies, plant protection services and industry	Halle (Saale), 21.09.2016
Weihrauch, F.	Results of copper monitoring by the organic farms associations in Germany – hops section	BÖLW & JKI, scientists and organic farming advisors from federal and regional authorities and the plant protection industry abroad	Berlin, 17.11.2016
Weihrauch, F.	Minimizing deployment of copper-containing fungicides in organic hop farming: trial outcomes 2015-2016	BÖLW & JKI, BÖLW & JKI, scientists and organic farming advisors from federal and regional authorities and the plant protection industry abroad	Berlin, 18.11.2016
Weihrauch, F.	Minimizing deployment of copper-containing fungicides in organic hop farming: trial outcomes 2015-2016	Hop Producer Group HVG, supervisory board of HVG Hop Producer Group	Wolnzach, 29.11.2016

9.3.4 Guided tours

Date	Name	Subject/Title	Guests	Nos.
15.01.16	Seigner, E. Kammhuber, K.	'Hop research of the LfL, hop breeding, plant protection, chemical analysis'	Students of St. Catherine University, Minnesota (28 attendees)	28
04.02.16	Lutz, A. Sichelstiel, W. Seigner, E.	'Hop research, hop breeding'	A-B InBev, raw materials management (2 attendees)	2
19.02.16	Seigner, E. Kammhuber, K. Lutz, A.	Hop breeding and hop aroma analytics	A-B InBev, management (2 attendees)	2
10.03.16	Sichelstiel, W. Lutz, A.	Hop growing in the Hallertau	Frankfurter Allgemeine Zeitung (1 attendee)	1
11.03.16	Lutz, A.	Hüll Special Flavor breeding	Tagblatt Freising (1 attendee)	1
18.03.16	Sichelstiel, W.	Hop Research Center Hüll, hop breeding	Systembaloget (2 attendees)	2
01.04.16	Lutz, A.	Hop breeding and 500 years of the beer purity law	Journalist from the Donaukurier (1 attendee)	1
11.04.16	Sichelstiel, W.	Hop Research Center Hüll	US craft brewers and hop growers (4 attendees)	4
20.04.16	Seigner, E. Lutz, A.	'Hops, hop breeding, goals, varieties and local breeds'	Frankfurter Allgemeine Zeitung (1 attendee)	1
26.04.16	Lutz, A. Kammhuber, K. Seigner, E.	'Hop research, hop breeding, new cultivars, aroma analytics'	A-B InBev, innovation team (3 attendees)	3
11.05.16	Sichelstiel, W. Lutz, A.	Hop growing and hop research	Univ. of Applied Sciences, Bingen,30 att.s	30
24.05.16	Sichelstiel, W.	Hop Research Center Hüll	Local Gov. Deputy Martin Schöffel (1 attendee)	1
02.06.16	Sichelstiel, W. Kammhuber, K. Lutz, A. Seigner, E.	Hop research, breeding, hop analytics, plant protection	A-B InBev, innovation team (3 attendees)	3
03.06.16	Lutz, A.; Sichelstiel, W. Weihrauch, F.	Hop Research Center Hüll	Federation of Fruit and Wine Growing Consultants S. Tirol (25 att.s)	25
14.06.16	Sichelstiel, W. Seigner, E.	Hop research at the LfL, hop breeding, plant protection	Education organization of Farming Federation (20 attendees)	20
17.06.16	Sichelstiel, W. Lutz, A.	Hop Research Center Hüll	Students Univ of Appl. Sciences Nürtingen (29)	29
28.06.16	Seigner, E.	LfL hop research, hop breeding, hop analytics	A-B InBev, raw materials management (2 attendees)	2
05.07.16	Sichelstiel, W. Seigner, E.	LfL hop research, hop breeding, plant protection, analysis of components, hop cultivation	Students, TUM, brewing and beverage technology (23 attendees)	23
13.07.16	Lutz, A. Seigner, E. Kammhuber, K.	'Hop research of the LfL, aroma analytics, Special Flavor hops'	Kirin Brewery, TUM, Chair of Beverage and Brewing Technology (2 attendees)	2

Date	Name	Subject/Title	Guests	Nos.
19.07.16	Lutz, A. Seigner, E.	Hop breeding, aroma und Special Flavor varieties	Boston Brewery (5 attendees)	5
21.07.16	Lutz, A. Seigner, E. Weihrauch, F. Kammhuber, K.	‘Hop research, aroma hops, Special Flavor hops, plant protection’	Sierra Nevada Brewing Company (3 attendees)	3
21.07.16	Seigner, E. Sichelstiel, W.	‘Hop research of the LfL, breeding, plant protection, chemical analysis’	Universität Göttingen, PhD students (18 attendees)	18
29.07.16	Münsterer, J. Lutz, A.	LfL hop research, hop breeding and crop cultivation	Agricultural College Pfaffenhofen (12 attendees)	12
11.08.16	Seigner, E.	‘Hop cultivars, hop production’	University of Chile, Agraring. (2 attendees)	2
18.08.16	Lutz, A.	An update on the 2016 hop harvest	DIN ISO businesses – hops (70 attendees)	70
24.08.16	Sichelstiel, W. Lutz, A.	Hop research, Special Flavor hops	Motor Presse, Magazin Bier (2 attendees)	2
25.08.16	Seigner, E. Lutz, A. Kammhuber, K. Weihrauch, F.	LfL hop research, breeding Special Flavor Varieties, aroma analytics, organic hop farming	TV journalist, Bayernkurier (1 attendee)	1
26.08.16	Seigner, E. Kammhuber, K.	‘Hop research, hop breeding, Special Flavor hops, hop analytics’	A-B InBev, Global Brewer (45 attendees)	45
29.08.16	Seigner, E. Kammhuber, K.	‘Hop research, hop breeding, plant protection, aroma analytics’	Cervecería Polar, Agraria (5 attendees)	5
30.08.16	Seigner, E. Sichelstiel, W. Kammhuber, K.	LfL hop research, hop breeding, Special Flavor hops, aroma analytics	A-B InBev, management/techn. operations managers (12 attendees)	12
31.08.16	Seigner, E. Kammhuber, K.	‘Hop research, hop breeding, hop analytics, xanthohumol’	A-B InBev (2 attendees)	2
31.08.16	Seigner, E. Kammhuber, K.	‘Hop research, hop breeding, hop chemical analytics’	Kalsec, A-B InBev (2 attendees)	2
01.09.16	Seigner, E. Lutz, A. Kammhuber, K.	Hop research, hop breeding, hop analytics	A-B InBev (3 attendees)	3
07.09.16	Lutz, A.	LfL hop research, hop breeding, Special Flavor hops	Braufactum, brewing journalists, Barth-Haas Group (50 attendees)	50
08.09.16	Lutz, A. Seigner, E. Portner, J. Weihrauch, F.	LfL hop research; hop breeding, plant protection, hop analytics	BMEL, W. Albrecht; (5 attendees)	5
09.09.16	Lutz, A.	The latest from hop breeding	Barth-Haas Group (8 attendees)	8
09.09.16	Seigner, E. Kammhuber, K.	LfL hop research, hop breeding, Special Flavor hops, hop analytics	Barth Academy (20 attendees)	20
14.09.16	Sichelstiel, W.	Hop Research Center Hüll	Früh Kölsch brewers (2 attendees)	2
16.09.16	Seigner, E.	‘Hop research, hop breeding, Special Flavor hops’	A-B InBev, brewers (3 attendees)	3

Date	Name	Subject/Title	Guests	Nos.
20.09.16	Seigner, E. Kammhuber, K.	'Hop research of the LfL, hop breeding, Special Flavor hops, hop aroma'	A-B InBev, brewers (4 attendees)	4
22.09.16	Seigner, E.	'Hop research of the LfL, hop breeding, hop aroma'	A-B InBev, global innovation group (3 attendees)	3
28.09.16	Lutz, A.	'Hop aroma assessment'	New Glarus Brewing, Hop Solutions (2 att.s)	2
28.09.16	Seigner, E. Lutz, A.	'Hop research of the LfL, hop breeding, Special Flavor hops, hop aroma'	A-B InBev, brewers (4 attendees)	4
29.09.16	Lutz, A. Kammhuber, K.	Hop research, breeding, plant protection, chemical analysis	Camba Bavaria (2 attendees)	2
30.09.16	Seigner, E.	'Hop research, hop breeding, Special Flavor hops, aroma analytics'	A-B InBev, distribution network (45 attendees)	45
10.10.16	Seigner, E. Portner, J.	'Hop research of the LfL, hop breeding, hop production'	Belgian hop growers (30 attendees)	30
18.10.16	Lutz, A. Sichelstiel, W.	Hop Research Center Hüll	Systembaloget (18 attendees)	18
14.11.16	Lutz, A.	'Hop research of the LfL, hop breeding, Special Flavor Hops'	Cooperativa Agrária Agroindustrial, craft brewers (5 attendees)	5
21.11.16	Lutz, A. Kneidl, J.	Harvest timing and aroma in the Hüll Special Flavor hops	Barth-Haas Group (5 attendees)	5
22.11.16	Lutz, A. Kneidl, J.	Harvest timing and aroma in the Hüll Special Flavor hops	GfH licensees of Special Flavor hops (10 attendees)	10

9.3.5 Shows/exhibitions and posters

Author(s)	Title	Event	Organizers
Kammhuber, K.	Constituent compounds in hop	Festival – Celebrating 500 Years of the Beer Purity Law Munich	Bavarian Brewers' Federation; private breweries in Bavaria; StMELF
Lutz, A. Seigner, E.	Special Flavor hops	Festival – Celebrating 500 Years of the Beer Purity Law Munich	Bavarian Brewers' Federation; private breweries in Bavaria; StMELF
Münsterer, J.	Hop conditioning	3rd German Hops Day, Bad Gögging	Association of German Hop Growers
Münsterer, J.	Hop drying	3rd German Hops Day, Bad Gögging	Association of German Hop Growers
Portner, J.	Application method to reduce accidental drifting with hop spraying equipment	3rd German Hops Day, Bad Gögging	Association of German Hop Growers
Portner, J.	Downy mildew warning service	3rd German Hops Day, Bad Gögging	Association of German Hop Growers
Seigner, E. Lutz, A.	Development of a new hop cultivar	Festival – Celebrating 500 Years of the Beer Purity Law Munich	Bavarian Brewers' Federation; private breweries in Bavaria; StMELF
Seigner, E. Lutz, A.	'The Picking Time is Crucial to Yield and Quality'	3rd German Hops Day, Bad Gögging	Association of German Hop Growers; HVG Hop Sales Cooperative
Seigner, E. Lutz, A.	The Hüll Special Flavor hops	Festival - Celebrating 500 Years of the Beer Purity Law Munich	Bavarian Brewers' Federation; private breweries in Bavaria; StMELF

9.4 Basic and Continuing Training

Name, Working Group	Subject	Target Group
Münsterer, J. IPZ 5a	17.06.2016 – Hop – a one-day course: Diseases and pests in hop growing, forecasting systems, Hüll	15 farmers
Münsterer, J. IPZ 5a	29.07.2016 – Hop – a one-day course: Forecasting downy mildew infection; the latest information on plant protection, Hüll	15 farmers
Portner, J. IPZ 5a	11.03.2016 – Master's certificate: topic assignment for practical job-specific project, Schlott	1 farmer
Portner, J. IPZ 5a	21.03.2016 - Master's certificate: topic assignment for practical job-specific project, Ried	1 farmer
Portner, J. IPZ 5a	21.03.2016 - Master's certificate: topic assignment for practical job-specific project, Dürnzhausen	1 farmer
Portner, J. IPZ 5a	21.03.2016 - Master's certificate: topic assignment for practical job-specific project, Kleingründling	1 farmer
Portner, J. IPZ 5a	21.03.2016 - Master's certificate: topic assignment for practical job-specific project, Scheuerhof	1 farmer
Portner, J. IPZ 5a	22.03.2016 - Master's certificate: topic assignment for practical job-specific project, Rohrbach	1 farmer
Portner, J. IPZ 5a	15.04.2016 - Master's certificate: topic assignment for practical job-specific project, Wolnzach	1 farmer
Portner, J. IPZ 5a	20.04.2016 - Master's certificate: topic assignment for practical job-specific project, Wolnzach	1 farmer
Portner, J. IPZ 5a	18.04.2016 - Master's certificate: topic assignment for practical job-specific project, Wolnzach	1 farmer
Portner, J. IPZ 5a	03.06.2016 - Master's certificate: topic assignment for practical job-specific project, Wolnzach	1 farmer
Portner, J. IPZ 5a	03.06.2016 - Master's certificate: topic assignment for practical job-specific project, Wolnzach	1 farmer
Portner, J. IPZ 5a	15.06.2016 – Master's certificate: practical job-specific project, follow-up visit, Scheuerhof	1 farmer
Portner, J. IPZ 5a	17.06.2016 - Master's certificate: practical job-specific project, follow-up visit, Ried	1 farmer
Portner, J. IPZ 5a	22.06.2016 - Master's certificate: practical job-specific project, follow-up visit, Rohrbach	1 farmer
Portner, J. IPZ 5a	13.07.2016 - Master's certificate: practical job-specific project, follow-up visit, Dürnzhausen	1 farmer
Portner, J. IPZ 5a	13.07.2016 - Master's certificate: practical job-specific project, follow-up visit, Kleingründling	1 farmer
Portner, J. IPZ 5a	19.08.2016 - Master's certificate: practical job-specific project, follow-up visit, Untereinöd	1 farmer
Portner, J. IPZ 5a	29.08.2016 - Master's certificate: practical job-specific project, follow-up visit, Schlott	1 farmer
Portner, J. IPZ 5a	30.08.2016 - Master's certificate: practical job-specific project, follow-up visit, Straß	1 farmer
Portner, J. IPZ 5a	30.08.2016 - Master's certificate: practical job-specific project, follow-up visit, Eschelbach	1 farmer
Portner, J. IPZ 5a	17. - 21.10.2016 – Instruction in hop growing, LS Pfaffenhofen	15 farmers

9.5 Participation in Working Groups. Memberships

Member	Organization
Fuß, S.	Board of Examiners – Qualified Agriculturalist at Landshut Authority for Continuing Education
Kammhuber, K.	Hop Analytics Working Group (AHA)
	European Brewery Convention (Hops Sub-committee) Analysis Commitee
	Society of German Chemists (GDCH)
Münsterer, J.	Board of Examiners – 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, Oberbayern-West, for Master's certificate Qualified Agriculturalist
Seigner, E.	Society of Hop Research
	Society of Plant Breeding
	International Society of Horticultural Science (ISHS)
	Scientific Commission of the International Hop Growers' Convention (Chair and Secretary)
Sichelstiel, W.	DPG, German Phytomedicinal Society
	EU Commodity Expert Group Minor Uses Hops (Chair)
	Society of Hop Research
Weihrauch, F.	Consortium of Bavarian Entomologists e.V.
	British Dragonfly Society
	DGaaE, Study Group Neuroptera (responsible for bibliography)
	DPG, German Phytomedicinal Society
	DgaaE, Study Group Beneficial Arthropods and Entomopathogenic Nematodes
	DgaaE, German Society for General and Applied Entomology
	DgfO, German Society for Orthopterology
	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
	Worldwide Dragonfly Society (member of the editorial board)

10 Personnel IPZ 5 - Hops Department

The following members of staff were employed at the Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, at Hüll, Wolnzach, and Freising in 2016 (WG = Working Group):

IPZ 5

Coordinator:
LD Wolfgang Sichelstiel

Hertwig Alexandra
Krenauer Birgit

IPZ 5a

AG Hopfenbau, Produktionstechnik
(WG Hop Cultivation/Production Techniques)
LD Portner Johann

Fischer Elke
LA Fuß Stefan
LAR Münsterer Jakob
Dipl.-Ing. (FH) Lutz Maria

IPZ 5b

AG Pflanzenschutz im Hopfenbau
(WG Plant Protection in Hop Growing)
LD Sichelstiel Wolfgang

BTA Eisenbraun Daniel
Felsl Maria
Dipl.-Ing. (FH) Jereb Marina (until 31.05.2016)
LI Meyr Georg
Weiher Johann
Dr. Weihrauch Florian (until 31.07.2016)
M.Sc. Wörner Laura
M.Sc. Wolf Silvana (from 17.11.2016)

IPZ 5c

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

Brummer Brigitte
Dandl Maximilian
LTA Enders Renate (from 01.04.2016)
CTA Forster Brigitte
Graßl Herbert (ab 20.06.2016)
Grebmair Hermann (from 15.02.2016)
CTA Hager Petra
LTA Haugg Brigitte
Hock Elfriede
Agr.-Techn. Ismann Daniel
LTA Kneidl Jutta
LAR Lutz Anton
Maier Margret
Mauermeier Michael
Pflügl Ursula
Suchostawski Christa

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 (from 01.08.2016)