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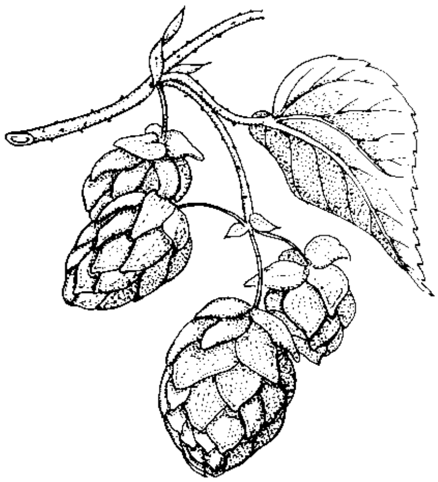
Gesellschaft für Hopfenforschung e.V.

Annual Report 2011

Special Crop: Hops



Bavarian State Research Center for Agriculture - -

- Institute for Crop Science and Plant Breeding -

and the

Society of Hop Research e.V.

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Research is the most important investment in the future

"If you ask what real knowledge is, my answer will be: real knowledge is what enables action." (Hermann Ludwig von Helmholtz)

The global hop market is currently characterised by considerable surplus production. Approximately 95 % of the global hop harvest is used in the brewing industry, where growth in demand is slow. A mere 5 % is put to other uses. Aligning hop farming with this situation and safeguarding long-term competitiveness pose a sizeable challenge. This goal can only be achieved if extensive research and development work is carried out and the results communicated directly to hop growers, the hop trade and the brewing industry and put into practice without delay.

The hop research performed by the Institute for Crop Science and Plant Breeding (IPZ) of the Bavarian State Research Center for Agriculture is a model example of a functioning public-private partnership between the Free State of Bavaria and the Society of Hop Research. There are very few institutes in the world that perform such extensive and holistic research into hops as the Hop Research Centre in Hüll. This research is performed by four work groups:

- WG Hop Cultivation/Production Techniques (IPZ 5a)
- WG Plant Protection in Hop Growing (IPZ 5b)
- WG Hop Breeding Research (IPZ 5c)
- WG Hop Quality and Analytics (IPZ 5d)

This structure allows optimum exploitation of all synergies. The Hop Research Centre cooperates closely with numerous university institutes, state and federal bodies, and brewing-industry and hop-growers' organisations. Apart from its ongoing tasks, a large number of projects financed by third parties are also carried out. The Hüll Hop Research Centre is in a position to react rapidly and flexibly to queries, suggestions and ideas from outside sources. Close contacts are maintained between high-profile representatives from the brewing industry and brewing science and the Hop Research Centre via the Advisory Board of the Society for Hop Research.

Climate change, environmentally friendly hop-growing practices, energy-efficient harvesting and post-harvest processing, irrigation, plant protection and breeding strategies that optimise resistance properties, yields and components for the brewing industry and for alternative uses are challenges that will require considerable efforts in the future.

“Flavour hops” offer a ray of hope for the future. Craft brewers, now enjoying considerable commercial success in the USA, need hops with very distinct aromas, even exotic aromas such as mandarine, melon, mango or currant. New breeding lines from Hüll show great promise in this connection. Apart from the classic bitter and aroma varieties, the "flavour hops" could become a new mainstay for hop farmers in Germany.

The numerous challenges and tasks cannot be met and solved without the hard work, commitment and creativity of all employees at Hüll, Wolnzach and Freising. We would therefore like to take this opportunity to thank them sincerely for their efforts.

Dr. Michael Möller
Chairman of the Managing Committee
of the Society of Hop Research

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

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1.1 Current research projects

Cross breeding with the Tettnanger landrace

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtung und AG Hopfenqualität/Hopfenanalytik *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Breeding Research and WG Hop Quality/Hop Analytics*
Financed by:	Ministerium für Ländlichen Raum, Verbraucherschutz und Ernährung, Baden-Württemberg *(Ministry for Rural Area, Consumer Protection and Food)* Hopfenpflanzerverband Tettnang *(Hop Grower Association Tettnang)*; Erzeugergemeinschaft Hopfen HVG e.G. *(HVG hop producer group)* Gesellschaft für Hopfenforschung e.V. (*Society of Hop Research*)
Project managers:	Dr. E. Seigner, A. Lutz
Project staff:	A. Lutz, J. Kneidl; D. Ismann, breeding team (all from IPZ 5c) Dr. K. Kammhuber, C. Petzina, B. Wyschkon, M. Hainzlmaier and S. Weihrauch (all from IPZ 5d)
Cooperation:	Versuchsgut Straß, f. Wöllhaf
Duration:	01.05.2011 - 31.12.2014

Objective

The aim of this breeding programme is to significantly improve yield and fungal resistance of the Tettnanger landrace while maintaining the aroma quality of the original Tettnanger. Since this objective cannot be achieved by pure selection within the naturally available variability of the Tettnanger landrace, it is necessary to attempt crossing Tettnanger with pre-selected male aroma lines showing broad disease resistance and having the potential to transmit good agronomic performance due to their pedigree.

Results

In summer 2011, four crosses were conducted with Tettnanger and traditional Hüll aroma lines on the father side. In addition, three crosses were performed with Hüll male lines revealing the potential to introduce more fruity aroma nuances into the classical Tettnanger hop aroma.

Pre-selection was initiated right at the beginning of this project with two Tettnang progenies which derived from crosses in the summer of 2011 and exactly matched the objectives pursued in this project. In autumn 2011, 242 female seedlings already assessed as being powdery-mildew-resistant were transplanted into the Hüll breeding yard.

There, they will be assessed as single plants under field conditions for vigour, disease resistance (resistance/tolerance to downy mildew, powdery mildew and *Verticillium* wilt) over the next three years. Finally, the most promising seedlings in terms of aroma quality and yield will be selected.

The prerequisites for achieving the project objectives are very good. With a total of seven new crosses conducted in 2011 and 242 seedlings which stem from two crosses in 2010 and have already been planted out, the project plan specifications concerning numbers of crosses and seedlings tested (50 - 60 seedlings per crossing) have already been fulfilled.

Breeding of dwarf hops for low trellis systems

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtung und AG Hopfenqualität/Hopfenanalytik *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Breeding Research and WG Hop Quality/Hop Analytics*
Financed by:	Bundesanstalt für Landwirtschaft und Ernährung (BLE) *(Federal Agency for Agriculture and Food)*
Project managers:	Dr. E. Seigner, A. Lutz
Project staff:	A. Lutz, J. Kneidl; A. Bogenrieder (all from IPZ 5c) Dr. K. Kammhuber, C. Petzina, B. Wyschkon, M. Hainzlmaier and S. Weihrauch (all from IPZ 5d)
Cooperation:	Hop farms: J. Schrag and M. Mauermeier
Duration:	01.04.2007 - 31.12.2011

Objective

The aim of this research project was to breed hops which, by virtue of their reduced height and more compact growth, broad disease resistance and excellent brewing quality, are particularly suitable for profitable and ecologically sustainable cultivation on low trellis systems.

Results

Work commenced in early March on the preliminary selection of seedlings from 15crosses conducted in 2010 (6 aroma- and 9 bitter-type). The seedlings were pre-selected for their disease resistance/tolerance towards powdery mildew and downy mildew. In mid-May, they were planted out in the vegetation hall, where their growth vigour and, once again, their resistance towards fungal attack were monitored under natural infection conditions until autumn. The plants were classified as male or female on the basis of flowers that formed as from July. Any seedlings that showed considerable deficiencies, such as severe aphid infestation, powdery mildew or root rot, were dug up by autumn.

In November, the 267 female and 39 male seedlings were planted out in the breeding yards in Hüll and Freising respectively. The seedlings will be monitored under high-trellis conditions over the next three years, with special attention being paid to their suitability for low-trellis growth and their resistance towards downy and powdery mildew under natural infection conditions. Once their root system is fully developed, the seedlings will also undergo initial testing for their resistance to *Verticillium* wilt.

In 2011, cones were harvested for the first time from 12 hop plants pre-selected as seedlings and obtained from the crosses performed specifically for this dwarf-hops project. The seedlings had been planted out on the 3-m trellis system in 2010.

A number of these breeding lines were characterised by a very fine and pleasant hop aroma, scoring 26 to 27 of 30 possible aroma points and thus drawing level for the first time with well-known Hüll aroma cultivars. Some also showed potential yields that approach those of our existing aroma cultivars bred for high-trellis systems.

Crosses in 2011

Although funding by Germany's Federal Agency for Agriculture and Food ceased with the official end of the project in December 2011, three more crosses were performed with the goal of obtaining plants boasting a combination of low-trellis suitability, aphid resistance and novel aroma nuances. Seeds were obtained from all three crosses in autumn.

Powdery mildew (PM) isolates and their use in breeding PM-resistant hops

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Breeding Research)*
Financed by:	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG hop producer group)*
Project managers:	Dr. E. Seigner, A. Lutz, Dr. S. Seefelder
Project staff:	A. Lutz, J. Kneidl, K. Oberhollenzer, Dr. S. Seefelder S. Hasyn (EpiLogic)
Cooperation:	Dr. F. Felsenstein, EpiLogic GmbH, Agrarbiologische Forschung und Beratung, Freising
Duration:	01.01.2011 – 31.12.2012

Objective

PM isolates with characteristic virulence properties have been used for PM resistance-testing in the greenhouse and lab since 2000. Together with the continually perfected testing systems, in the greenhouse and the lab, they enable the breeding of hop cultivars that guarantee optimum brewing and food quality along with reliable supplies even in years marked by high levels of fungal attack.

Results

Eleven different single-spore isolates of *Podosphaera macularis*, the fungus that causes powdery mildew in hops, and the above resistance-testing systems were used in 2011 for the following purposes:

- As every year, to assess the virulence situation of all the PM isolates (i.e. the 11 mentioned above) prior to commencing tests. To this end, a selection of eleven hop varieties carrying all the hitherto-known resistance genes were used to differentiate between the virulence properties of all 11 PM isolates. This provided certainty that, even years after their isolation, none of the isolates available for testing had lost any of their virulence genes via mutation. No new isolates with unknown virulence properties were included in 2011.
- To assess PM resistance in 203 breeding lines, 10 cultivars and 2 wild hops under standard infection conditions in the greenhouse.

- To this end, approx. 120,000 seedlings from 91 crosses performed in 2010 were inoculated artificially with two PM isolates carrying all the virulences widespread throughout the Hallertau region of Bavaria. In addition, 109 seedlings from an earlier mapping population for the R2 resistance gene were tested for their PM resistance. Hop plants assessed in the greenhouse as resistant were re-assessed by EpiLogic in laboratory leaf tests. 160 breeding lines, one foreign variety and two wild hops were tested, first with an English PM isolate (R2 resistance gene) and then with an isolate of regional importance from the Hallertau growing area. Only hops found in both tests to show broad resistance to powdery mildew were used for advanced breeding purposes.
- To investigate hop/powdery mildew interaction histologically. The reactions of epidermal cells from Northern Brewer, a PM-susceptible cultivar, were compared with those from eight wild hop varieties, two breeding lines and two cultivars, all of which are classified as PM-resistant. The use of a PM isolate showing four virulences widespread in the Hallertau growing region provided closer insight into the different resistance mechanisms found in Hüll cultivars and breeding material. Such knowledge is essential if different resistance mechanisms with mutually complementary effects are to be combined successfully in future varieties.
- To establish a transient leaf expression system and validate it via the functional assessment of genes suspected of being involved in the resistance mechanism. To this end, a gene transfer technique was used to introduce a gene construct into hop leaf cells. The reactions of the fungus and of the leaf cells were then monitored in the lab.

Overview of PM-resistance breeding in 2011

2011	Greenhouse tests		Laboratory leaf tests	
	Plants	**Assessments**	**Plants**	**Assessments**
Seedlings from 91 crosses	Approx. 120,000 via mass screening		-	-
Breeding lines	203	560	160	1,099
Cultivars	10	40	1	5
Wild hops	2	4	2	12
1 mapping population for developing DNA markers	109	360	31	77
Virulence properties of the 11 PM isolates	-	-	11	367
Various resistance-mechanism studies		Comparison of 8 wild hops, 2 breeding lines and 2 cultivars with Northern Brewer -> Microscopic investigations: altogether 30,170 interactions investigated and characterised		
Gene-expression studies to identify markers and clarify functions		42 different techniques for investigating specific patterns in active genes involved in fungal resistance		

Mass screening in seed dishes, otherwise selection of individual plants in pots.

Characterisation of hop/hop powdery mildew interaction at cell level and functional analysis of defence-related genes

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Breeding Research)*
Financed by:	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG hop producer group)*
Project manager:	Dr. E. Seigner
Project staff:	K. Oberhollenzer, B. Forster, A. Lutz
Cooperation:	Professor R. Hückelhoven and Dr. Ruth Eichmann of Munich Technical University, Chair of Phytopathology at the Wissenschaftszentrum Weihenstephan *(Centre of Life and Food Sciences)* Dr. F. Felsenstein, EpiLogic GmbH, Agrarbiologische Forschung und Beratung, Freising
Duration:	01.04.2008 – 31.12.2011

Objective

The aim of this research project was to characterise cell-level defence responses in various wild hop varieties, breeding lines and cultivars using fluorescence and laser microscopy techniques, and thereby to identify new resistance carriers for breeding PM-resistant hops.

Another component of this project supported resistance breeding via a molecular biological approach. What is known as a transient transformation assay system was developed for hops, which will make it possible to characterise the functions of PM-defence-related genes.

Methods

Twelve PM-resistant genotypes from the Hüll breeding programme were inoculated with powdery mildew. Fungal structures and cell-level defence responses were visualized by means of various histochemical staining techniques and examined with a fluorescent microscope. As it turned out that the PM fungus also colonises hair cells, and that these show a defence response that differs from that of normal epidermal cells, the resistance mechanism of the hair cells was also investigated.

To establish a transient transformation assay system for hops, protocols were developed for particle-gun transformation of epidermal cells and for subsequent inoculation of the leaves. A "knock-down" construct for a hop *Mlo* gene was then generated in order to validate the transient transformation assay by silencing this suspected susceptibility gene in individual epidermal cells.

Results

Microscopic analyses of the PM-defence-related responses showed that resistance in all 12 genotypes was by way of apoptosis of the cells under attack. Hair cells were susceptible in all the genotypes investigated. However, since they only account for a small proportion of the leaf surface area, this fact appears unimportant for the resistance phenotype.

The transient transformation assay was validated by functional characterisation of an *Mlo* gene. Knock-down experiments in the susceptible Northern Brewer variety showed that cells that had undergone transient knock-down of this susceptibility gene contained fewer haustoria than the control. In other words, silencing the gene made the cells less susceptible.

Investigation of *Verticillium* infections in the Hallertau district

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen und AG Hopfenbau/Produktionstechnik *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Breeding Research and WG Hop Cultivation/Production Techniques*
Financed by:	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG hop producer group)* Wissenschaftsförderung der Deutschen Brauwirtschaft (Wifö)
Project managers:	Dr. S. Seefelder; Dr. E. Seigner
Project staff:	K. Drofenigg , C. Püschel, S. Petosic, E. Niedermeier
Cooperation:	Dr. S. Radisek, Slovenian Institute of Hop Research and Brewing, Slovenia Prof. B. Javornik, Lublijana University, Slovenia Prof. G. Berg, University of Graz, Austria IPZ 5a (Work Group for Hop Cultivation/Production Techniques)
Duration:	01.03.2008 - 31.05.2013

Objective

Exceptionally high incidence of wilt in all hop varieties is now causing considerable yield reductions in some regions of the Hallertau. The intention is therefore to investigate various aspects of the disease in a number of sub-projects. In addition to analysing the genetics and virulence of *Verticillium*, the fungus that causes hop wilt, and looking at the causes, measures to contain the disease are being explored. The focus of the investigation is on establishing a fast diagnostic system for hop farmers and testing the effectiveness of bioantagonists, bacterial adversaries of *Verticillium* used to protect hop plants from infection.

Methods

- Conventional breeding techniques to cultivate single-spore *Verticillium* isolates from hop bine samples
- DNA isolation from pure cultures of fungi, hop bines and soil samples
- Molecular and microscopic examinations to differentiate between *Verticillium albo-atrum* and *V. dahliae*
- Molecular analytical characterisation of the *Verticillium* isolates using AFLP and SCAR markers

- Infection test to determine virulence
- Isolation of hereditary *Verticillium* material directly from hop bines and soil particles
- Testing of specific bioantagonists as possible control measures
- Conducting of field trials on leased hop yards seriously affected by wilt

Results

Evidence of the occurrence of both milder and more aggressive forms of *Verticillium* in the Hallertau region was obtained for the first time during this project. To this end, bine sections from hop yards heavily infected with wilt were collected and processed via extremely labour-intensive steps to produce pure fungus cultures. Single-spore isolates were cultivated from these pure cultures and the *Verticillium* species then determined using molecular methods and, to some extent, microscopy. The fungal material was allowed to continue growing so as to produce sufficient DNA for more detailed molecular examination. The Hallertau *Verticillium* isolates were genotyped by means of AFLP analysis and compared with reference isolates from Slovenia and England. Analysis with specific AFLP primer combinations showed an identical DNA band pattern in isolates from Hallertau hop yards seriously affected by wilt and in lethal Slovenian and English *Verticillium* races. An initial artificial *Verticillium* infection test performed in Slovenia in 2009 was verified in 2010 under optimised conditions. In this repetition test, lethal Slovenian and English reference isolates showed the same high virulence as Hallertau isolates from previously wilt-tolerant cultivars such as Northern Brewer or Hallertauer Tradition. Mild reference isolates from abroad and *Verticillium* isolates from only slightly damaged Hallertau hop yards demonstrated similar, much lower, levels of virulence. Previous molecular findings indicating the occurrence in the Hallertau growing region of very aggressive *Verticillium* races were thus confirmed. Promising experiments on the establishment of an urgently needed rapid diagnostic test were carried out as part of a recently commenced dissertation. With the help of a homogenizer, special glass/ceramic mixtures and a commercial fungus isolation kit, the genetic material of Verticillium was extracted directly from hop bines. This method would make it possible to avoid the hitherto tedious and expensive fungal-cultivation step.

Outlook

Centre-stage, in addition to further molecular and virulence assays, will be the recently commenced testing of specific bacterial strains for their effectiveness, as bioantagonists, in protecting young hop plants from *Verticillium* attack in seriously wilt-infected hop yards. Another focus will be on potential resistance selection in wild hops and Hüll breeding lines planted in 2010 on seriously *Verticillium*-contaminated leased land.

Monitoring for dangerous viroid and viral hop infections in Germany

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenschutz, AG Pathogendiagnostik und Institut für Pflanzenbau und Pflanzenzüchtung, AG Züchtungsforschung Hopfen *(Bavarian State Research Center for Agriculture, Institute for Plant Protection, WG for Pathogen Diagnostics, and Institute for Crop Science and Plant Breeding, WG for Hop Breeding Research)*
Financed by:	Wissenschaftliche Station für Brauerei in München e.V. *(Scientific Station for Brewing in Munich)*
Project managers:	Dr. L. Seigner, Institute for Plant Protection (IPS 2c); Dr. E. Seigner, A. Lutz (both from IPZ 5c)
Project staff:	V. Auzinger, C. Huber, L. Keckel, M. Kistler, D. Köhler, F. Nachtmann (all from IPS 2c); A. Lutz, J. Kneidl (IPZ 5c)
Cooperation:	Dr. K. Eastwell, Washington State University, Prosser, USA Professor R. Hückelhoven of Munich Technical University, Chair of Phytopathology at the Wissenschaftszentrum Weihenstephan *(Centre of Life and Food Sciences)* IPZ 5a (Work Group for Hop Cultivation/Production Techniques)
Duration:	01.04.2011 - 30.09.2011

Objective

The aim of monitoring for hop stunt viroid (HSVd) and four different hop viruses was to help secure high hop quality and competitiveness for German hop farmers. Virus and viroid infections cause pronounced yield and alpha-acid losses, especially in weather-stressed plants. Since it is impossible to combat these pathogens directly with plant protectives and the pathogens can be easily and quickly transmitted mechanically or by aphids, this monitoring of our breeding yards, the propagation facilities and hop yards was intended to detect primary infection centres and, ultimately, prevent the disease from spreading.

Methods

Young leaf samples were taken from suspicious-looking plants at the start of the vegetation period. To permit reliable identification of the hop mosaic carlavirus (HMV), apple mosaic ilarvirus (ApMV) and arabis mosaic virus (ArMV), the hop samples were examined with the DAS-ELISA (Double Antibody Sandwich Enzyme Linked Immunosorbent Assay) method using commercially available polyclonal antisera. The hop samples were tested for hop stunt viroid (HSVd) and latent hop carlavirus (HLV) with the RT-PCR (Reverse trancriptase polymerase chain reaction) process, using primers from Eastwell und Nelson (2007) and from Eastwell (personal communication, 2009). This molecular technique was also used to test for American hop latent carlavirus (AHLV) in a number of hop cultivars from the USA. To verify individual results, PCR bands were also sequenced.

Most of the testing was performed by a TUM (Technisches Universität München) undergraduate working jointly with the LfL's pathogen diagnostics lab (IPS 2c) in Freising.

Results

Monitoring for HSVd infections in hops, commenced in 2008, was continued in 2011. The leaf samples were additionally tested for HMV and ApMV, diseases subject to routine testing by IPZ 5b in Hüll, and for HLV and ArMV. In all, IPS 2c conducted tests on 282 leaf samples from hop farms in the Hallertau, Tettnang and Elbe-Saale growing regions, from one of the Society of Hop Research's propagation facilities and from the various breeding yards in Hüll, Rohrbach, Schrittenlohe and Freising. Leaves from foregn hop varieties were also monitored.

No HSVd was detected in any of the samples, which means that the nine plants in which HSVd was detected last year and which were destroyed immediately remain the only plants to have tested HSVd-positive among the altogether 938 plants screened since 2008. However, the HSVd band was missing in a total of 33 plants due to a failed internal RT-PCR control run (Seigner et al., 2008), making unequivocal confirmation of HSVd-freeness impossible for these plants. The findings obtained since 2008 are reassuring, as they show that no HSVd has been introduced so far from countries with high infection pressure, such as Japan in the past, and the USA, where hop stunt viroid infections have been recorded since 2006.

The situation is different with regard to virus diseases. Even the Hüll breeding yards are severely infected with HMV, ApMV and HLV, the reason being that numerous foreign varieties have been planted out in these breeding yards for decades. In most cases, the starting material was not examined for virus infections at all and therefore no efforts were made to create virus-free planting stock by way of meristem culture. These hop plants were usually grown in four-plant blocks, providing ideal conditions for the virus to be spread mechanically or via aphids from these small infection centres to neighbouring hop plants. Double infections with HLV/HMV or HMV/ApMV were detected frequently, while in a few cases three, and in one case all four, viruses were identified in a single hop sample. At the propagation facility of the Society of Hop Research, a number of HMV- and HLV-infected plants were destroyed. In the case of the leaf samples from hop farms, in which HMV, ApMV and also HLV were detected alone or in combination in many cases, the actual infection situation looked worse than it really was because sample material sent in for testing was taken exclusively from hop plants showing disease symptoms. Since positive controls for AHLV were not yet available during the 2011 testing season, samples taken merely at random from 10 US cultivars were tested for AHLV by RT-PCR; the virus was detected in six plants and confirmed by sequencing. These findings show only too clearly that virus infection levels are extremely serious.

Eastwell, K.C. and Nelson, M.E., 2007: Occurrence of Viroids in Commercial Hop (Humulus lupulus L.) Production Areas of Washington State. Plant Management Network 1-8.

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.

Long-term optimisation of aphid (*Phorodon humuli*) control in hops (*Humulus lupulus*) by means of control thresholds and breeding of aphid-tolerant hop cultivars

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Pflanzenschutz Hopfen *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Plant Protection)*
Financed by:	Deutsche Bundesstiftung Umwelt (DBU)
Project managers:	B. Engelhard (until 03/2011), Dr. F. Weihrauch
Project staff:	Dr. F. Weihrauch
Cooperation:	Hop growers
Duration:	01.04.2008 - 31.03.2011; continued at own expense during the 2011 season on account of insufficient data.

Objective

The first, more extensive, part of the project involved investigating whether and, if yes, under what conditions (e.g. variety, growth stage, time until harvest) a certain number of hop aphids per leaf/cone can be tolerated without their being qualitatively and quantitatively detrimental to the harvested cones. The plan was to use these findings to formulate a threshold control strategy. However, since pest pressure was too low for two of the three scheduled project years (2008-2010), the project was continued in 2011 at our own expense with a view to presenting the strategy at the DBU's "Woche der Umwelt", to be held June 5-6th 2012 at Schloss Bellevue in Berlin.

Results

Contrary to 2010, where slight damage was recorded in only three of 57 untreated control plots, aphid infestation in 2011 caused massive damage in some areas. Some of the high-alpha varieties, in particular, were affected to an extent scarcely witnessed in the past, with the plants undergoing growth arrest on reaching 75 % of the trellis height. Seven out of a total of 12 trial harvests from insecticide-free control plots (three for each of the varieties HM, HS, HT and PE) suffered significant yield losses (3 HM, 3 HS, 1 HT) and four of them (2 HM, 2 HS) significant alpha-acid losses. In one case (HT), a significant alpha-acid increase was obtained in the untreated control plot. In five comparisons of yield and seven of alpha-acid content, no statistically significant differences were found between plots treated with insecticide and control plots.

The intention is to largely complete further analysis of the comprehensive data obtained during this project by the summer of 2012.

Development of integrated methods of plant protection against the alfafa snout beetle (*Otiorhynchus ligustici*) in hops

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Pflanzenschutz Hopfen *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Plant Protection)*
Financed by:	Bundesanstalt für Landwirtschaft und Ernährung (BLE) *(Federal Agency for Agriculture and Food)*
Project managers:	B. Engelhard (until 03/2011), Dr. F. Weihrauch, J. Schwarz
Project staff:	J. Schwarz
Cooperation:	Part of the joint project "Erarbeitung von integriertenPflanzenschutzverfahren gegen Bodenschädlinge" *(Development of integrated methods of plant protection against soil pests)*
Duration:	01.03.2008 – 28.02.2012

Objective

- To control alfafa snout larvae in the soil by means of entomopathogenic nematodes (EPN) and entomopathogenic fungi (EPF), with the aim of obtaining, if possible, a permanent colony of beneficial organisms.
- To identify and log *Otiorhynchus* species that actually occur as pests in German hop-growing areas.

Results

In pot trials, predefined numbers of alfafa snout beetle eggs were introduced into each experimental pot. A project-specific breeding method was developed in which eggs were produced by beetles collected from hop fields and kept in containers, where they were fed lucerne and red clover. 25 eggs were transferred to the soil surrounding the root collar of the red clover planted in each pot. The pots were either left untreated (controls) or treated with EPN or EPF. In contrast to the preceding years, no evidence of successful beetle control was obtained in 2011 because none of the larvae developed, not even those in the untreated controls. The reasons are as yet unclear. The joint project has since been concluded, but the pot trials are being continued in 2012 at our own expense.

To identify and log Otiorhynchus species occurring in German hop-growing areas, pitfall traps were set up. Evidently, the alfafa snout beetle *(Otiorhynchus ligustici)* is in fact the only *Otiorhynchus* species that occurs as a regular pest in all German hop-growing regions. Evidence of hop damage caused by a different snout beetle, the vine weevil *(Peritelus sphaeroides),* was found at only one location, near Geisenfeld in Bavaria.

Testing of two forecasting models for the control of powdery mildew in hops and implementation of one of the models for controlling the disease in practice

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Pflanzenschutz Hopfen *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Plant Protection)*
Financed by:	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG hop producer group)*
Project managers:	B. Engelhard (until 03/2011), Dr. F. Weihrauch
Project staff:	J. Schwarz, G. Meyr
Duration:	01.01.2010 – 31.12.2012

Objective

A preliminary forecasting model (formulated by B. Engelhard on the basis of empirical data) and a weather-based forecasting model (formulated by S. Schlagenhaufer on the basis of scientific data) were developed over a number of years and have already been tested in field trials. The infection pressure in several untreated plots was too low at the time of the trials to permit conclusive statements on the reliability of the forecasts. These tests are intended to clarify the issue.

Results

The test was performed at four locations and involved three test variants and three cultivars:

Hemhausen - HM, HT
Reitersberg - TU
Einthal - HM
Eichelberg - TU

The three test variants comprised untreated plots of approx. 500 m² and plots treated in accordance with spray warnings based on the preliminary and the weather-based forecasting models. They were situated at all four locations and covered all three cultivars.

As in the preceding years, PM outbreak on the untreated plots was again low in 2011; with one exception, neither model triggered any spray warnings at all. At harvesting time, infection levels in the untreated plots were accordingly much too low to furnish conclusive results.

The only genuine spray warning of the season was triggered by the preliminary model for all cultivars on July 14th. This model also triggered a pre-weekend preventive warning for susceptible cultivars at three locations on June 3rd following four relevant daily sections. The weather-based model did not trigger any spray warning at all because infection levels were too low. However, here too, all plots received preventive treatment on August 8th so as to minimize the risk of late downy mildew.

These tests will be continued unchanged in 2012.

Reducing or replacing copper-containing plant protectives in organic hop farming

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Pflanzenschutz Hopfen *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Plant Protection)*
Financed by:	Bundesanstalt für Landwirtschaft und Ernährung (BLE) *(Federal Agency for Agriculture and Food),* Bundesprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft (BÖLN)
Project managers:	B. Engelhard (until 03/2011), Dr. F. Weihrauch
Project staff:	J. Schwarz, D. Ismann, G. Meyr
Cooperation:	Georg Pichlmaier's Naturland farm, Haushausen
Duration:	19.04.2010 - 18.03.2013

Objective

After assessing the toxicological effects of copper-containing plant protectives on the environment and users, the German Federal Environment Agency considers that these products should no longer be used. However, organic hop farmers are currently unable to do without this active agent. The aim of this three-year experimental project is thus to test the extent to which the amount of copper used per season can be reduced without affecting the quality of harvested hops. The intention is to reduce the currently permitted copper dose rate of 4.0 kg/ha/year by at least 25 %, to 3.0 kg/ha/year.

Results

- As in 2010, a downy mildew station for monitoring zoosporangia was set up on an organic hop farm and the findings evaluated. Zoosporangium counts were up to 15 times higher (10 times higher in 2010) than at comparable stations set up by the warning service in conventional hop yards. Once again, the numbers of zoosporangia increased and decreased according to almost identical time patterns.
- A formal problem concerning US approval (NOP) made it necessary to switch, at short notice, from the Cu-hydroxide-based products used in 2010 to a different product. The entire experimental project was conducted instead with copper oxychloride, which is NOP-unproblematic. With hydroxides, even better results would probably have been possible.
- The copper dose rates of 4.0, 3.0 and 2.0 kg/ha were distributed over six sprayings. Conventional organic products (stone dust and brown algae) were added alternately to each spray.
- Marketable hops were produced under all test conditions except in the Cu-free control plot.
- Addition of the plant tonics Herbagreen und Biplantol enhanced the effect of the copper product, while mixtures with Frutogard, which contains potassium phosphonate, produced the best results by far.
- Assessment of the results should take account of the fact that the experiment was carried out on the Perle variety, which is tolerant towards downy mildew.

Click-beetle monitoring in Hallertau hop yards with the help of pheromone traps

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Pflanzenschutz Hopfen *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Plant Protection)*
Financed by:	Self-financed; Syngenta Agro GmbH, Maintal
Project manager:	Dr. F. Weihrauch
Project staff:	Dr. F. Weihrauch, J. Schwarz, A. Bogenrieder
Cooperation:	Julius Kühn Institute, Braunschweig; German Phytomedical Society (WG Cereal Pests); Göttingen University; Syngenta Agro GmbH, Maintal
Duration:	2010 - 2012

Objective

The soil pests commonly referred to as wireworms are in fact the larvae of click beetles (Elateridae). Wireworms have been causing more and more damage to hops (especially young plants) over the last few years. The actual biology of this pest is, however, still largely unknown and insight gained so far into the period of larval development, for instance, stems solely from studies conducted several decades ago on the striped click beetle, *Agriotes lineatus*. Other species, however, have much shorter periods of larval development, which should be taken into consideration, of course, if measures to combat this pest are to be effective. The actual range of click beetles currently found in hops has not been ascertained to date.

Within the framework of a nation-wide, multi-year joint project aimed at remedying this situation, click-beetle monitoring was also performed in the Hallertau in 2010 for the first time. In the second project year, 2011, beetles caught in pheromone traps in an organic hop yard (Ursbach, Kehlheim district, 430 m a.s.l., soil: clay) and in a conventional yard on the edge of the Ilm valley (Eichelberg, Pfaffenhofen district, 395 m a.s.l., soil: sand) were compared.

Results

Over a 14-week period in 2011, a total of 207 click beetles (11 species) were caught (Eichelberg: 123 beetles, Ursbach: 84 beetles). The total catch was distributed over 15 species, of which the six *Agriotes* species are classed as agricultural pests causing varying degrees of damage (Tab. 1). The striped click beetle, *A. Lineatus,* was the main species in two hop yards and the dusky click beetle, *A. Obscurus,* in the other two. The third species occurring regularly, in moderate numbers, at all four locations was the common click beetle, *A. Sputator.* These three species were found regularly in the traps from the end of April to mid-July. The *A. ustulatus* species, which also causes considerable damage, was also identified at all four locations, albeit in very small numbers and only in mid-summer. One pleasing aspect is the fact that the thermophilic *A. sordidus*, a dangerous pest currently spreading in central Europe from the south along the large rivers (e.g. Upper Rhine), does not appear to have reached the Hallertau region yet.

Differentiating the world hop range with the help of low-molecular polyphenols

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenqualität und –analytik *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Quality/Hop Analytics)*
Financed by:	Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten *(Bavarian State Ministry for Food, Agriculture & Forestry)*
Project manager:	Dr. K. Kammhuber
Project staff:	Dr. K. Kammhuber, B. Sperr, E. Neuhof-Buckl, B. Wyschkon
Duration:	01.01.2010 - 31.12.2011

Objective

The intention was first to devise a suitable sample preparation technique and HPLC method for analysing the entire world hop range available in Hüll. The aim was then to establish whether it is possible to differentiate between hop varieties and divide them up into groups, possibly even by country.

Results

The entire global range of hop varieties harvested in 2009 and 2010 was analysed using the sample preparation technique and HPLC method devised for the purpose. Quercetin and kaempferol glycosides are particularly suitable for variety differentiation. The main components were identified in cooperation with Dr. Coelhan (Institute for Chemical and Technical Analysis at the Technical University of Munich). Some varieties are easily distinguishable but others, such as the landrace varieties, have very similar flavonoid compositions. A country-based classification was not possible. Cluster analysis was employed to classify the global hop range in 20 clusters by flavonoid similarity.

Response of various hop cultivars to reduced trellis height (6 m) and testing of new plant-protective application techniques

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenbau und Produktionstechnik *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Cultivation/Production Techniques)*
Financed by:	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG hop producer group)*
Project manager:	J. Portner
Project staff:	S. Fuß
Cooperation:	Mitterer, Terlan
Duration:	01.01.2008 – 31.12.2011

Objective

In this project, the height of the hop trellis was reduced from 7 m to 6 m in trial plots in a number of commercial hop yards (growers of various hop cultivars). The aim was to study the reaction of various cultivars to reduced trellis height (plant growth, susceptibility to disease/pests, yield and quality). Tests were conducted on the aroma varieties Perle and Hallertauer Tradition and the bitter varieties Hallertauer Magnum, Hallertauer Taurus and Herkules. During the second phase of the project, Mitterer sprayers adapted to low trellis heights (of the kind used in fruit growing) were tested and compared with conventional hop sprayers. The plan was to investigate the extent to which water consumption can be cut, active-agent adhesion improved and environmental risks caused by drift reduced.

Results

Yields from hops grown on 7m trellises tended to be higher, with the difference being highly significant in the case of Herkules. Alpha-acid content was scarecly affected by the difference in trellis heights. Noteworthy was the fact that green-hop moisture content, when averaged over the four years of the trial, was significantly higher in all the cultivars except Perle when the hops were grown on the lower trellis system. This suggests that the optimum harvesting time is reached later on lower trellis systems. Cone assessment showed no differences in size or disease infestation. Evaluation of the extensive application trials with the modified sprayer and the relevant deposit measurements had not been completed by the editorial deadline for the Annual Report. The results will be published separately.

Studies to investigate the structural design of hop trellis systems

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenbau und Produktionstechnik *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Cultivation/Production Techniques)*
Financed by:	Erzeugergemeinschaft Hopfen HVG e.G. *(HVG hop producer group)*
Project manager:	J. Portner
Project staff:	S. Maier (Dipl.-Bauing.)
Duration:	2010 – 2012

Objective

Disastrous storm damage during the last few years, which caused hop trellis systems in the Hallertau region to collapse prior to harvesting, has prompted studies to investigate the strengths and weaknesses of the various trellis designs in the different growing areas and ascertain whether structural improvements are possible.

Results

In 2010, within the framework of a project and with the assistance of a civil engineer who comes from a hop farm and has experience in structural engineering, civil engineering students at the Regensburg University of Applied Sciences carried out extensive bibliographical research, undertook excursions to the Hallertau, Tettnang and Elbe-Saale hop-growing regions and then performed simulations with the various trellis designs (Hallertau, Tettnang and Elbe-Saale trellises).

This enabled them to identify the strengths and weaknesses of the different designs and make proposals for possible improvements. The results were summarized in a catalogue and discussed with trellis builders and hop growers at various events. The aim of further investigations and simulations, some performed in 2011 and others scheduled for 2012, is to clarify the issues raised.

Development and optimisation of an automatic hop-picking machine

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenbau und Produktionstechnik und Institut für Landtechnik und Tierhaltung *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Cultivation/Production Techniques, and Institute for Agricultural Engineering and Animal Husbandry)*
Financed by:	Bundesanstalt für Landwirtschaft und Ernährung (BLE) *(Federal Agency for Agriculture and Food)*
Project manager:	J. Portner
Project staff:	IPZ 5 and Drs. G. Fröhlich and Z. Gobor from the Institute for Agricultural Engineering and Animal Husbandry
Cooperation:	Fuß Maschinenbau GmbH & Co. KG, Schkölen
Duration:	01.09.2011 – 31.03.2014

Objective

The aim is to automate attachment of the hop bines to the intake arm of the picking machine without compromising picking quality, thereby obviating the need for seasonal workers, most of them foreign, who currently do this job. The first step will be to cut the hop bines, which are 6-7 m long, into pieces measuring 0.5-1 m in length. The cutting machine is under development. A metering device will then feed the bine segments uniformly to a modified picker that is basically similar to the already-improved lateral picker produced by Fuß Maschinenbau GmbH. The picker will strip the hop cones from the bine segments and convey them as before, together with the loose leaves, to the cleaning unit.

Results

Various configurations for the future cutting device were tested during the 2011 hop harvest, and preliminary hop picking was filmed with a high-speed camera. The findings will be incorporated in the development and design of an automatic hop-picker prototype to be tested for the first time during the 2012 harvest.

Optimisation of irrigation management in hop growing

Sponsored by:	Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenbau und Pflanzenzüchtung, AG Hopfenbau und Produktionstechnik *(Bavarian State Research Center for Agriculture, Institute for Crop Science and Plant Breeding, WG Hop Cultivation/Production Techniques)*
Financed by:	Dt. Bundesstiftung Umwelt (DBU) and Erzeugergemeinschaft HVG e.G. *(HVG hop producer group)*
Project manager:	Dr. M. Beck
Project staff:	T. Graf, J. Münsterer
Cooperation:	Dr. M. Beck, Weihenstephan-Triesdorf University of Applied Sciences
	A. Werner, Thuringia State Research Centre for Agriculture
	ATEF, Oberhartheim
Duration:	01.12.2011 – 30.11.2014

Objective

The use of irrigation systems in hop growing helps reduce yield fluctuations and guarantees a steady supply of high-quality hops. For irrigation purposes, use is made almost exclusively of drip hoses.

Usually, however, they are installed and operated unsystematically owing to lack of experience and information. Inefficient operation can cause high costs and environmental problems stemming from high water consumption and nutrient displacement.

The aim of this project is therefore to investigate the issue of drip-hose positioning, determine ideal irrigation times and water volumes and find out which soil moisture sensors are most suitable. To this end, field trials will be performed on various soil types, initially with the Herkules cultivar. The intention is to substantiate crop-based results by performing physiological examinations of hop plants under water stress as a function of various soil moisture tensions and meteorological conditions. The plan is to publish the basic findings and recommendations in the form of a guide at the end of the project.

1.2 Main research areas

1.2.1 Main research area: Hop Breeding

New hop breeding trend – hops with floral, citrus and fruity aromas

Project managers:	A. Lutz, Dr. E. Seigner
Project staff:	A. Lutz, J. Kneidl, Team von IPZ 5c
Cooperation:	Dr. K. Kammhuber, IPZ 5d team
	Anheuser-Busch InBev, W. Lossignol
	BayWa, Dr. D. Kaltner
	Bitburger Brewing Group, Dr. S. Hanke
	Schönram brewery, E. Toft
	Veltins brewery, W. Bauer,
	Hopfenveredlung St. Johann *(St. Johann hop processing facility)*, A. Gahr
	Hopfenverwertungsgenossenschaft HVG *(HVG Hop Processing Cooperative)*
	Hopsteiner
	J. Barth & Sohn
	New Glarus Brewing Company, D. Carey
	Städt. Berufsschule für das Braugewerbe, München *(Munich vocational school for brewing),* D. Stegbauer
	The Boston Beer Company, D. Grinnell
	Urban Chestnut Brewing Company, F. Kuplent

Objective

Initial crosses aimed at developing hop cultivars with fruity, citrus and floral fragrances and flavours were performed in 2006. These were the first of their kind in the Hüll Research Centre's breeding history trying to support US craft brewers in their quest to substantially enhance the diversity of their beers with novel citrus and fruity aroma nuances. Other creative brewers outside the USA are adopting this new beer philosophy in increasing numbers.

Material and methods

Thirty-three crosses with this breeding goal had been performed by 2011. All the seedlings were pre-selected for their disease resistance, growth vigour, sex, cone formation and cone production. Cones were only harvested from breeding lines with pleasant fruity or floral aromas. The aroma of the dried hop cones was determined organoleptically and also analysed chemically. Bitter substances were determined by HPLC as per EBC 7.7. Although the headspace GC method was the standard method used, essential oils were additionally analysed and quantified by EBC gas-chromatography methods 7.10 and 7.12 using steam distillation.

Results

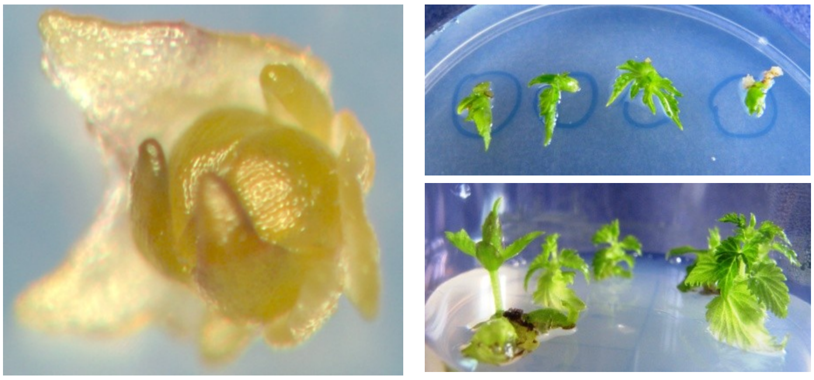
Most of the 33 crosses performed are based on the US cultivar Cascade, which shows specific aroma characteristics stemming from its North American ancestry. The male plants were selected from Hüll breeding material, which boasts fine aroma quality of European origin as well as enhanced disease resistance and agronomic performance. Over a period of three years, 2,208 pre-selected female lines from this breeding programme were cultivated as individual plants in Hüll and assessed. The most promising lines are being cultivated in replicate at two different locations in order to test their cropping suitability. Cones from a number of breeding lines in keeping with this new aroma and flavour trend were harvested and analysed chemically, using Cascade, with its fruity-citrus aroma, as a reference cultivar. Initial brewing experiments with eight new Hüll breeding lines have proved highly promising. The beers developed distinctive aromas reminiscent of tangerines, melons, grapefruit and peaches. Floral and resinous aromas were also identified. For the first time in Hüll, hops have been bred with a wide variety of fruity, citrus and floral aroma and flavour profiles that are in demand by creative brewers the world over. Applications for registration as cultivars have been filed with the Community Plant Variety Office for two breeding lines.

Meristem cultures to eliminate viruses – a basic requisite for virus-free planting stock

Project manager:	Dr. E. Seigner
Project staff:	B. Haugg, A. Lutz
Cooperation:	O. Ehrenstraßer, IPZ 5b
	Dr. L. Seigner, IPS 2c and team

Goal and methods

Meristem culture is a means of producing virus-free hop plants. The shoot tips are first heat-treated prior to excision of the uppermost growth zone (= meristem), located at the apex of the shoot. Following heat therapy, these 0.2-0.3 mm meristematic centres are considered virus-free. The meristems are transferred to special culture media, where they grow into complete plants. To verify that hops grown from meristems are really free of virus infections, their leaves are examined for four different viruses and for Hop stunt viroid with the ELISA (enzyme linked immunosorbent assay) or RT-PCR techniques.



Meristem after 5 days on culture medium (left); 3 and 15 weeks (top and bottom centre) following excision and *in-vitro* plants ready for virus testing after 6-10 months

Results

The importance of virus-free planting stock as part of our quality drive will be explained in Section 4.1.4. Following Mr. Hesse's retirement, the technique had to be newly established. A number of factors influenced the effectiveness of meristem culture as a means of producing virus-free hop plants. These included the growth vigour and vitality of the starting material, distinct seasonal fluctuations in meristem growth and associated plant development, and the variations in *in vitro* growth shown by the various genotypes. The standard *in vitro* medium was varied to meet the specific requirements of various genotypes.

HMV (hop mosaic virus) was successfully eliminated from all the infected starting material by regeneration from heat-treated meristems. Eliminating ApMV (apple mosaic virus) was more difficult. Seventy per cent of the heat-treated meristem plants were defintely virus-free, but ApMV was still detectable with ELISA or RT-PCR in 30 % of the plants. The effectiveness of the virus elimination process increases with increasing temperature and the length of time the shoot tips are exposed to this heat. Effectiveness is also greatly enhanced if the excised meristems measure < 0.5 mm. As a consequence, the number of virus-free plants we obtained grew as we obtained more experience in meristem excision. That said, it was found that the meristems of certain varieties, such as Hüller Bitterer, tolerate relatively long heat exposure, whereas the English variety Wye Target, in particular, proved to be highly heat-sensitive, causing a fair number of excised meristems to die.

Since not only the HMV/ApMV combination but also HLV (hop latent virus) was detected in the starting material, and, as shown by our virus monitoring in 2011 (see Section 4.1.4), HLV infections are very widespread, plants will, in future, also be tested for HLV. In the past, routine ELISA testing was performed only for HMV and ApMV. One reason was that, in comprehensive studies performed at least 20 years ago by Dr. Kremheller, hop latent virus infections in German hop-growing areas were classed as unimportant. The other reason was, and still is, the absence of a commercially available antiserum for HLV testing with ELISA. It was only within the framework of the project "Monitoring for dangerous viral and viroid infections in hops", funded by the Scientific Station for Brewing in Munich, that the Work Group for Pathogen Diagnostics (IPS 2b) was able to develop the RT-PCR method as a molecular alternative for HLV testing. Since then, we have been able to test for HLV and AHLV infections in the starting material and also the plants obtained from the meristems. We were able to regenerate highly successful, HLV-free plants from virus-infected starting material and to rule out infection with AHLV in our parent plants. All the starting material was additionally confirmed HSVd-free by RT-PCR (method: see Section 4.1.4). Research has been going on for years to investigate the extent to which meristem culture preceded by heat or cold therapy might also be used to eliminate the viroid from hops infected with hop stunt viroid. These projects clearly show how important meristem culture is for the provision of virus-free planting stock.

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Kremheller, H. T., Rossbauer, G., and Ehrmaier, H. 1989. Reinfection of virus-free planted hop gardens with *Prunus* necrotic ringspot and hop mosaic virus. Effects of the virus infection upon the yield, alpha acids, and the disease symptoms of the various hop varieties. 133-136 in: Proc. Int. Workshop Hop Virus Dis. Giessen.

Kremheller, H.T., Ehrmaier, H., Gmelch, F., Hesse, H. (1989): Production and propagation of virus-free hops in Bavaria, Federal Republic of Germany. Deut. Phytomed. Gesellschaft, 131-134.

Momma, T., and Takahashi, T. (1983): Cytopathology of shoot apical meristem of hop plants infected with hop stunt viroid. Phytopath. Z., 106, 272-280.

Adams, A. N., D. J. Barbara, A. Morton, and P. Darby. 1996. The experimental transmission of Hop latent viroid and its elimination by low temperature treatment and meristem culture. Annals of Applied Biology 128:37-44.

1.2.2 Main research area: Hop Cultivation/Production Techniques

Trials to investigate irrigation control in hop growing

Project staff: J. Münsterer

An irrigation trial is being conducted in Schafhof to determine how much water is needed to obtain optimum hop yields and when it is needed. The trial involves a number of experimental variants and stages. In this trial, conventional irrigation-control systems were compared with computer-aided water-supply models and direct methods of measuring soil moisture. The trials already underway are being continued as part of the research project on irrigation management in hop growing, which was described in Section 1.1.

Positioning of drip hose in hop irrigation

Project staff: J. Münsterer

Trials are being conducted at Ilmendorf and Oberempfenbach, locations with different soils, to determine the extent to which growth and yield are affected by differences in drip-hose positioning during routine hop irrigation. Irrigation via a hose positioned on top of the hilled row is being compared with a technique where the drip hose is buried permanently in the ground alongside the row. In actual practice, hop farmers also position drip hoses in the middle of the tractor aisles in order to reduce labour costs. This alternative is being investigated in a further experiment being conducted on a clay soil in Unterhartheim and a sandy soil in Eichelberg.

Optimising nitrogen fertilisation by means of banded application

Project manager: J. Portner
Project staff: E. Niedermeier
Duration: 2007 – 2012

Earlier trials in the Hallertau and in Thuringia show that if fertiliser is applied by banding rather than by broadcasting, the same yield can be achieved with up to a third less fertiliser. In addition to beneficial environmental effects, there are advantages for hop farmers at risk of exceeding the acceptable nutrient balance surplus as defined by the German regulation on fertiliser use with their nitrogen fertilisation activities.

The nitrogen enrichment trial is investigating whether the surplus limit of 60 kg N/ha for hop farms is sufficient and whether nitrogen can really be saved via banded fertiliser application.

Testing of an Adcon weather model for the downy mildew warning service

Project manager:	J. Portner
Project staff:	J. Schätzl
Duration:	2008 – 2013

To forecast the probability of a downy mildew outbreak, the number of zoosporangia is being determined daily with spore traps at five locations in the Hallertau, one in Spalt and one in Hersbruck. If the economic threshold is exceeded and the weather conditions are favourable for the pest, a regional spray warning is issued, which varies according to variety.

In other hop-growing regions (Elbe-Saale, Czech Republic), early-warning forecasts are based purely on weather models. Infection potential is ignored. The 5-year trial is intended to determine the extent to which the time-consuming and labour-intensive counting of zoosporangia at downy mildew locations is necessary. To this end, the index calculated by the Adcon weather stations is compared with the warnings based on the Kremheller model in order to determine Adcon thresholds for susceptible and tolerant varieties. Scientific tests are then performed to determine whether the different methods of triggering spray warnings have influenced yield and quality.

1.2.3 Main research areas: Hop Quality and Analytics

Performance of all analytical studies in support of the Hop Department work groups, especially Hop Breeding Research

Project manager:	Dr. K. Kammhuber
Project staff:	E. Neuhof-Buckl, S. Weihrauch, B. Wyschkon, C. Petzina, B. Sperr, M. Hainzlmaier, Dr. K. Kammhuber
Cooperation:	WG Hop Cultivation/Production Techniques, WG Plant Protection in Hop Growing, WG Hop Breeding Research
Duration:	Long-term task

Hops are grown and cultivated mainly for their components. Component analysis is therefore essential to successful hop research. The IPZ 5d team (Hop Quality and Analytics work group) carries out all analytical studies needed to support the experimental work of the other work groups. Hop Breeding Research, in particular, selects breeding lines according to laboratory data.

Development of an NIRS calibration model for alpha-acid and moisture content

Project manager: Dr. K. Kammhuber
Project staff: E. Neuhof-Buckl, B. Wyschkon, C. Petzina, M. Hainzlmaier, Dr. Klaus Kammhuber
Duration: September 2000 to (open-ended)

As of 2000, work commenced on the development of an HPLC-data-based NIRS calibration equation in Hüll and the laboratories of the hop-processing firms. In view of the rising number of alpha-acid analyses, the aim was to replace wet chemical analysis by a cheap, fast method with acceptable repeatability and reproducibility for routine use.

It was decided, within the working group for hop analysis (AHA), that such a method could be deemed suitable for routine use and for use as an analytical method for hop supply contracts if it was at least as accurate as conductometric titration according to EBC 7.4.

However, as no further improvement was possible, it was decided to discontinue development of a common calibration equation in 2008. At the Hüll laboratory, however, work on developing an NIRS model continues. A NIRS model for determining moisture content is also being developed. NIRS is suitable as a screening method for hop breeding. It saves a lot of time and cuts the costs for chemicals.

Development of analytical methods for hop polyphenols

Project manager: Dr. K. Kammhuber
Cooperation: Arbeitsgruppe für Hopfenanalytik (AHA) *(Working group for hop analysis)*
Project staff: E. Neuhof-Buckl, Dr. K. Kammhuber
Duration: 2007 to (open-ended)

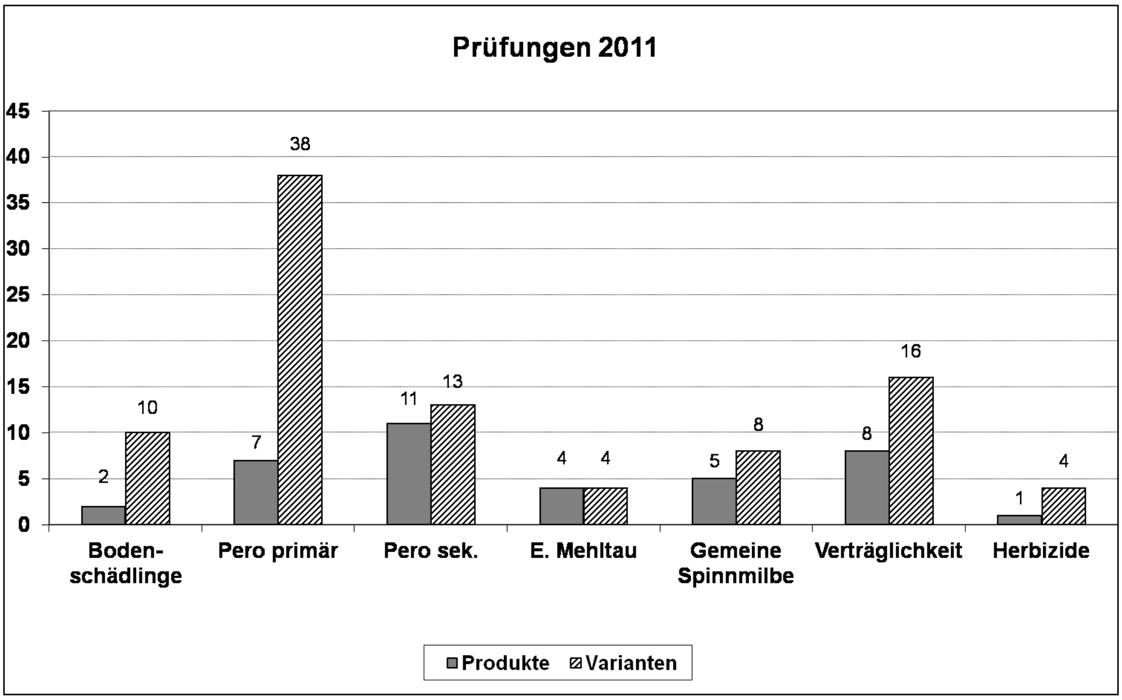
Polyphenols are attracting increasing attention within the context of alternative uses of hops, primarily on account of their health-promoting properties. It is therefore important to have suitable analytical methods available. To date, however, no officially standardized methods exist. The AHA has been working on improving and standardizing the analytical methods for total polyphenol and total flavonoid contents in hops since 2007.

During the most recent ring tests with international involvement, however, the variation coefficients (cvr) for these techniques were so high that they are not yet suitable as official methods. The intention for the future is to place greater emphasis on more specific HPLC methods.

1.2.4 Plant protection in hops

Testing of plant protectives for licensing and approval, and for the 2011 advisory-service documentation

Project manager: B. Engelhard
Project staff: J. Schwarz, G. Meyr, J. Weiher, O. Ehrenstraßer, M. Felsl



2 Weather conditions and hop growth in 2011

LA Erich Niedermeier

The warm, dry spring in 2011 made for good soil structure, facilitating soil cultivation, training and maintenance work. Being a permanent crop, hops are able to tap into water deep underground and meet their springtime requirements for a long time.

The dry weather negatively impacted watering treatment to combat primary downy mildew infection and soil pests because the plant protectives remained in the upper soil layers, where the lack of water prevented them from being absorbed to a sufficient extent by the roots.

Frost damage early in May killed off isolated shoots but had no economic consequences. The warm spring accelerated hop growth, giving it a headstart of up to 14 days and causing well advanced Hallertauer Mfr. and some stands of Hallertauer Magnum to flower prematurely. A hailstorm on 6th June heralded a change in the weather. Up to 70 cm rain fell in the south-eastern part of the Hallertau region within a very short time, causing massive flooding and soil erosion.

The rest of the summer was wet and cool. Growth slowed, so that the initial headstart was lost and harvesting dates coincided with the long-term average for most cultivars. Mid-summer temperatures and hot, humid weather conditions were experienced again as of mid-August, exerting a positive effect on component formation and yield.

Weather conditions, extremes and their impact on the harvest

- Accelerated start of the growing season

Early spring temperatures of 10 – 15 °C were measured in southern Bavaria on 7th February. Hazel, and in a few instances alder, commenced flowering in warm regions - earlier than usual. As of mid-February, Bavaria saw a renewed influx of cold air from eastern Europe, with temperatures dropping as low as -10 °C. Nature returned to dormancy. Precipitation in February remained below average. In sum, the winter in our latitudes brought a snowy December, a mild January and a divided February.

The sunniest March since 1953 followed. Coltsfoot commenced flowering as from the middle of the month, triggering the start of spring-grain sowing and the uncovering and pruning of hops. Precipitation was again below average.

- A dry April with above-average temperatures

An average temperature of 11.1 °C was measured at the Hüll weather station, 2 °C above the 10-year average for April. Precipitation was far below average, measuring 36.3 mm as compared with the 10-year average of 59.2 mm. The northern part of the Hallertau, towards the Danube, had even less precipitation (14.4 mm were measured at the Sandharlanden agrometeorological weather station). The wonderfully dry soil made it possible to perform all soil cultivation, crowning and pruning work without doing any structural damage. However, the dry weather did affect watering treatment against primary downy mildew infection and soil pests because the plant protectives remained in the upper soil layers, where the lack of water prevented them from being absorbed to a sufficient extent by the roots. Training of the shoots was largely concluded in April and was followed immediately by initial hilling, so that soil-working measures, including the planting of catch crops, had been completed by the beginning of May.

- Vegetation cycle 14 days ahead of time in May

By the end of May, the hops had grown to an above-average height of 3.5 – 6 m, depending on the variety and location. On 4th May, the Hüll weather station measured temperatures of -1.9 °C and -2.4 °C at heights of 2 m and 20 cm above the ground respectively. Frost damage killed off isolated shoots in valley locations. Unlike the situation with respect to fruit and wine growing, however, no economic losses were incurred.

Precipitation in May totalled 64.2 mm, 37.5 mm less than the 10-year average. The precipitation deficit, along with below-average humidity, was maintained. Whereas other agricultural crops suffered as a result of the dry weather and produced lower yields, hops, being a perennial crop with an extensive root system, were able to tap the water reserves deep underground. Young hop shoots do not need much water in spring anyway, due to their small leaf-surface area. The warm spring accelerated hop growth, giving it a headstart of up to 14 days and causing well advanced Hallertauer Mfr. and some stands of Hallertauer Magnum to flower prematurely. Secondary hilling and between-row soil cultivation measures to combat weeds and remove ground shoots were conducted during the last few days of May.

- Storm on 6th June marks start of weather change

A hailstorm on 6th June heralded a change in the weather. Up to 70 cm rain fell in the south-eastern part of the Hallertau fell within a very short time, causing massive flooding and soil erosion. This was mainly due to the fact that the storm hit during the secondary hilling phase, when the soil had been loosened and lacked the protection of well rooted weeds and catch crops. The hail damaged approx. 1,500 ha hops to varying degrees. The overall loss incurred as a result of head damage right through to complete crop failure was estimated at 1,000 t. June temperatures remained -0.5 °C below the 10-year average. Despite 104.6 mm precipitation in June, the Hüll weather station recorded a deficit of 50 mm compared to the 10-year average for the months of April, May and June.

- Wet, cool July slows growth to normal levels

The initial headstart in growth melted away during a wet, cool July, during which 229.4 mm rain were recorded, more than twice the average for the last 10 years (103.9 mm). The average temperature was 16.3 °C, 2.1 °C below the 10-year average. The consequence was slower, stress-free growth, prolific flower-budding and a long flowering phase. Protecting plants from fungal diseases under these conditions, where weather time frames for plant protection measures are short, is a challenge for horticulturists.

- Weather conditions up until harvesting made for good yields and promoted component formation

The cool, wet weather that prevailed until mid-August prolonged flowering duration, delaying cone formation and maturation. Mid-summer temperatures and hot, humid weather conditions were experienced again as of mid-August. The average temperature in August was 1.1 °C higher, and rainfall 17.1 mm lower, than the 10-year averages. There were only isolated cases of drought stress, with thundershowers usually supplying the necessary fresh supply of water to locations with light soil. The warm, humid weather benefited yields and component formation. The start of harvesting coincided with the long-term average for most cultivars, the exception being the already-mentioned early-flowering cultivars which matured prematurely and produced lower yields.

2.1 Weather data (monthly means or monthly totals) for 2011 compared with 10- and 50-year means

Month		Temp. 2 m above ground Mean (°C)	Min.∅ (°C)	Max.∅ (°C)	Relative hum. (%)	Precipitation (mm)	Days with ppn. >0.2 mm	Sunshine (h)
January	2011	-0.6	-3.8	2.9	95.1	57.7	16.0	53.7
∅	10-yr.	-1.0	-4.5	2.8	88.0	51.0	11.8	73.1
	50-yr.	-2.4	-5.1	1.0	85.7	51.7	13.7	44.5
February	2011	0.3	-3.1	4.5	90.3	15.9	7.0	86.6
∅	10-yr.	0.3	-4.1	5.3	84.8	42.7	12.4	94.6
	50-yr.	-1.2	-5.1	2.9	82.8	48.4	12.8	68.7
March	2011	4.8	-1.2	12.1	79.4	48.5	5.0	199.1
∅	10-yr.	3.9	-1.1	9.6	80.7	75.0	13.4	144.2
	50-yr.	2.7	-2.3	8.2	78.8	43.5	11.3	134.4
April	2011	11.1	3.5	18.9	67.6	36.3	5.0	269.8
∅	10-yr.	9.1	2.8	15.8	72.8	59.2	11.0	201.6
	50-yr.	7.4	1.8	13.3	75.9	55.9	12.4	165.0
May	2011	14.1	6.5	21.7	65.7	64.2	10.0	296.2
∅	10-yr.	13.8	7.6	20.1	74.4	101.7	14.3	212.7
	50-yr.	11.9	5.7	17.8	75.1	86.1	14.0	207.4
June	2011	16.7	10.9	23.1	76.2	104.6	17.0	184.4
∅	10-yr.	17.2	10.7	23.8	74.0	94.1	14.3	237.8
	50-yr.	15.3	8.9	21.2	75.6	106.1	14.2	220.0
July	2011	16.3	10.8	23.2	78.5	229.4	18.0	192.9
∅	10-yr.	18.4	12.0	25.5	75.6	103.9	14.8	246.4
	50-yr.	16.9	10.6	23.1	76.3	108.4	13.9	240.3
August	2011	18.6	12.1	26.8	78.5	90.3	14.0	263.5
∅	10-yr.	17.5	11.5	24.5	79.7	107.4	13.1	210.0
	50-yr.	16.0	10.2	22.5	79.4	94.9	13.3	218.4
September	2011	15.2	9.0	23.4	82.7	70.3	12.0	214.1
∅	10-yr.	13.0	7.5	19.6	83.5	66.1	11.2	165.5
	50-yr.	12.8	7.4	19.4	81.5	65.9	11.4	174.5
October	2011	8.7	3.2	16.9	83.0	45.1	8.0	154.3
∅	10-yr.	8.7	4.2	14.4	88.0	59.8	11.8	120.6
	50-yr.	7.5	2.8	13.0	84.8	60.0	10.4	112.9
November	2011	2.8	-1	9.0	91.3	0.9	1.0	80.1
∅	10-yr.	3.9	0.5	7.6	91.5	66.2	13.5	61.7
	50-yr.	3.2	-0.2	6.4	87.5	58.8	12.6	42.8
December	2011	3.2	0.2	7.0	85.5	101.5	21	34.9
∅	10-yr.	-0.4	-3.4	2.8	91.5	58.2	14.4	56.4
	50-yr.	-0.9	-4.4	1.6	88.1	49.1	13.3	34.3
∅ 2011		9.3	3.9	15.8	81.2	864.7	134.0	2029.6
10 – year mean		8.7	3.6	14.3	82.0	885.4	156.0	1824.4
50 – year mean		7.4	2.5	12.5	81.0	828.8	153.3	1663.2

The 50-year average refers to the years 1927 up until and including 1976, the 10-year average refers to the years 2001 up until and including 2010.

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
1963	13,259	0.68	1992	3,796	6.05
1973	8,591	2.33	1993	3,616	6.37
1974	8,120	2.48	1994	3,282	6.69
1975	7,654	2.64	1995	3,122	7.01
1976	7,063	2.79	1996	2,950	7.39
1977	6,617	2.90	1997	2,790	7.66
1978	5,979	2.94	1998	2,547	7.73
1979	5,772	2.99	1999	2,324	7.87
1980	5,716	3.14	2000	2,197	8.47
1981	5,649	3.40	2001	2,126	8.95
1982	5,580	3.58	2002	1,943	9.45
1983	5,408	3.66	2003	1,788	9.82
1984	5,206	3.77	2004	1,698	10.29
1985	5,044	3.89	2005	1,611	10.66
1986	4,847	4.05	2006	1,555	11.04
1987	4,613	4.18	2007	1,511	11.70
1988	4,488	4.41	2008	1,497	12.49
1989	4,298	4.64	2009	1,473	12.54
1990	4,183	5.35	2010	1,435	12.81
1991	3,957	5.70	2011	1,377	13.24

Tab. 3.2: Acreage, no. of hop farms and average hop acreage per farm in the German hop-growing regions

Hop-growing region	Hop acreages				Hop farms				Hop acreage per farm in ha	
	in ha		Increase + / Decrease - 2011 to 2010				Increase + / Decrease - 2011 to 2010			
	2010	2011	ha	%	2010	2011	Farms	%	2010	2011
Hallertau	15,387	15,229	- 158	- 1.0	1,164	1,119	- 45	- 3.9	13.22	13.61
Spalt	376	366	- 10	- 2.6	75	70	- 5	- 6.7	5.01	5.23
Tettnang	1,226	1,222	- 4	- 0.3	165	157	- 8	- 4.8	7.43	7.78
Baden and Bitburg	20	20	± 0	± 0	2	2	± 0	± 0	10.00	10.00
Elbe-Saale	1,379	1,392	+ 13	+ 1.0	29	29	± 0	± 0	47.54	48.01
Germany	**18,386**	**18,228**	**- 158**	**- 0.9**	**1,435**	**1,377**	**- 58**	**- 4.0**	**12.81**	**13.24**

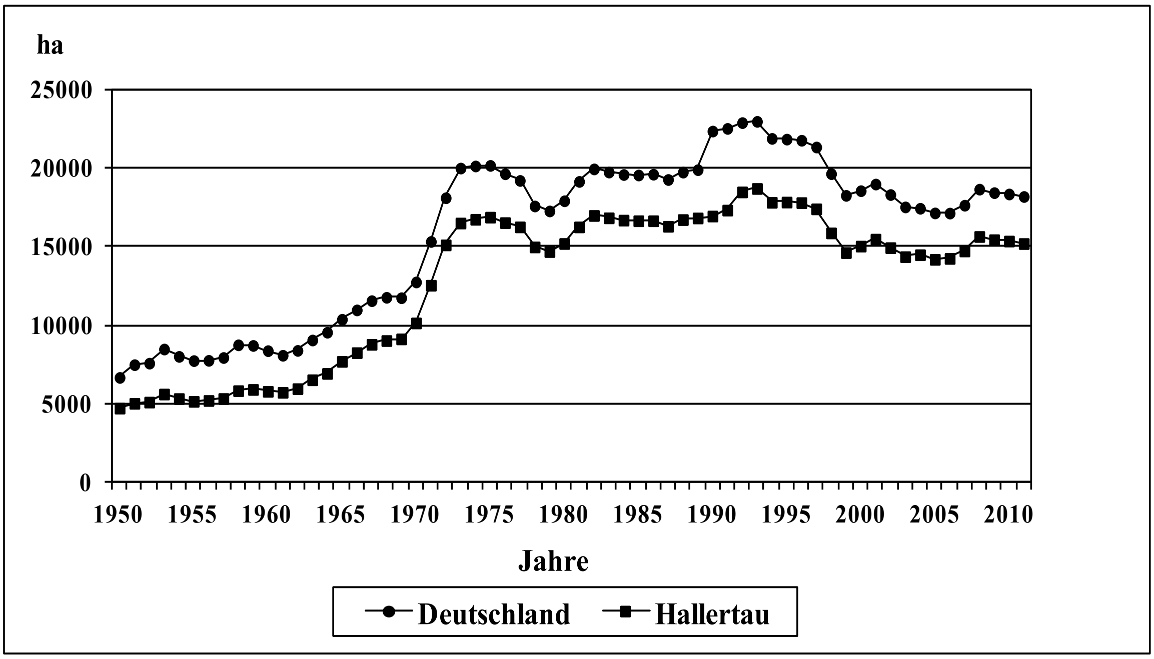


Fig. 3.1: Hop acreages in Germany and in the Hallertau

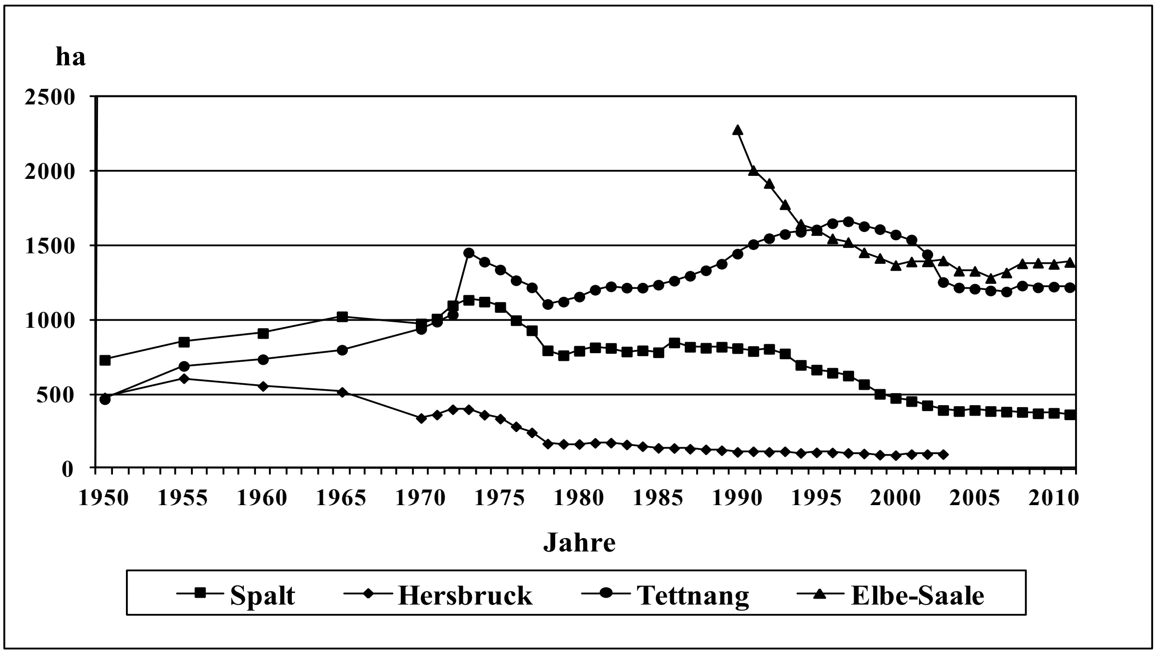


Fig. 3.2: Hop acreages in the Spalt, Hersbruck, Tettnang and Elbe-Saale regions

Hersbruck hop-growing region has been included in the Hallertau since 2004.

3.1.2 Hop varieties

The production shift away from aroma varieties towards bitter varieties, as observed during recent years, came to a halt in 2010 and was even reversed in 2011. The acreage under aroma varieties increased by 95 ha in 2011 while the acreage planted with bitter varieties decreased by 253 ha. Aroma varieties now account for 54.3 % (plus 1.0 %) of the total acreage under hop production, and bitter varieties for 45.7 %.

In 2011, the area under hop production in Germany declined by 158 ha, to 18,228 ha, as a result of the saturated market. Of the aroma varieties, Spalter Select saw complete clearance of a noteworthy area previously under cultivation, namely 82 ha, while Hall. Tradition, Saphir and Hersbrucker Spät witnessed increases in acreage. With the exception of Herkules (+ 72 ha), all the bitter varieties saw some of their acreage cleared.

An exact breakdown of varieties according to growing regions is given in Tab. 3.3 and Tab. 3.4.

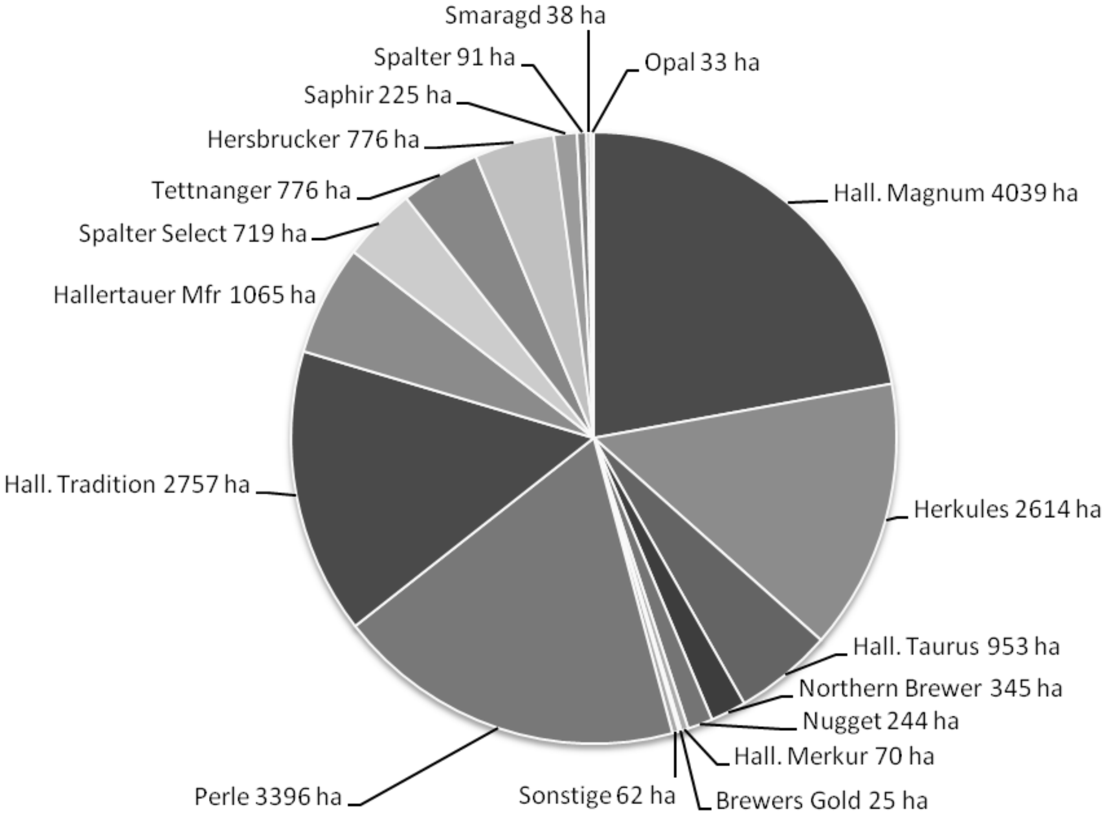


Fig . 3.3: Distribution of hop varieties in Germany in 2011

Tab. 3.3: Hop varieties by German hop-growing region in ha in 2011
Aroma varieties

Region	Total acreage	HA	SP	TE	HE	PE	SE	HT	SR	OL	SD	Other	Aroma varieties	
													ha	%
Hallertau	15,229	729			773	3.129	614	2.634	220	33	30	11	8,172	53.7
Spalt	366	72	91		3	26	99	32	3				326	89.2
Tettnang	1,222	263		776		80	4	53	2		8		1,186	97.1
Baden, Bitburg and Rhine. Pal.	20	1				8	2	5					16	80.4
Elbe-Saale	1,392					153		33				8	193	13.9
Germany	**18,228**	**1,065**	**91**	**776**	**776**	**3,396**	**719**	**2,757**	**225**	**33**	**38**	**18**	**9,895**	**54.3**
% acreage by variety		5.8	0.5	4.3	4.3	18.6	3.9	15.1	1.2	0.2	0.2	0.1		

Variety changes in Germany

2010 ha	18,386	1,069	91	772	758	3,403	801	2,624	196	33	38	16	9,800	53.3
2011 ha	18,228	1,065	91	776	776	3,396	719	2,757	225	33	38	18	9,895	54.3
Chamge in ha	-158	-4	0	4	18	-7	-82	133	29	0	0	2	95	1.0

Tab. 3.4: Hop varieties by German hop-growing region in ha in 2011
Bitter varieties

Region	NB	BG	NU	TA	HM	TU	MR	HS	Other	Bitter varieties	
										ha	%
Hallertau	220	25	213	3	3,164	925	52	2,422	32	7,056	46.3
Spalt					4		8	27		40	10.8
Tettnang						6		29	1	35	2.9
Baden, Bitburg and Rhine. Pal.					3			1		4	19.6
Elbe-Saale	125		30		868	22	11	134	8	1,199	86.1
Germany	**345**	**25**	**244**	**3**	**4,039**	**953**	**70**	**2,614**	**40**	**8,334**	**45.7**
% acreage by variety	1.9	0.1	1.3	0.0	22.2	5.2	0.4	14.3	0.2		

Variety changes in Germany

2010 ha	375	27	266	3	4,202	1,054	85	2,542	34	8,586	46.7
2011 ha	345	25	244	3	4,039	953	70	2,614	40	8,334	45.7
Change in ha	-30	-2	-22	0	-162	-101	-14	72	6	-253	-1.0

3.2 Yields in 2011

Approximately 38,110,620 kg (= 762,212 cwt.) hops were harvested in Germany in 2011, compared with 34,233,810 kg (= 684,676 cwt.) in 2010. This represents an increase of about 3,876,810 kg (= 77,536 cwt.), or roughly 11.3 %, over the previous year.

With a mean per-hectare yield of 2.091 kg, the crop is above-average despite widespread hail damage and, in some cases, even total crop failure in the southern Hallertau region. Alpha content was also well above average in 2011.

Tab. 3.5: Per-hectare yields and relative figures in Germany

	2006	2007	2008	2009	2010	2011
Yield kg/ha and (cwt./ha)	1,660 kg (33.2 cwt.)	1,819 kg (36.4 cwt.)	2,122 kg (42.4 cwt.)	1,697 kg (33.9 cwt.) (severe hail damage)	1,862 kg (37.2 cwt.) (Hail damage)	2,091 kg (41.8 cwt.) (Hail damage)
Acreage in ha	17,170	17,671	18,695	18,473	18,386	18,228
Total yield in kg and cwt.	28,508,250 kg = 570,165 cwt.	32,138,870 kg = 642,777 cwt.	39,676,470 kg = 793,529 cwt.	31,343,670 kg = 626,873 cwt.	34,233,810 kg = 684,676 cwt.	38,110,20 kg = 762,212 cwt.

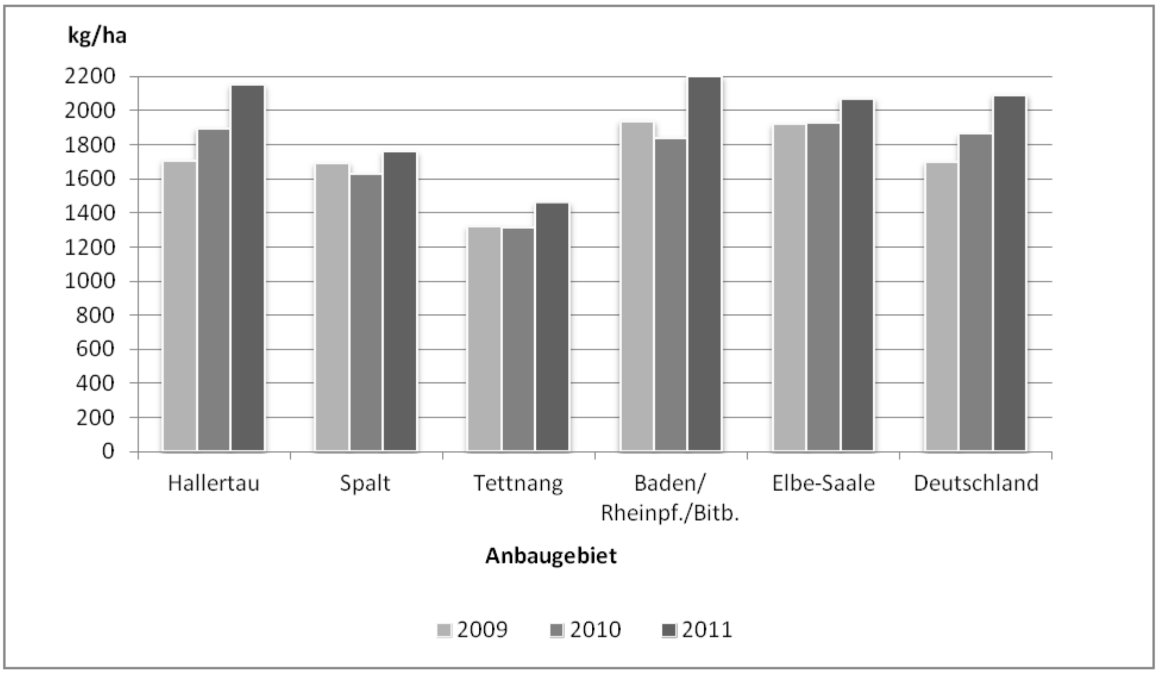


Fig. 3.4: Average yields by hop-growing region in kg/ha

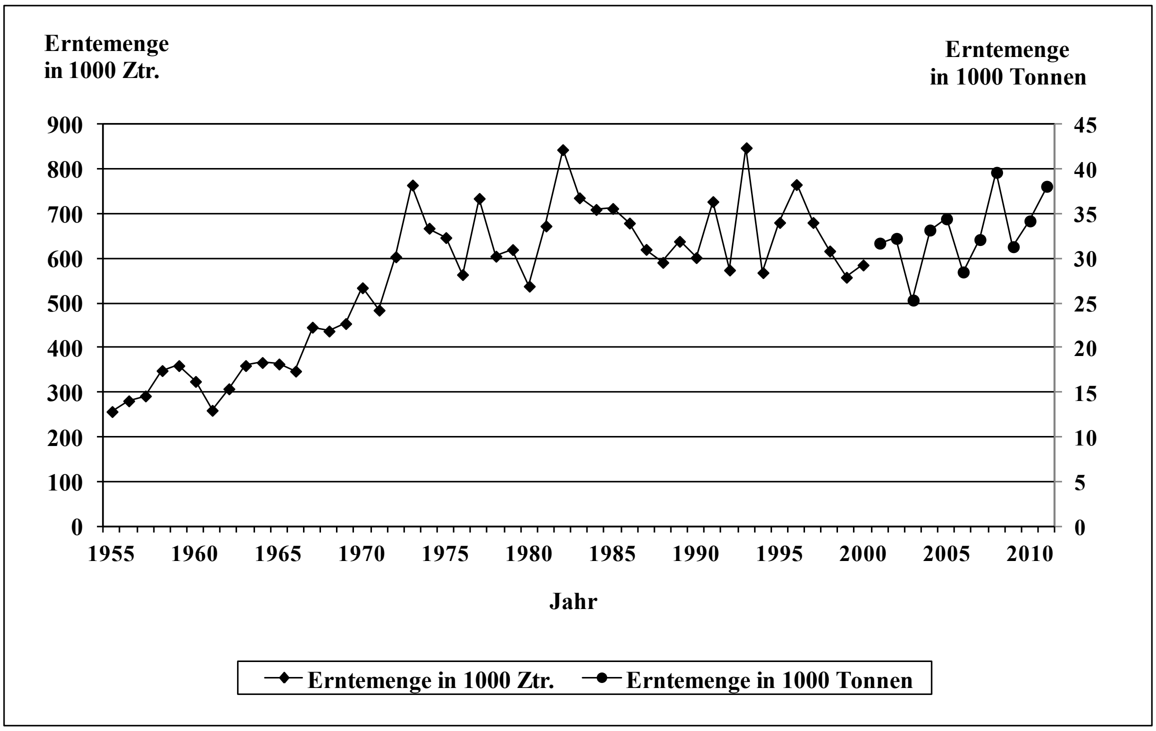


Fig. 3.5: Crop volumes in Germany

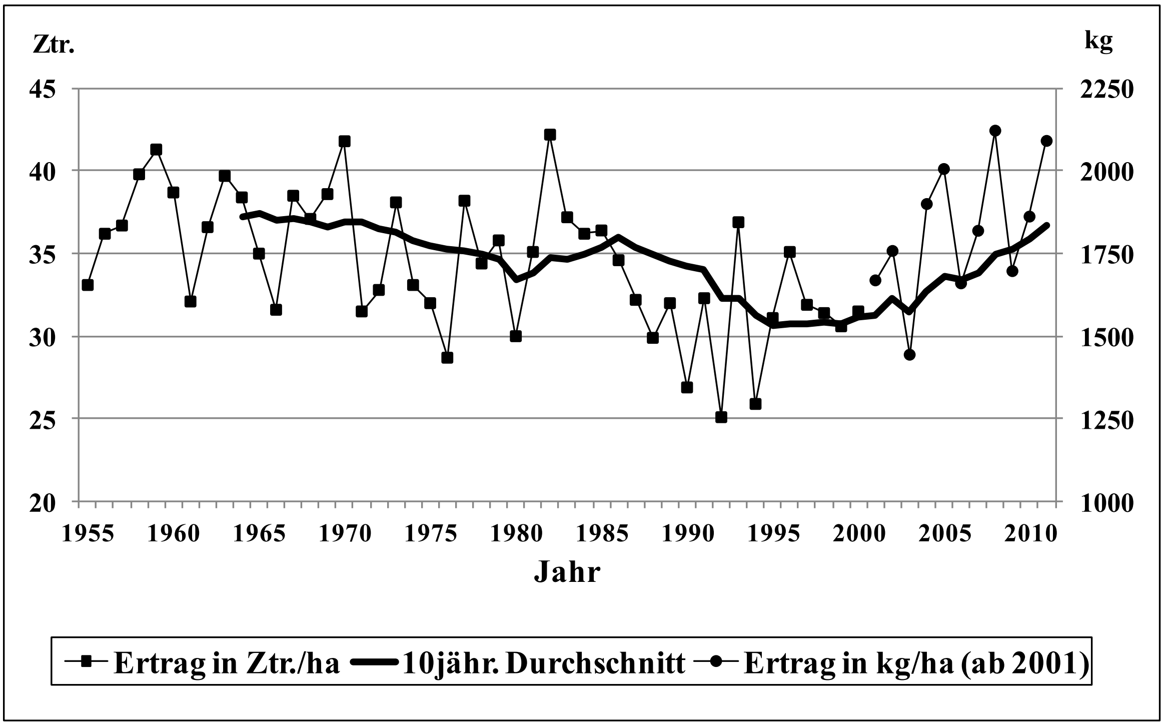


Fig. 3.6: Average yields (cwt. and kg/ha) in Germany

Tab. 3.6: Yields per hectare by German hop-growing region

Region	Yields in kg/ha total acreage								
	2003	2004	2005	2006	2007	2008	2009	2010	2011
Hallertau	1,462	1,946	2,084	1,701	1,844	2,190	1,706	1,893	2,151
Spalt	1,131	1,400	1,518	1,300	1,532	1,680	1,691	1,625	1,759
Tettnang	1,216	1,525	1,405	1,187	1,353	1,489	1,320	1,315	1,460
Baden./Rhine-Pal.	1,936	1,889	1,881	1,818	2,029	1,988	1,937	1,839	2,202
Bitburg Elbe-Saale	1,555	1,895	1,867	1,754	2,043	2,046	1,920	1,931	2,071
∅ Yield / ha **Germany**	**1,444 kg**	**1,900 kg**	**2,006 kg**	**1,660 kg**	**1,819 kg**	**2,122 kg**	**1,697 kg**	**1,862 kg**	**2,091 kg**
Total crop Germany (t and cwt.)	25,356 t 507,124	33,208 t 664,160	34,467 t 689,335	28,508 t 570,165	32,139 t 642,777	39,676 t 793,529	31,344 t 626,873	34,234 t 684,676	38,111 t 762,212
Acreage Germany	17,563	17,476	17,179	17,170	17,671	18,695	18,473	18,386	18,228

Tab. 3.7: Alpha-acid values for the various hop varieties

Region/Variety	2002	2003	2004	2005	2006	2007	2008	2009	2010	**2011**	∅ 5 years	∅ 10 years
Hallertau Hallertauer	4.6	3.1	4.3	4.4	2.4	3.9	4.4	4.2	3.8	**5.0**	**4.3**	**4.0**
Hallertau Hersbrucker	3.2	2.1	3.0	3.5	2.2	2.6	2.9	3.4	3.5	**4.5**	**3.4**	**3.1**
Hallertau Hall. Saphir			3.4	4.1	3.2	4.6	5.1	4.5	4.5	**5.3**	**4.8**	
Hallertau Opal						7.4	9.4	9.0	8.6	**9.7**	**8.8**	
Hallertau Smaragd						6.1	6.7	6.4	7.4	**8.0**	**6.9**	
Hallertau Perle	8.6	3.9	6.4	7.8	6.2	7.9	8.5	9.2	7.5	**9.6**	**8.5**	**7.6**
Hallertau Spalter Select	6.0	3.2	4.9	5.2	4.3	4.7	5.4	5.7	5.7	**6.4**	**5.6**	**5.2**
Hallertau Hall. Tradition	7.2	4.1	6.3	6.3	4.8	6.0	7.5	6.8	6.5	**7.1**	**6.8**	**6.3**
Hallertau North. Brewer	10.1	6.0	9.8	9.8	6.4	9.1	10.5	10.4	9.7	**10.9**	**10.1**	**9.3**
Hallertau Hall. Magnum	14.6	11.7	14.8	13.8	12.8	12.6	15.7	14.6	13.3	**14.9**	**14.2**	**13.9**
Hallertau Nugget	12.4	8.5	10.6	11.3	10.2	10.7	12.0	12.8	11.5	**13.0**	**12.0**	**11.3**
Hallertau Hall. Taurus	16.5	12.3	16.5	16.2	15.1	16.1	17.9	17.1	16.3	**17.4**	**17.0**	**16.1**
Hallertau Hall. Merkur			13.5	13.3	10.3	13.0	15.0	14.8	12.6	**15.2**	**14.1**	
Hallertau Herkules						16.1	17.3	17.3	16.1	**17.2**	**16.8**	
Tettnang Tettnanger	4.6	2.6	4.7	4.5	2.2	4.0	4.2	4.2	4.0	**5.1**	**4.3**	**4.0**
Tettnang Hallertauer	4.8	3.1	5.0	4.8	2.6	4.3	4.7	4.5	4.2	**5.1**	**4.6**	**4.3**
Spalt Spalter	4.6	3.1	4.4	4.3	2.8	4.6	4.1	4.4	3.7	**4.8**	**4.3**	**4.1**
Elbe-S. Hall. Magnum	13.9	10.2	14.0	14.4	12.4	13.3	12.2	13.7	13.1	**13.7**	**13.2**	**13.1**

Source: Working group for hop analysis (AHA)

4 Hop breeding research

RDin Dr. Elisabeth Seigner, Dipl. Biol.

4.1 Classical breeding

By breeding new hop cultivars, the Work Group for Hop Breeding Research seeks to remain constantly at the cutting edge of developments. Breeding activities in Hüll encompass the entire hop spectrum, from the noble aroma hops through to super-high-alpha varieties. Improved resistance mechanisms against major diseases and pests constitute the main criterion for selection of new seedlings. The aim is to enable German hop farmers to grow new top-quality, higher-performance cultivars even more cost efficiently and with even less impact on the environment. Classical cross-breeding has been supported for years by biotechnological methods. Virus-free planting stock, for example, can only be produced by way of meristem culture. Use is also made of molecular techniques, e.g., for investigating the genetic material of hop plants themselves and of hop pathogens.

4.1.1 Crosses in 2011

A total of 91 crosses were carried out during 2011. Tab. 4.1 shows the number of crosses performed for each breeding goal.

Tab. 4.1: Cross-breeding goals in 2011

Breeding direction combined with resistance/tolerance to various hop diseases	Further requirements	Number of crosses
Aroma type	Special aroma expressions	24
	New powdery mildew (PM)-resistance (from wild hops)	28
	Aphid resistance	2
	High beta-acid content	1
High-alpha-acid type	Improved PM-resistance	27
	High beta-acid content	7
Mapping	PM and wilt	2

4.1.2 Breeding of dwarf hops for low trellis systems

Objective

The aim of this research project, funded by Germany's Federal Agency for Agriculture and Food, is to breed hop cultivars which, by virtue of their shorter height, broad disease resistance and excellent brewing quality, are particularly suitable for profitable and ecologically sustainable cultivation on low trellis systems. Until now, the absence of modified varieties of this kind has stood in the way of achieving substantial reductions in production costs with 3-metre trellis systems. This new method of raising hops could also have environmental benefits because the required pesticide and fertilizer volumes are lower. Plus, recycling tunnel sprayers can be employed and potential drift thus reduced.

Results

Seedlings 2008 -2010

After the 2010 harvest, 13 breeding lines were selected from the seedlings bred in 2008 and 2009 for this breeding project for vegetative propagation and subsequent trial cultivation in the low-trellis yard in Starzhausen. Selection was based on crop performance, cone assessment, analytical results and organoleptically determined aroma values. The seedlings were planted out at the beginning of June and had grown well by autumn, so that a full harvest can be expected in 2012.

In the Hüll breeding yard, close monitoring and assessment of the 2008 – 2010 seedlings continued. A total of 73 promising breeding lines (6 from the 2008 seedlings, 14 from the 2009 seedlings and 53 from the 2010 seedlings) were selected for harvesting in 2011. Of these, a total of nine breeding lines have been earmarked for propagation and trial cultivation in the low-trellis yard in Starzhausen.

Whereas seedlings with an enhanced aroma quality were the main ones selected during 2009 and 2010, the 2011 harvest showed up a number of breeding lines with very high alpha-acid contents, pointing to clear breeding progress in this area, too. Surprisingly, two seedlings also had an intensive citrus aroma. In view of the fact that a new trend is emerging worldwide towards hops with pronounced citrus-like, fruity or floral aromas (see 4.1.3), it is extremely important that strains with hints of such aromas should be selected as soon as possible from low-trellis breeding material, too.

2011 seedlings

The preliminary selection of seedlings from the 15 crosses (6 aroma- and 9 bitter-type) performed in 2010 began early in March, as every year, and was conducted according to the following routine. First of all, a total of 18,000 greenhouse seedlings in seed dishes were inoculated with four PM (*Podosphaera macularis*) races typical of the Hallertau region. Approx. 1,900 seedlings not visibly infected with PM were transferred from the seed dishes into individual pots. They were kept in the greenhouse under conditions conducive to PM infection and monitored for PM until mid-April.

The PM-resistant seedlings and a further 1,100 seedlings, which had not been pre-selected as PM-resistant, were then tested for tolerance towards downy mildew (*Pseudoperonospora humuli*). In mid-May, 592 seedlings pre-selected for disease resistance/tolerance were planted out in the vegetation hall, where their growth vigour and, once again, their resistance towards fungal infection were monitored under natural conditions until autumn. The plants were also classified as male or female on the basis of the flowers that formed as from July. Any plants that showed considerable deficiencies, such as severe aphid infestation, powdery mildew or root rot, or were of unsuitable growth type were dug up by autumn.

In November, 267 female and 39 male seedlings were planted out in the high-trellis breeding yards in Hüll and Freising respectively, where their growth vigour on 7-metre trellises, their resistance to downy mildew and powdery mildew under natural infection conditions and, for the first time, their resistance to *Verticillium* wilt will be monitored over the next 3 years. Testing for the latter requires a plant's root system to be fully developed, which means that it will not be possible to vegetatively propagate and transplant the most promising breeding lines to the low-trellis yards until the seedlings are at least two-to-three years old. To obtain seedlings with broad fungal resistance, field data are being supplemented at this stage by laboratory leaf tests for PM-resistance to non-endemic races.

Crosses in 2011

Although funding by Germany's Federal Agency for Agriculture and Food ceased with the official end of the 5-year project in December 2011, three more crosses were performed with the goal of obtaining plants boasting "low-trellis suitability". An additional selection criterion for the parent plants, apart from their internodal lengths, was their novel-aroma potential.

Cultivation on the two low-trellis systems in Starzhausen and Pfaffenhofen

English dwarf varieties, low-growth breeding lines from other breeding programmes and, for comparison purposes, traditional high-trellis Hüll cultivars have been grown on the low-trellis systems since 1993 to gain insights into hop cultivation on 3-m trellis systems.

Cultivation in the low-trellis yard at the Mauermeier hop farm in Starzhausen

In 2011, cones were harvested for the first time from twelve hop plants pre-selected as seedlings and obtained from the crosses performed specifically for the dwarf-hops project. The seedlings had been planted out on the 3-m trellis system in 2010. A further 15 preselected seedlings were planted out in 2011. Whereas these young hop plants (in their first year of cultivation) unfortunately do not allow any conclusive estimates as to crop yields, resistance qualities or components, and thus cannot be assessed in terms of brewing quality, the seedlings planted out in 2010 can be reliably assessed on the basis of their crop performance.

In the absence of irrigation means, the warm, dry spring led to drought damage and premature commencement of flowering at both locations. Many hop plants showed stunted growth, producing a cone crop that was in part unsatisfactory in comparison with the promising results obtained in 2010. Dwarf types were particularly affected because they grow very slowly at the start of the season and do not reach their full height until the second half of July. As these seedlings were already in full flower by then, they failed to make up their growth deficit despite the wet weather in July. Besides their shorter aboveground growth, dwarf lines are characterised by a relatively small rootstock. Under drought conditions, the reduced root system is probably unable to tap sufficient water from deep down. Breeding lines 2001/040/002 and 2001/045/702 also suffered severe deer damage.

Yields obtained from the semi-dwarf types, which are characterised by much more vigorous growth, were of the same order as in 2010. Growth was much more prolific during the dry weather and they reached their full height in July.

At the Starzhausen location, long-life synthetic strings were tested in 2011 as an alternative to rigid galvanised-iron wires. Climbing shoots obtain a much better hold on synthetic strings, which become flexible in warm weather. The bines, which are relatively heavy by harvesting time, were effectively prevented from slipping down, the strings thus providing a solution to this long-existing problem.

Major progress was also made in combating the red spider mite. In contrast to recent years, in which spider-mite treatments had to be repeated several times, only a single initial treatment was applied at the Starzhausen location in 2011. This was followed by the distribition of beneficial organisms. Use was made of a mixture of the two predatory mite species *Phytoseiulus persimilis* and *Amblyoseiulus californicus.* The predatory mites kept the spider mites completely under control for the rest of the growing season and the crop was free of infestation at harvesting time. Since both species are heat-loving and do not overwinter in Germany, the trials are scheduled to continue in 2012 with the indigenous overwintering species *Thyphlodromus pyrii.*

Fig. 4.1: Harvesting in the Starzhausen low-trellis yard

Tab. 4.2: LT-Starzhausen – breeding line yields in 2011

Breeding line/ Cultivar	Direc -tion	Yield[1] in kg/ha	α-acids in %	β-acids in %	Cohumulone in %	Aroma 1-30
English dwarf hops as comparative cultivar						
Herald	B	761	13.1	5.1	31.2	21
Pioneer	A	1,132	10.9	4.4	31.9	22
Hüll high-trellis varieties as comparative cultivars						
Perle	A	1,130	12.9	5.6	27.7	25
Hall. Magnum	B	1,281	18.2	6.9	26.9	23
Hall. Taurus	B	1,114	16.0	4.2	24.9	22
Herkules	B	1,544	20.1	6.9	29.6	23
2000/109/728	B	1,259	20.5	6.0	25.3	23
Shorter-growth breeding lines from other breeding programmes						
99/097/702	B	879	13.9	5.5	27.0	23
99/097/706	B	923	6.8	4.6	37.2	25
99/097/725	B	599	14.7	5.8	31.7	23
2000/102/004	B	518	8.4	3.5	26.6	21
2000/102/005	B	1,228	14.4	6.0	30.6	24
2000/102/012	B	963	11.0	5.0	32.3	23
2000/102/019	B	1,433	**16.0**	4.5	27.2	24
2000/102/032	B	1,157	**16.4**	6.5	33.4	23
2000/102/043	B	1,220	13.3	5.2	26.8	23
2000/102/054	B	1,564	15.7	4.4	30.5	23
2000/102/074	B	931	11.8	4.5	27.0	24
2000/102/791	B	1,405	**16.3**	6.2	29.7	22
2001/040/002	A	353	11.1	4.6	24.2	25
2001/045/702	A	502	9.2	4.8	25.0	26
2003/039/022	B	1,730	14.6	7.1	34.0	23
2004/098/010	A	834	11.2	4.6	29.4	23
2004/107/719	B	1,272	14.2	6.5	32.0	23
2004/107/736	B	1,318	5.86	3.8	35.3	23
2005/098/005	B	1,088	14.2	6.1	31.0	23
2005/098/744	B	965	13.6	4.5	30.3	22
2005/100/718	B	1,758	**17.5**	6.0	28.8	21
2005/101/001	B	901	7.3	3.9	36.8	23
2005/102/009	B	1,131	9.1	3.2	31.8	23
2005/102/028	B	1,189	13.3	5.7	35.1	23
2005/102/710	B	1,576	13.9	6.1	29.3	23
2006/048/720	B	954	14.4	5.6	25.9	22
2006/047/735	B	1,322	10.7	5.1	34.1	23
2006/047/768	B	1,283	9.1	8.0	25.5	19
2006/049/006	B	1,470	14.1	4.6	27.4	21
2007/074/702	B	1,212	13.8	6.1	32.3	20
2007/074/709	B	930	14.7	5.0	32.2	19
2007/074/724	B	1,486	11.2	5.0	32.9	21
2007/074/736	B	1,212	15.7	5.6	32.1	22
2007/080/007	B	1,492	14.8	5.5	32.6	20
2007/080/015	B	1,188	10.5	6.8	32.1	21
2007/074/002	B	529	11.6	5.7	30.4	23
2007/080/012	A	1,524	11.2	5.7	27.5	24

Breeding line/ Cultivar	Direc -tion	Yield[1] in kg/ha	α-acids in %	β-acids in %	Cohumulone in %	Aroma 1-30
2007/080/021	A	**1,980**	10.9	5.5	33.5	24
2007/081/703	B	**2,041**	12.3	5.4	27.3	22
First seedling generation from the breeding project funded by Germany's Federal Agency for Agriculture and Food						
2008/073/054	A	1,555	10.0	3.7	30.2	**26**
2008/073/056	A	**1,959**	10.1	3.4	30.4	**27**
2008/073/064	A	**2,301**	11.5	3.9	29.3	**27**
2008/073/103	A	**1,892**	10.7	4.1	30.5	**26**
2008/073/110	A	1,389	12.2	4.9	25.1	25
2008/073/701	A	988	9.4	4.2	25.7	24
2008/076/014	A	1,087	9.1	5.1	24.1	25
2008/076/099	A	1,286	7.8	4.1	28.9	**26**
2008/077/084	A	636	6.9	3.0	32.2	**26**
2008/078/017	A	1,243	7.8	3.8	27.6	**26**
2008/082/001	B	1,489	11.1	6.3	30.2	23
2008/082/006	B	1,834	13.3	6.4	31.6	23

A= aroma type; B= bitter type; [1]= yield from 12 plants/plot, extrapolated to 1 ha. Aroma: aroma assessment up to a maximum of 30 points for a particularly fine aroma. Components were analysed by the WG Hop Quality/Hop Analytics (IPZ 5d). LT = low-trellis yard; bold = breeding goal met

As Tab. 4.2 shows, some of the breeding lines from which initial harvests were obtained (2008 seedlings) were characterised by a pleasant and very fine hop aroma, scoring 26 to 27 out of 30 possible aroma points and thus drawing level for the first time with well-known Hüll aroma cultivars. Breeding lines 2008/073/056, 2008/073/064 and 2008/073/103 also boasted higher yields. Initial progress has thus been made in the breeding of LT cultivars, particularly with respect to aroma.

Cultivation in the low-trellis yard at the Schrag hop farm in Pfaffenhofen

Tab. 4.3: LT-Pfaffenhofen – breeding line yields in 2011

Breeding line	Direc-tion	Yield in kg/ha	α-acids in %	β-acids in %	Cohumulone in %	Aroma 1-30
Shorter-growth breeding lines from other breeding programmes						
2000/102/005	B	945	15.6	5.6	30.1	21
2000/102/008	B	1,778	14.6	6.8	28.0	23
2000/102/019	B	983	15.4	4.6	27.4	23
2000/102/032	B	989	15.4	6.2	33.6	23
2000/102/791	B	943	13.8	4.9	29.4	22

A= aroma type; B= bitter type; aroma assessment up to a maximum of 30 points for a particularly fine aroma. Components were analysed by the WG Hop Quality/Hop Analytics (IPZ 5d). LT= low-trellis yard

Downy mildew infection in the crop grown on the heavy clay soil in Pfaffenhofen again posed a major problem.

Although it was possible to keep the disease under control by way of selective spraying, the infection quickly flared up again after the last spray application and caused substantial damage to the crop.

Comparison of different cultivation systems

The rows (75 cm within-row spacing) in the two low-trellis yards were all cultivated in the conventional manner, with bines trained up galvanized wires. A further two rows of each of two promising breeding lines had been planted at both the Pfaffenhofen and Starzhausen locations in order to compare different methods of cultivation: "conventional – non-cultivation" and "training wires – netting". The entire trial stand was harvested on September 14th and 15th 2011, this being the third time that harvest yields could be compared in terms of cultivation methods employed.

Tab. 4.4: LT Pfaffenhofen – 2011 yields in terms of cultivation methods employed

Breeding line	Cultivation method	Yield in kg/ha	α-acids in %	kg α-acids/ha	β-acids in %
2000/102/008	Conventional, wire	977	14.1	138	6.4
2000/102/008	Conventional, netting	1,579	14.2	224	6.7
2000/102/008	Non-cultivation, wire	1,666	14.1	234	6.7
2000/102/008	Non-cultivation, wire and fleece	1,412	13.2	187	6.3
2000/102/791	Conventional, wire	598	14.3	85	5.0
2000/102/791	Non-cultivation, wire	739	14.3	106	5.0

Tab. 4.5: LT Starzhausen – 2011 yields in terms of cultivation methods employed

Breeding line	Cultivation method	Yield in kg/ha	α-acids in %	kg α-acids/ha	β-acids in %
2000/102/008	Conventional, wire	2,139	15.5	328	7.1
2000/102/008	Conventional, netting	2,473	15.4	396	7.1
2000/102/008	Non-cultivation, wire	2,106	13.9	292	7.0
2000/102/791	Conventional, wire	1,581	14.6	232	5.7
2000/102/791	Non-cultivation, wire	1,529	17.6	268	5.1
2000/102/791	Non-cultivation, wire and fleece	1,404	17.4	244	5.5

As stated above, it was the dwarf types that were particularly affected by the lack of rain in spring and early summer. Breeding line 2000/102/791 is one of them. Whereas the yield obtained at the Starzhausen location in 2010 was even higher than for the considerably more prolific semi-dwarf 2000/102/008, the 2011 yield was approx. 35 % lower than that of the semi-dwarf. Despite the dwarf's higher alpha-acid content, it was unable to make up the shortfall. As Tab. 4.3 and Tab. 4.4 show, the yields obtained in Pfaffenhofen for the two breeding lines differed by as much as roughly 100 %. On the very heavy soil there, the semi-dwarf's more extensive root system had an even greater effect on yield.

As far as training material is concerned, the third trial year again showed that the breeding lines' yield potential can be better exploited by using netting.

By harvesting time, a homogeneous hedge has formed with uniform cone distribution. The only problem is that much less light reached the inside of the hedge than when bines are trained up individual wires. If the weather is cloudy and wet during cone formation, they are unable to develop fully and many are killed off by fungal pathogens such as *Alternaria.* Particular care must therefore be taken when selecting breeding lines that they are not susceptible to cone death of this kind.

3-metre trellis systems are expected to have major labour-related advantages, particularly as far as hop cultivation and husbandry are concerned. The aim is therefore to clarify the extent to which the conventional, distinctly more labour-intensive cultivation method can be replaced by what is called the “non-cultivation” method, in which the plants are not pruned and soil tilling is reduced. A clear trend was still not apparent after the third crop year. Whereas the conventional cultivation method had seemed superior in 2010, the "non-cultivation” method was almost on a par at the Starzhausen location in 2011 and showed distinct advantages in Pfaffenhofen.

With the aim of further reducing labour input, some of the rows in the “non-cultivation” plots were covered over with a permanent fleece for the first time in 2010. A 60-cm-wide strip was laid directly over the row of plants and, every 75 cm, an approx. 20-cm cross-slit cut above each hop crown. Hop crowns usually send up shoots in a broad strip along the entire row of hops. Surplus shoots have to be removed with a hydraulically operated circular cultivator, a time-consuming and costly job. Otherwise, too many shoots start climbing and foliation is so prolific that plant-protection problems arise and a lot of growing energy is “wasted” vegetatively. The aim of this trial was to regulate the number of shoots and thus obtain a homogeneous stand with little labour input. This system was very successful on the well-drained sandy soil in Starzhausen but not on the heavy soil in Pfaffenhofen, where the stand had already become heterogenous by the second trial year. Conditions under the fleece probably favour saprogens that impair the health of the rootstock.

The latest breeding results and findings pertaining to cultivation on 3-metre trellis systems will be published on conclusion of the breeding project, which has been funded since 2007 by the German Federal Agency for Agriculture and Food.

4.1.3 New hop breeding trend – hops with floral, citrus and fruity aromas

Objective

Until recently, the aim of all breeding programmes was to breed aroma cultivars with a fine, traditional aroma profile and develop cultivars with high yields and high alpha-acid contents. Hop growers and brewers alike were and still are fully satisfied with both categories of Hüll cultivars. US craft brewers were the first to take an interest in novel hop aromas and flavours for their beers, and these ideas have now been taken up by other creative brewers the world over. This prompted Hüll researchers to launch an additional breeding programme in 2006, with the aim of producing cultivars that impart a wide variety of floral, fruity, citrus and resinous aromas and flavours to beers.

Material and methods

By 2011, 33 crosses had been performed with the goal of producing these new aroma profiles. All the seedlings were pre-selected for their disease resistance, growth vigour and sex. The female breeding lines were cultivated in the Hüll breeding yard, while the male progeny was kept and assessed in a special hop yard in Freising. Cones were harvested exclusively from breeding lines with pleasant fruity or floral aromas. The aroma of the dried hop cones was determined organoleptically and also analysed chemically. Bitter substances were determined by the HPLC method as per EBC 7.7. Headspace gas chromatography, a technique used routinely in Hüll to analyse large numbers of breeding samples quickly and economically, was used to identify oil components. To facilitate comparison with the essential oils of foreign flavour hops, which had been analysed and quantified via EBC methods 7.10 and 7.12, the Hüll Hop Analytics team also analysed the steam destillates of the new flavour breeding lines by gas chromatography, using the methods prescribed by the EBC.

Results

Nineteen of the 33 crosses performed stem from crosses with the US variety Cascade as mother plant. The intention was to blend the fruity, citrus-like Cascade flavours, which are highly valued by craft brewers, with the fine, typically hoppy aroma components of father plants bred in Hüll. Use of the Hull breeding lines was also intended to confer improved disease resistance and higher agronomic performance on the progeny. 2,208 pre-selected female lines from this breeding programme were cultivated as individual plants in Hüll and assessed. The most promising lines were cultivated in replicate in Hüll and Rohrbach in order to test their suitability for different locations and the effect of the latter on the aroma. Cones from a number of breeding lines showing this new trend in aroma and flavour were harvested, analysed chemically and compared with Cascade, which has a fruity-citrus aroma, and the landrace variety Hallertauer Mittelfrüher, which has a typically European hop aroma.

The aroma of these new breeding lines was evaluated not only by the breeder but also by numerous experts from the hop and brewing industries. Hops with a wide variety of fruity, citrus and floral aromas and flavours have now been included in the Hüll breeding range for the first time and are attracting great interest from brewers, including US craft brewers, hop traders and hop growers alike.

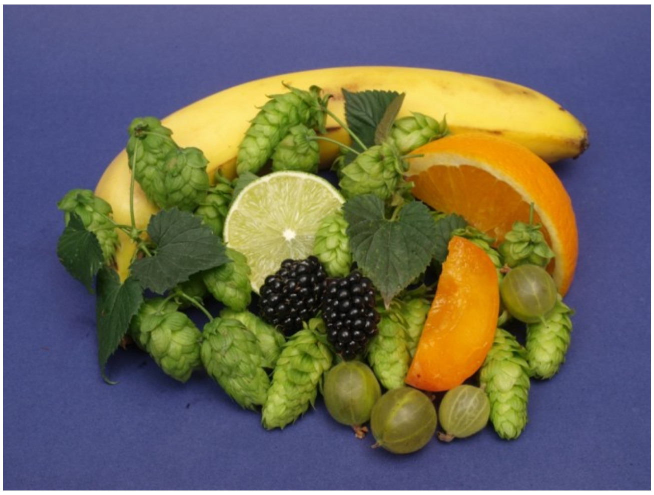
The most frequent aroma descriptions for the new Hüll breeding lines are:

- Cascade (reference for a typical “flavour hop”* aroma): medium intensity, floral, with a strong citrus tone
- Hallertauer Mittelfrüher (repesentative of the fine aroma of landrace varieties): mild, herbal, woody, with a hint of citrus
- 2007/018/013: fruity aroma with a particularly pronounced tangerine/citrus tone, slightly sweetish
- 2007/019/008: intense, long-lasting floral aroma with diverse fruity tones, e.g., of passion fruit, grapefruit, gooseberry and pineapple, comparable with the bouquet of a fine white wine
- 2008/020/004: diverse fruity aroma nuances, such as melon, mint, banana, strawberry and lemon

- 2009/001/718: pleasantly fruity aroma reminiscent of melon, water melon and grapefruit, along with honey tones and a fresh, minty overtone
- 2009/002/706: intensely fruity, slightly sweetish aroma reminiscent of honeydew melon and strawberry
- 2000/109/728: pleasantly fruity aroma and also very refreshing, minty overtones
- 2006/078/009: intense fruity tone reminiscent of lemon and mint, and a very pronounced banana aroma
- 2008/059/003: diverse fruity aromas, of which pineapple is particularly noticeable, floral impressions, as of lavender, and slightly peppery

*The term "flavour hops" was coined 20 years ago by Charles N. Papazian, the president of the American Association of Brewers. It describes hop varieties that confer somewhat hop-atypical aromas to beer, such as fruity, floral and citrus aromas.

These aroma descriptions, which were based on dried hop cones, were rounded off by chemical analyses of the essential oil components. Headspace gas chromatography, in particular, which is used routinely in Hüll to test and evaluate the aroma quality of new breeding material, backs up and confirms the organoleptic classification of these new breeding lines.



Forty-nine substances were identified from a total of 76 peaks in the GC oil profile. On the basis of their scent, and in some cases also their taste, it was possible to assign 39 of these essential oil components to one of five categories: fruity (7 components), citrus-like (4), floral (4), herbal (9), spicy/resinous (3) and woody (1). A comparison of the oil profile of the landrace variety Hallertauer Mittelfrüher, on whose fine aroma all aroma-breeding programmes have been modelled since the start of breeding activities in Hüll, with that of the new breeding lines attested to their novelty.

Additional evidence is provided by the occurrence of peaks in the headspace chromatogram that were visible merely as background peaks in the analyses of previous Hüll cultivars and breeding lines. For example, breeding line 2007/018/013 produced a peak with a peak area similar to that of humulene. The aim is to identify these novel substances as soon as possible in cooperation with analytical teams experienced in MS-GC.

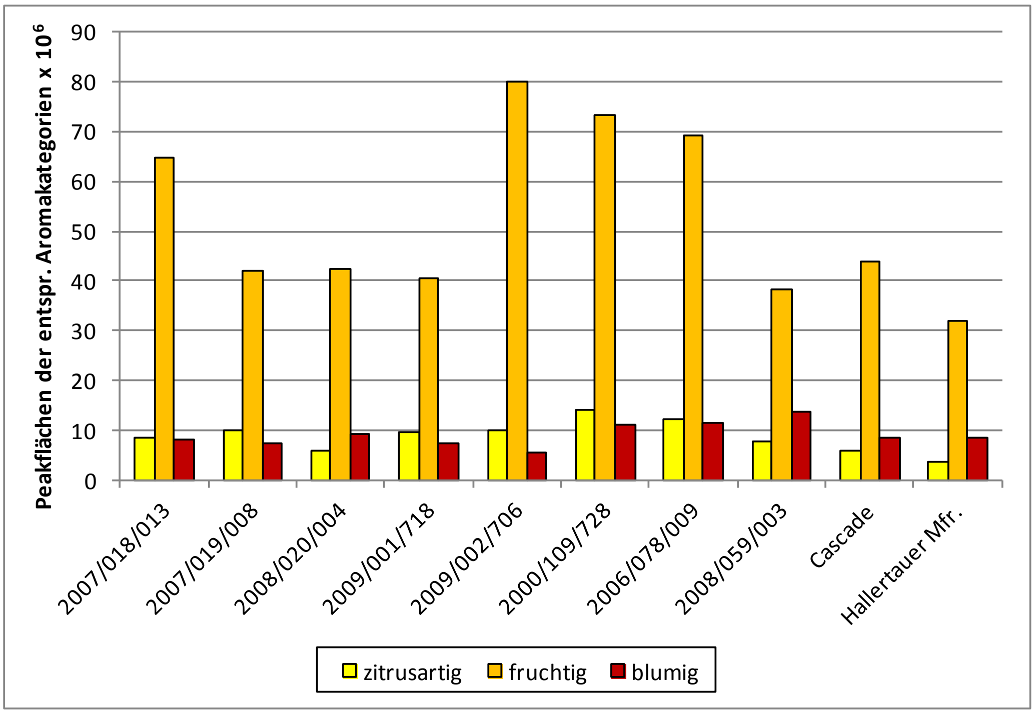


Fig. 4.2: Fruity, citrus and floral oil components in the new Hüll breeding lines. The data shown are primary data.

As beer brewers often calculate hop quantities on the basis of their essential-oil content, the amounts of oil in all new Hüll breeding lines were determined from the steam distillates in preparation for the brewing trials. The very high oil content of breeding lines 2008/059/003 and 2000/109/728 was particularly striking, with levels of 3.8 and even 4.4 ml/100 g hops, respectively, exceeding those of all other breeding lines by far (0.80 – 2.5 ml/100 g hops), and even that of Cascade (1.80 ml/100g hops) and Hallertauer Mfr. (0.95 %).

The results of the HPLC analyses attested to the success of this breeding programme aimed at breeding lines that boast fruity/citrus and floral aromas irrespective of high or low alpha-acid contents. For example, lines 2007/018/013, 2007/019/008, 2008/020/004, 2009/001/718 and 2009/002/706 have alpha-acid levels between 6.5 % and 12.0 %, while 2006/078/009 and 2008/059 have levels up to 16 % and 2000/109/728 even up to 23 %. Beta-acid levels range from 3.1 to 6.5 %. Cohumulone content ranges from 21 to 40 %

Although it is extremely difficult to draw conclusions as to the aroma quality in beer from aroma impressions gained via organoleptic assessment of dried hop cones or from chemical data pertaining to the essential oils, the results of initial brewing trials with these eight new Hüll breeding lines were very promising. The beers developed distinctive aromas reminiscent of tangerines, melons, grapefruit and peaches, and floral and resinous aromas were also identified.

A report containing a detailed description of the aroma tones and initial brewing-trial results has been published in Brewing Science - Monatsschrift für Brauwissenschaft, 65 (March/April 2012), pp. 24-32.

Applications for registration as cultivars have been filed at the Community Plant Variety Office for two breeding lines. The findings still to be obtained from a number of brewing trials will decide whether we file applications for registration of one or two more flavour-hop lines.

Propagation of the flavour-hop cultivars 2000/109/728 (Polaris), 2007/018/013 (Mandarina Bavaria), 2007/019/008 (Hallertauer Blanc) and 2009/002/706 (Huell Melon) started in April 2012 so that sufficient numbers of mother plants could be supplied to the GfH's propagation facility. Cuttings are expected to be available in autumn 2012 and first commercially available beers with these new cultivars after harvest 2013.

4.1.4 Monitoring for dangerous viroid and viral hop infections in Germany

Objective

The aim of a broad-based monitoring project for dangerous viroid and viral diseases was to clarify the prevailing infection situation in German hop-growing regions. Both viruses and viroids, first and foremost the dreaded hop stunt viroid (HSVd), pose a special problem in hop-growing. The diseases are spread easily and rapidly by mechanical means both within hop stands and from stand to stand, but often go unnoticed for many years. Their potential to cause economic damage in the form of yield and alpha-acid losses is only revealed under stressful weather conditions. Neither plant protectives for controlling these diseases nor effective resistance carriers that might be bred in to develop high-performance, virus- and viroid-resistant hop cultivars are available. Precautionary measures, including monitoring activities to detect and eliminate primary infection centres and clarify the way in which these pathogens are spread, are therefore an urgent necessity.

Methods

Work groups IPZ 5c and 5a were responsible for choosing the monitoring locations, organizing the project and taking samples. The samples came from hop farms in the various hop-growing regions of Germany, from one of the Society of Hop Research's propagation facilities and from the Hop Research Centre's breeding yards. Wild hops from the Hüll wild-hop collection were also sampled. Samples were preferably taken from plants with a suspicious appearance, which means that monitoring was selective and not random. Numerous foreign varieties from the international cultivar collection in Hüll were also tested. Samples were tested for HMV, ApMV and ArMV via the DAS-ELISA method, using commercially available polyclonal antisera. The RT-PCR method was used to test for hop stunt viroid, using primer information from Eastwell und Nelson (2007). The RT-PCR method was also used to test for HLV and, in some cases, for AHLV, because there are no commercially available antisera for this purpose. The primer sequences were kindly provided by Dr. Ken Eastwell (communicated personally to Dr. L. Seigner, IPS 2c, 2009). To verify individual results, PCR bands were also sequenced. Most of the testing was performed by a TUM (Technische Universität München) undergraduate working jointly with the LfL's pathogen diagnostics lab (IPS 2c) in Freising.

Tab. 4.6: Alphabetical overview of the viroids and viruses for which the samples were tested and of the detection methods used

Viroid/Virus German name	**Viroid/Virus English name**	**Abbreviation**	**Detection method**
Latentes Amerikanisches Hopfen-Carlavirus	American hop latent carlavirus	AHLV	RT-PCR
Apfelmosaik-Ilarvirus	Apple mosaic ilarvirus	ApMV	DAS-ELISA
Arabis Mosaik-Nepovirus	Arabismosaik nepovirus	ArMV	DAS-ELISA
Latentes Hopfen-Carlavirus	Hop latent carlavirus	HLV	RT-PCR
Hopfenmosaik-Carlavirus	Hop mosaic carlavirus	HMV	DAS-ELISA
Hopfenstauche-Viroid	Hop stunt viroid	HSVd	RT-PCR

Results

The dreaded HSVd was not detected in any of the 282 hop samples (Tab. 4.7) tested in 2011. However, the internal RT-PCR control run failed in 4 % of the samples, making unequivocal confirmation of the negative result impossible for these plants. On the other hand, since only nine of altogether 938 hop samples tested since 2008 during the monitoring project were found to be infected with HSVd, and all 9 of these were growing in the Hüll cultivar yard, it is clear that HSVd is not yet prevalent in the German hop-growing areas. By contrast, reports from Japan and Korea tell of massive yield and quality losses there in the past, and HSVd has been recorded in the USA since 2006 (Nelson and Eastwell, 2007).

The situation with respect to the majority of hop viruses tested for is different, although the actual infection situation is overestimated because the sample material came mainly from plants showing disease symptoms. The Hüll breeding yards are severely infected with HMV, ApMV and HLV, the reason being that numerous foreign varieties have been planted out in these breeding yards for decades. In most cases, the starting material was not examined for virus infections at all and therefore no efforts were made to create virus-free planting stock by way of meristem culture. These hop plants were usually grown in four-plant blocks, providing ideal conditions for the virus to be spread mechanically or via aphids from these small infection centres to neighbouring hop plants. Double infections with HLV/HMV or HMV/ApMV were detected frequently, while in a few cases three, and in one case all four viruses were identified in a single hop sample. At the GfH's propagation facility, 11 plants infected with HMV and/or HLV were destroyed. HMV, ApMV and HLV were detected alone or in combination in many of the samples from hop farms (Tab. 4.7). These findings show only too clearly that virus infection levels are extremely serious. The relatively high proportion of plants infected with HMV and HLV carlaviruses is very probably a consequence of non-persistent aphid transmission of these viruses. Once plants in a hop yard are infected, the infection is gradually spread within the stand via aphids. Even a brief trial feed on the part of the aphid suffices for the virus to be transmitted from the aphid to the plant or vice versa.

It is almost impossible to control these viruses in the field via plant-protective measures, especially when infestation with aphids, the virus vectors, is high.

However, the use of carlavirus-free planting stock, as obtained via meristem culture, is advisable because these hop stands produce much higher yields and only become reinfected after several years. Basically, it appears to be easier to prevent the spread of mechanically transmissible ApMV than that of carlaviruses, and the percentage of hop-yard plants infected with ApMV is comparatively low despite intensive cultivation activities. Dr. Eastwell was unable to provide the infected material (positive control) required for AHLV testing until September 2011, and so only a very small selection of plants representing ten US cultivars was tested for this virus by the RT-PCR method. The AHLV band was identified in six hop plants and the result confirmed by sequencing. As the HLV infection rate appears to be high, it is intended in future to test all starting material not only for HMV and ApMV but also for HLV before supplying it to the GfH's propagation facility. These findings, moreover, underscore the need for meristem culture as a means of providing virus-free planting stock.

Tab. 4.7: HSVd and virus tests in 2011

Origin and nature of the 2011 sample material	**Number of hop samples**	**RT-PCR HSVd positive**	**RT-PCR HLV positive**	**ELISA HMV positive**	**ELISA ApMV positive**	**ELISA ArMV positive**
Hüll breeding yard: mother plants	19	0	8 (42 %)	19 (100 %)	10 (53%)	1 (5%)
Hüll breeding yard: cultivar yard	89	0	61 (69%)	78 (88%)	45 (51%)	0
Hüll breeding yard: registered varieties	28	0 + (10 without IPC)	15 (54%)	12 (43 %)	2 (7%)	0
Freising breeding yard: male hop plants	2	(2 without IPC)	1	2 (100%)	0	0
GfH Hallertau propagation facility: mother plants	32	0	11 (34%)	4 (12%)	0	0
Elbe-Saale field crop:	6	0	6 (100%)	4 (67%)	0	0
Hallertau field crops: cultivars	37	0	25 (69%)	30 (83%)	18+1 (47 %)	1+1 (5%)
Tettnang experimental station and field crops: cultivars	10	0	10 (100%)	10 (100%)	9 (90%)	0
Foreign cultivars	23	0	8 (35%)	3 (13%)	3 (13%)	0
Diverse (foreign) cultivars – not tested for viruses	36	0	3 (8%)	-	-	-
Total	**282**	**0**	**148**	**162**	**87**	**3**

The extent of virus infections is possibly overestimated because most of the samples sent in from hop farms for testing came from diseased-looking plants.

Literatur

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Appreciation

Our thanks go to Dr. Ken Eastwell for providing primer data and positive controls. Our thanks go likewise to Prof. Dr. Ralph Hückelhoven for his scientific mentoring of Bachelor student Vanessa Auzinger, whom we also thank for her reliable and meticulous work.

4.2 Biotechnology

4.2.1 Characterisation of hop/hop powdery mildew interaction at cell level and functional analysis of defence-related genes

Objective

The aim of this research project was to characterise cell-level defence responses in various wild hop varieties using fluorescence and laser microscopy techniques and thereby identify new resistance carriers for breeding PM-resistant hops.

Another component of this project was intended to support resistance breeding via a molecular biological approach. What is known as a transient transformation assay system was developed for hops, a system that will make it possible to characterise the functions of PM-defence-related genes.

*Fig. 4.3: Images from individual project stages. **A)**, Inoculated leaves for microscopic investigation. **B)**, Two haustoria (arrows) of the PM fungus in a transformed hair cell, stained blue by the GUS reporter system. **C)**, Cell death (arrow) as a defence response to the PM fungus. **D)**, Sporulation of the PM fungus following infection of a single hair cell. Arrow: haustorium in hair cell. Scale: A: 1 cm; B,C,D: 25 µm*

Methods

Eight wild hops, two breeding lines and two cultivars, all from the Hüll breeding programme and all classified as PM-resistant, as well as the susceptible control variety Northern Brewer, were inoculated with powdery mildew (Fig. 4.3 A). The infection process was halted at various points in time after inoculation (24 h, 48 h and 7 d) and fungal structures and cell-level defence responses visualized by histochemical staining techniques. A total of 30,170 interactions between individual epidermal cells and the PM fungus were then examined under a fluorescence microscope. As it turned out that the PM fungus also colonises hair cells and that these show a defence response that differs from that of normal epidermal cells, the resistance mechanism of the hair cells was also investigated.

To establish a transient transformation assay system for hops, a protocol for particle-gun transformation of epidermal cells was first developed. Hair cells proved more suitable then epidermal cells for the transient assay because the required minimum number of interactions between transformed epidermal cells and the PM fungus is obtained more easily with hair cells. A method of propagating the PM fungus on living plants in climatic chambers was also developed, as it was assumed that more vital spores can be obtained this way than via PM propagation in petri dishes. To validate the transient transformation assay for characterising the functions of genes suspected of being involved in the resistance mechanism, use was made of a hop *Mlo* gene. *Mlo* genes are known to be susceptibility genes in other crops. Loss of *Mlo* function of one or more of these genes makes these plants more resistant (Bai et al., 2008; Panstruga, 2005; Consonni et al., 2006; Pavan et al., 2011). First of all, the activity of the chosen hop *Mlo* gene was examined post PM infection in a susceptible and in a resistant variety. A "knock-down" construct for characterising the functions of this gene was then generated via transient transformation of hair cells by microparticle bombardment.

Results

Microscopic analyses of the PM-defence-related responses showed that resistance in all 12 genotypes was by way of apoptosis of the cells under attack (Fig. 4.3 C). In 11 genotypes, this hypersensitive cell death reaction of the attacked cells was detectable as early as 24 h post inoculation. In one genotype, resistance was imparted via cell death at a later stage. Cell-wall apposition, which prevents fungal penetration, played a minor role in all genotypes investigated. Hair cells were susceptible in all genotypes investigated, and individual sporulating colonies with a susceptible hair cell at the centre were detected microscopically in 10 genotypes (Fig. 4.3 D). However, since hair cells only account for a small proportion of leaf surface area, this observation appears to play no role in the resistance phenotype.

A protocol for transient transformation of epidermal cells in hops by microparticle bombardment was generated, to which end the following points/aspects were investigated and optimised: the optimum acceleration pressure for microparticle bombardment was determined and the cell sizes of different epidermal cell types compared; PM maintenance and cultivation was optimised. Hop *Mlo*-gene expression studies in a susceptible and a resistant variety suggested enhanced activity of the gene following PM infection and hence a role of this gene in hop/hop powdery mildew interaction.

The transient transformation assay was subsequently validated by characterising the functions of this *Mlo* gene. The knock-down experiments with the susceptible Northern Brewer variety showed that cells which had undergone transient knock-down of this susceptibility gene contained fewer haustoria than the control.

In other words, silencing the gene made the cells less susceptible. Fig. 4.3 C shows the interaction between the PM fungus and a transformed hair cell containing two haustoria as an example of the microscopic evaluation of the transient assay.

Publications on this work are in preparation.

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4.3 Genome analysis

4.3.1 Investigation of *Verticillium* infections in the Hallertau district

Objective

In the Hallertau district, where incidence levels of hop wilt are high, both mild and lethal hop-wilt races have now been identified via genetic analyses and artifical Verticillium infection tests. The aim is therefore to devise an *in-planta* test for diagnosing the Verticillium fungus and its race as quickly as possible so that suitable phytosanitary measures can be taken. Another goal, even if very difficult to achieve, is the identification of *Verticillium* in soil samples. This is of immense importance to farmers as it will enable them to tackle the risk of *Verticillium* infection, particularly when establishing new hop yards. Since chemical means of controlling this soil pathogen are not yet available, it is intended to test bioantagonists (biological opponents), which have demonstrated a successful preventive effect when used experimentally to combat wilt in other crops such as strawberries, for their ability to combat the hop-wilt fungus.

Methods

Since a basic requirement for a quick *in-planta* lab test is to homogenenize the very woody bine sections of hop plants and this cannot be done with the ball mill routinely used in genome analysis, a homogenizer was purchased for this purpose. In contrast to ball mills with two-dimensional movements, this homogenizer breaks up the plant material at high speed (up to 6 m/s) with special balls using a three-dimensional movement.

Before testing a wide variety of commercial DNA isolation kits for their suitability for this project, it was first of all necessary to test a large number of macerating parameters, such as ball material, ball size and shape and optimal homogenizer oscillation frequency. To establish a multiplex real-time PCR, primers and real-time probes for the respective *Verticillium* species were developed on the basis of specific, already-published genome sequences for *Verticillium albo-atrum (V. a.a.)* and *Verticillium dahliae (V.d.)* already established for qualitative PCR.

To obtain an initial basis for examining soil samples molecularly for *Verticillium*, earth was mixed with *Verticillium albo-atrum* fungal mycelia or fungal DNA and used in a PCR. The search for microorganisms suitable for controlling the *Verticillium* pathogen biologically led to the selection of five bacterial strains belonging to the genera *Bacillus, Burkholderia, Pseudomonas, Serratia* and *Stenotrophomonas*. The test was conducted with Hallertauer Tradition on account of the high Verticillium incidence level in this variety. To this end, roots of young hop rhizomes were dipped into rifampicin-resistant suspensions of bacteria that had undergone spontaneous mutation, planted in pots and then freed of earth again 4 weeks later. Both the endosphere and rhizosphere of the roots were examined for bacterial colonisation, and the number of antagonist colonies per g root was determined on standard bacterial media with rifampicin.

Results

In an initial preliminary run involving 150 samples, the rapid *in-planta Verticillium* test, i.e. fungus identification directly from the hop bine without preceding fungus cultivation and DNA isolation, was successful. It was possible to verify the new technique on the basis of these hop samples as they had already been tested for *Verticillium albo-atrum* in 2010 by means of the conventional, time-consuming method.

In 2010, the fungus had first been cultivated and then left to grow in a liquid medium. Fungal DNA was subsequently extracted via the conventional isolation method.

With the new *in planta* test, *Verticillium dahliae* was identified even in 5 bine samples that had previously appeared to be phenotypically healthy. Fig. 4.4 shows the real-time amplification of *in-planta* V.a.a.-DNA (A) compared with DNA from cultivated V.a.a. reference isolates (B). The primers and real-time probes developed for *Verticillium albo-atrum* and *Verticillium dahliae* were successfully tested in initial real-time PCR reactions using artificial mixtures of DNA from V. a. a and V. d. references.

In the two experimental series conducted so far, each with 12 potted Hallertauer Tradition plants/bacterium, all the bacterial strains were first tested for their ability to colonise the hop roots (endosphere and rhizosphere). This is a prerequisite for investigating their antagonistic effect on the pathogen. So far, all genera have been able to colonise hop roots.

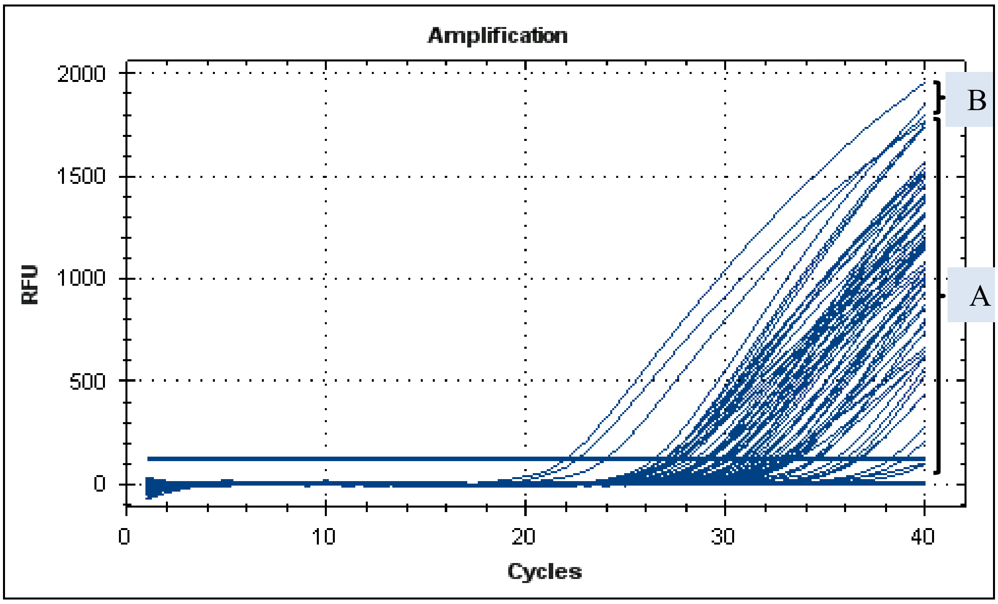


Fig. 4.4: Identifying Verticillium albo-atrum in hop bines directly via real-time PCR
A = fungus from bine, B = reference isolate; RFU = relative fluorescence units

Outlook

A more comprehensive experimental series is planned for the coming hop season to provide statistical verification of the *Verticillium in-planta* test. In addition, it is planned to use indicator plants to test soil from *Verticillium*-contaminated hop yards for the fungal pathogen. Developing specific primers to differentiate between mild and lethal *Verticillium* isolates on the basis of already-identified AFLPs is proving more difficult than expected, and we are redoubling our efforts.

5 Hop cultivation and production techniques

LD Johann Portner, Dipl. Ing. agr.

5.1 N_{min} test in 2011

The N_{min} nitrogen fertiliser recommendation system has been in place for some time and has become an integral part of fertiliser planning on hop farms. In 2011, 3,396 hop yards in Bavaria were tested for their N_{min} levels and the recommended amount of fertiliser calculated.

Tab. 5.1 tracks the numbers of samples tested annually for N_{min} since 1983. N_{min} levels in Bavarian hop yards averaged 76 kg N/ha in 2011, 10 kg less than in 2010. The average recommended amount of fertiliser, which is calculated from this figure, increased accordingly to 154 kg N/ha.

As every year, levels fluctuated considerably from farm to farm and, within farms, from hop yard to hop yard and variety to variety. Separate tests are therefore essential for determining the ideal amount of fertiliser needed.

Tab.5.1: Number of N_{min} tests, average N_{min} levels and recommended amounts of fertiliser in hop yards in Bavarian hop-growing regions

Year	Number of samples	N_{min} kg N/ha	Fertiliser recommendation kg N/ha
1983	66	131	
1984	86	151	
1985	281	275	
1986	602	152	
1987	620	93	
1988	1031	95	
1989	2523	119	
1990	3000	102	
1991	2633	121	
1992	3166	141	130
1993	3149	124	146
1994	4532	88	171
1995	4403	148	127
1996	4682	139	123
1997	4624	104	147
1998	4728	148	119
1999	4056	62	167
2000	3954	73	158
2001	4082	59	163
2002	3993	70	169
2003	3809	52	171
2004	4029	127	122
2005	3904	100	139
2006	3619	84	151
2007	3668	94	140
2008	3507	76	153
2009	3338	85	148
2010	3610	86	148
2011	3396	76	154

Tab. 5.2 lists the number of hop yards tested, average N_{min} levels and average recommended amounts of fertiliser by administrative district and hop-growing region in Bavaria in 2011. It can be seen from the list that N_{min} levels are highest in the area around Hersbruck and in the Jura mountains. In contrast to 2010, the lowest values measured in 2011 were in the Spalt growing region.

Tab. 5.2: Number, average N_{min} levels and fertiliser recommendations for hop yards by administrative district and region in Bavaria in 2011

District / Region	Number of samples	N_{min} kg N/ha	Fertiliser recommendation kg N/ha
Hersbruck	50	125	103
Eichstätt (plus Kinding)	250	94	143
Landshut	174	77	150
Kelheim	1296	76	156
Pfaffenhofen	1198	74	155
Freising	341	69	160
Spalt (minus Kinding)	87	64	149
Bavaria	**3396**	**76**	**154**

Tab.5.3 lists N_{min} levels by variety and recommended fertiliser amount.

Tab.5.3: Number, average N_{min} levels and fertiliser recommendation in 2011 for various hop varieties in Bavaria

Variety	Number of samples	N_{min} kg N/ha	Fertiliser recommendation kg N/ha
Herkules	491	72	173
Brewers Gold	7	55	167
Nugget	48	70	162
Hall. Magnum	617	71	159
Hall. Taurus	270	76	153
Saphir	42	79	149
Perle	644	79	148
Hall. Tradition	584	81	148
Hersbrucker Spät	178	84	147
Opal	10	73	146
Spalter Select	172	84	145
Northern Brewer	47	82	144
Hallertauer Mfr.	226	70	142
Hall. Merkur	8	77	142
Spalter	37	66	139
Smaragd	6	85	139
Other	9	73	156
Bavaria	**3396**	**76**	**154**

5.2 Reaction of various cultivars to reduced trellis height (6 m)

5.2.1 Objective

Disastrous storm damage during the last few years, which caused hop trellis systems in the Hallertau region to collapse prior to harvesting, has prompted studies to investigate whether trellis height can be reduced to 6 m without compromising yields. According to initial calculations, this measure would reduce the static load on the Hallertau trellis system by around 15 - 20 % and greatly improve its stability under conditions of extreme wind velocities.

In addition, trellis costs could be reduced without impairing stability through use of the shorter, weaker central poles.

Potential plant protection benefits might exist as well, because the tops of the hop plants, being closer to the target area, would receive more spray. In this project, the height of the hop trellis was reduced from 7 m to 6 m in trial plots in a number of commercial hop yards (growers of various hop cultivars). The aim was to study the reaction of the different cultivars to reduced trellis height (plant growth, susceptibility to disease/pests, yield and quality). Tests were conducted on the following aroma varieties: Perle und Hallertauer Tradition, and on the following bitter varieties: Hallertauer Magnum, Hallertauer Taurus and Herkules.

5.2.2 Methods

Suitable commercial hop yards in which various hop cultivars are grown were divided into 4 equal-size plots, each of which was 10 pole intervals long and one pole interval wide. The trellis height in two plots was reduced from 7 m to 6 m by insertion of additional wire netting. The two-pole-wide 6-m trellises were thus directly adjacent to the 7-m trellises.

In each plot, twice replicated randomized trial blocks of 20 adjacent hop plants each were earmarked for harvesting. It was agreed with the hop growers that the trial plots be farmed conventionally.

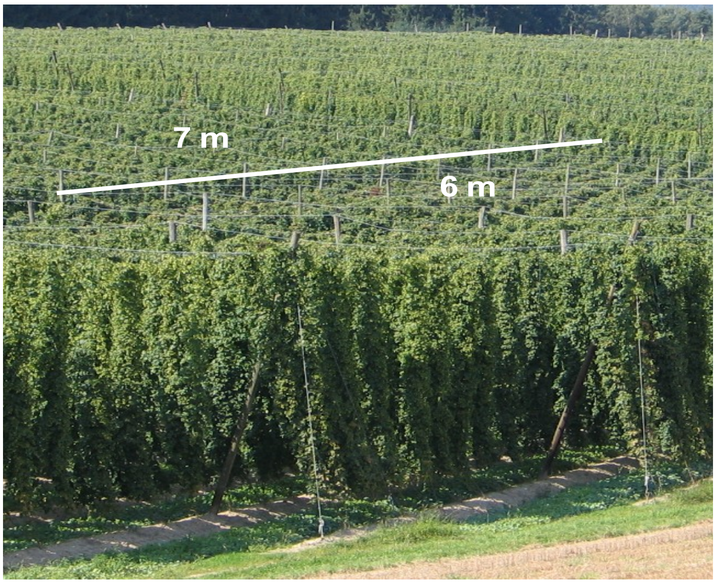


Fig. 5.1 and Fig. 5.2: 7-m trellis reduced to 6 m by additional wire netting

Yield, alpha-acid content and moisture content of the green cones were measured for the harvested trial blocks. For the bitter varieties, the alpha-acid yield in kg/ha was also calculated. In the first trial year, a cone sample was collected from each plot and 500 cones from each sample individually examined for cone formation and disease.

The project was extended by a year because four of the six trial locations were destroyed by hail in 2009.

5.2.3 Results

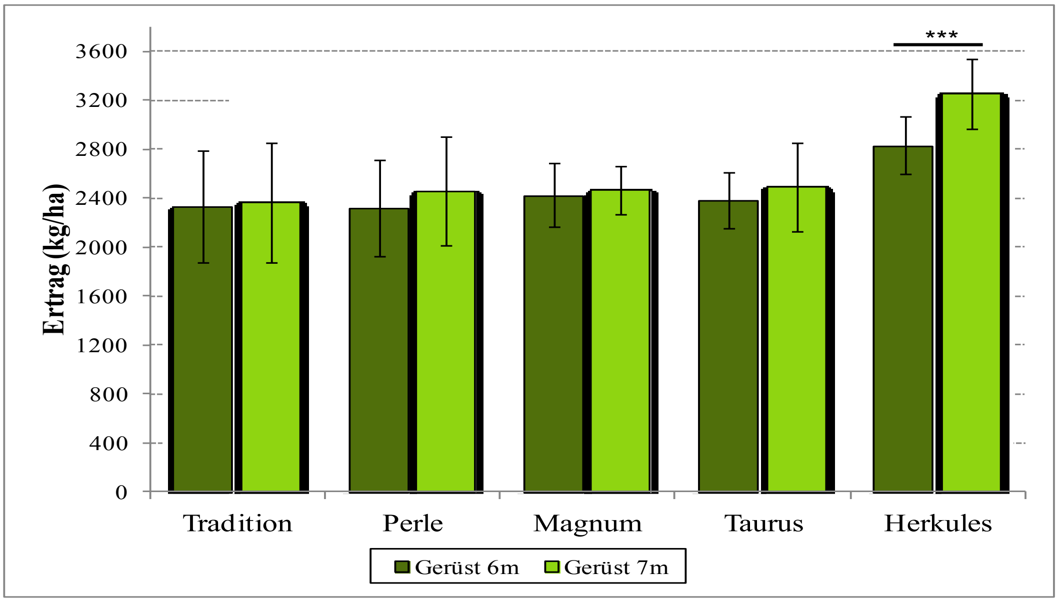


Fig.5.3: Influence of trellis height on yields of various hop cultivars

*Comparison of yields (kg/ha), with standard deviation, obtained on 6-m and 7-m trellises for the aroma varieties Hallertauer Tradition and Perle (n = 12 in each case) and for the bitter varieties Hallertauer Magnum (n = 12), Hallertauer Taurus and Herkules (n = 16). Significant differences in yield were tested for each cultivar via multifactor ANOVAs and characterised ($p < 0.05$ *, $p < 0.01$ ** and $p < 0.001$***).*

No significant differences in yield were recorded for the 6-m and 7-m Hallertauer Tradition variants at the Winkelsbach location. The slight increase in yield measured in Gebrontshausen for the Perle cultivar grown on the 7-m trellis is not statistically significant, either. At the Winkelsbach location, Hallertauer Magnum was also tested. However, trellis height was found to have no influence on yield. Taurus was tested at the Niederulrain location. The higher yield obtained on the 7-m trellis is not statistically significant. In Kirchdorf, the increased yield of 423 kg/ha obtained for Herkules on the 7-m trellis variant is highly significant.

All varieties were found to show a trend towards higher yields on 7-m trellises but the difference was only statistically significant for Herkules. This should be taken into account, particularly with the Herkules variety, when trellis systems are being erected in locations conducive to good yields.

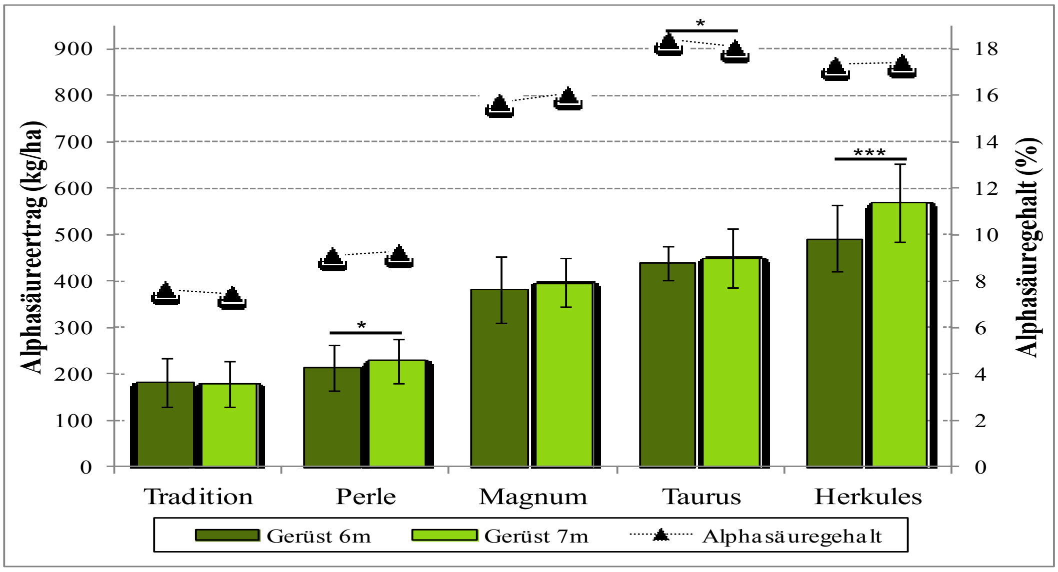


Fig. 5.4: Influence of trellis height on alpha-acid content and yields of various hop cultivars

*Comparison of alpha-acid content (%) and alpha-acid yield (kg/ha) obtained on 6-m and 7-m trellises for the aroma varieties Hallertauer Tradition and Perle (n = 12 in each case) and for the bitter varieties Hallertauer Magnum (n = 12), Hallertauer Taurus and Herkules (n = 16). Significant differences in yield were tested for each cultivar via multifactor ANOVAs and characterised (p < 0.05 *, p < 0.01 ** and p < 0.001***).*

The slight differences in alpha-acid content are negligible. As no trend is recognizable, the significant difference for Hall. Taurus may be attributable to other variables such as location, variety, etc. The higher crop yield obtained for Herkules on the 7-m trellis meant a higher alpha-acid yield per hectare, although alpha-acid content was the same for both variants.

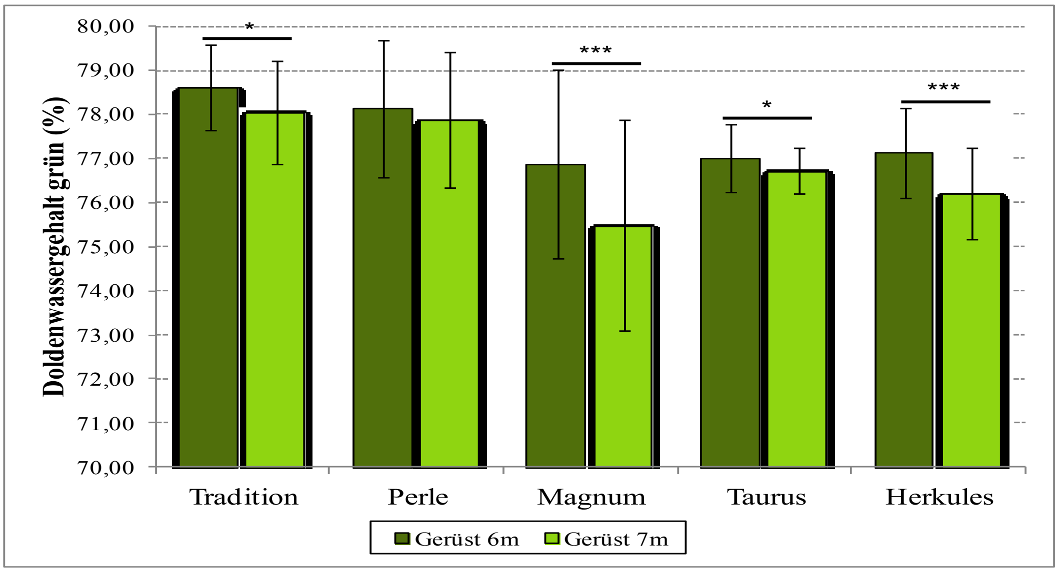


Fig. 5.5: Influence of trellis height on cone moisture content at the same harvesting time

*Comparison of alpha-acid content (%) and alpha-acid yield (kg/ha) obtained on 6-m and 7-m trellises for the aroma varieties Hallertauer Tradition and Perle (n = 12 in each case) and for the bitter varieties Hallertauer Magnum (n = 12), Hallertauer Taurus and Herkules (n = 16). Significant differences in yield were tested for each cultivar via multifactor ANOVAs and characterised (p < 0.05 *, p < 0.01 ** and p < 0.001***).*

Green-hop moisture content, when averaged over the duration of the trial, was significantly higher in all the cultivars except Perle when the hops were grown on the lower trellis system. This indicates that the optimum harvesting time is reached later on 6-m trellises and that maximum yields will not be achieved if crops are harvested too early (see LfL fact sheet: "Hopfenqualität – Ernte zum richtigen Zeitpunkt" (Hop quality – the correct time for harvesting), p. 33). The size of the increase in yield that might be expected if the 6-m crop is harvested later was not investigated in this trial and therefore cannot be quantified. However, hop farmers who have grown healthy crops of the same hop variety on both trellis variants are clearly advised to harvest the 6-m crop last. This will enable them to obtain optimal yields on 6-m trellis systems too.

Cone assessment showed no differences in size or disease infestation.

A general recommendation that hop farmers reduce trellis height for structural reasons is not yet possible on the basis of the trial results because only one location was tested per cultivar. It is only in locations vulnerable to storm and disease damage, particularly if they are also low-yield locations, that the advantages of reduced trellis height compensate for the disadvantage of possible lower yields.

5.3 Testing of various substances for their efficacy and ability to intensify the effect of initial hop-stripping formulations

5.3.1 Initial situation, problem and objective

Hop stripping promotes growth of the main shoots and has a phytosanitary effect. Growers in the Hallertau region have so far made exclusive use of nitrogenous solutions for initial hop stripping, during which the hop plant's lower leaves and lateral shoots are desiccated to a height of about 2 m above the ground. Adhesives and, if required, micronutrient fertilisers in the form of salts may be added to intensify the effect. A permissible quantity of Lotus, which is licensed for weed control in hop growing, may also be added to the stripping solution to further reinforce its aggressiveness. The addition of Lotus is essential to ensure a satisfactory result. However, Lotus must not be used for hops intended for export to the USA.
Moreover, the use of Lotus will be prohibited as from 2014.
For these reasons, there is an urgent need to search for alternative substances with which to reinforce the aggressiveness of these fertiliser solutions. Within the framework of tentative trials aimed at remedying this situation and conducted at several locations, various formulations and solutions were tested for their caustic effect.

5.3.2 Methods

During the planning of the experiments it was decided that as many formulations as possible should be tested. It was technically impossible to apply the formulations in the usual manner with a spray tank and plant-base spray boom because the number of test variants was too great. Instead, two knapsack sprayers were fitted with TurboDrop nozzles (TD 80-04) and calibrated in litres. During spray application, hop stripping with a plant-base spray boom was simulated by observing the respective distances to the plants and the ground. The various formulations were assessed for the percentage of desiccated leaf-surface area and dead shoot tips. Superficial burns on the treated sections of the bines were also recorded as a percentage of the surface area. Assessment was performed on all the test cultivars 5 – 6 days after spray application.

5.3.2.1 Trial design, Part 1, of May 6, 2011

The mixtures listed in Tab. 5.4 were tested on Perle, Herkules and Taurus at the Oberhartheim location. All the spray variants were applied at a dose rate of 400 l/ha. The standard spray mixture consisted of 267 l water, 133 l UAN solution (=AHL) and the micronutrient fertilisers (SE) zinc (0.3 %) and boron (0.2 %). Adhäsit was used as wetting agent. Tab. 5.4 shows which other components were used in the spray variants, i.e. how the spray mixtures differed in composition, and indicates the amounts of nutrients applied in kg/ha or g/ha.

Explanation of variants I to XII:

I. Untreated control
II. Mixture used by hop farmers, which includes Lotus but no micronutrients
III. Mixture used by hop farmers, which includes Lotus
IV. UAN solution from the Piesteritz (P.) factory, well tolerated by field crops
V. UAN solution from the Duslo Sala (D.S.) factory, often poorly tolerated by field crops
VI. Ammonium sulphate as substitute for UAN
VII. 1.66 % pelargonic acid (product: Finalsan) to intensify the effect
VIII. ISAGRARwax GLI, a new substitute for Adhäsit
IX. 10 % (40 kg) 47 % magnesium chloride salt to intensify the effect
X. 15 % (60 kg) 47 % magnesium chloride salt, without UAN
XI. 20 % (80 kg) 47 % magnesium chloride salt, without UAN
XII. Increased amount of micronutrient fertiliser (0.5 % zinc, 0.5 % boron)

Tab. 5.4: Trial design, Part 1, showing dose rates and nutrient amounts per ha

Variante	Aufwandmenge 400 l/ha	Nährstoffe/ha	Variante	Aufwandmenge 400 l/ha	Nährstoffe/ha
I	unbehandelt		VII	1,66 % = 6,64 l Finalsan	**48 kg N 209 g Zn 170 g B**
II	80 ml Lotus 100 l AHL (P.)	**36 kg N**	VIII	1,0 % = 4 l GLI	**48 kg N 209 g Zn 170 g B**
III	80 ml Lotus 100 l AHL (P.)	**36 kg N 209 g Zn 170 g B**	IX	10 % = 40 kg Magnesiumchlorid	**48 kg N 8 kg MgO 209 g Zn 170 g B**
IV	133 l AHL (P.)	**48 kg N 209 g Zn 170 g B**	X	15 % = 60 kg Magnesiumchlorid	**12 kg MgO 209 g Zn 170 g B**
V	133 l AHL (D.S.)	**48 kg N 209 g Zn 170 g B**	XI	20 % = 80 kg Magnesiumchlorid	**16 kg MgO 350 g Zn 170 g B**
VI	133 kg SSA	**28 kg N Zn+B nicht lösl.**	XII	0,5 % = 2 kg Zinksulfat 0,5 % = 2 kg Borsalz	**48 kg N 350 g Zn 350 g B**

Part 1 results

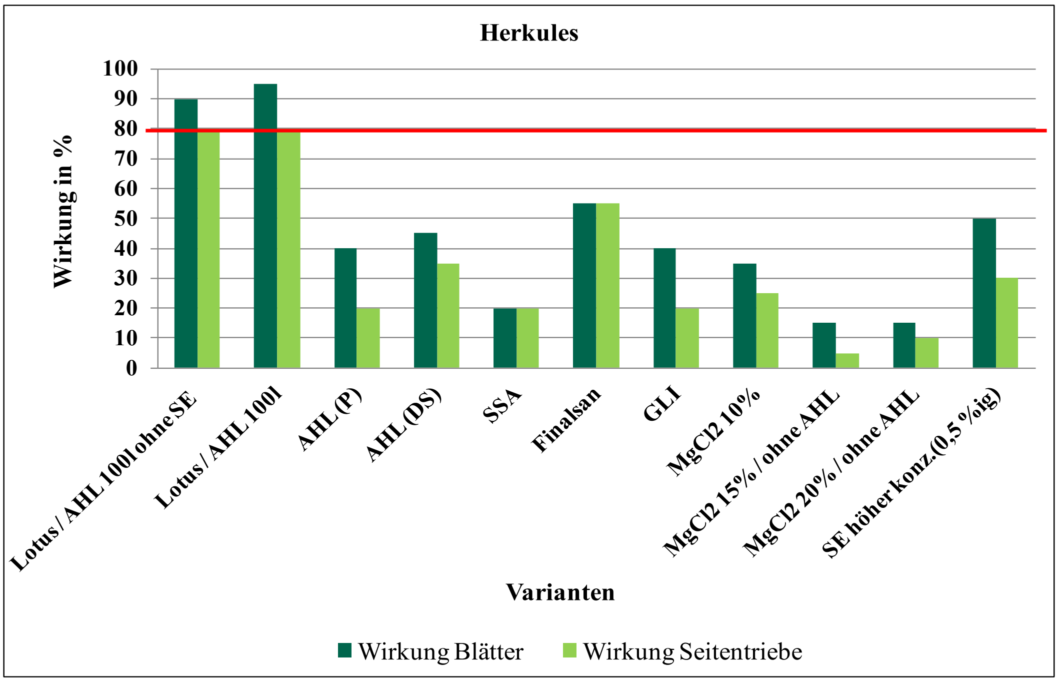


Fig. 5.6: Efficacy on Herkules

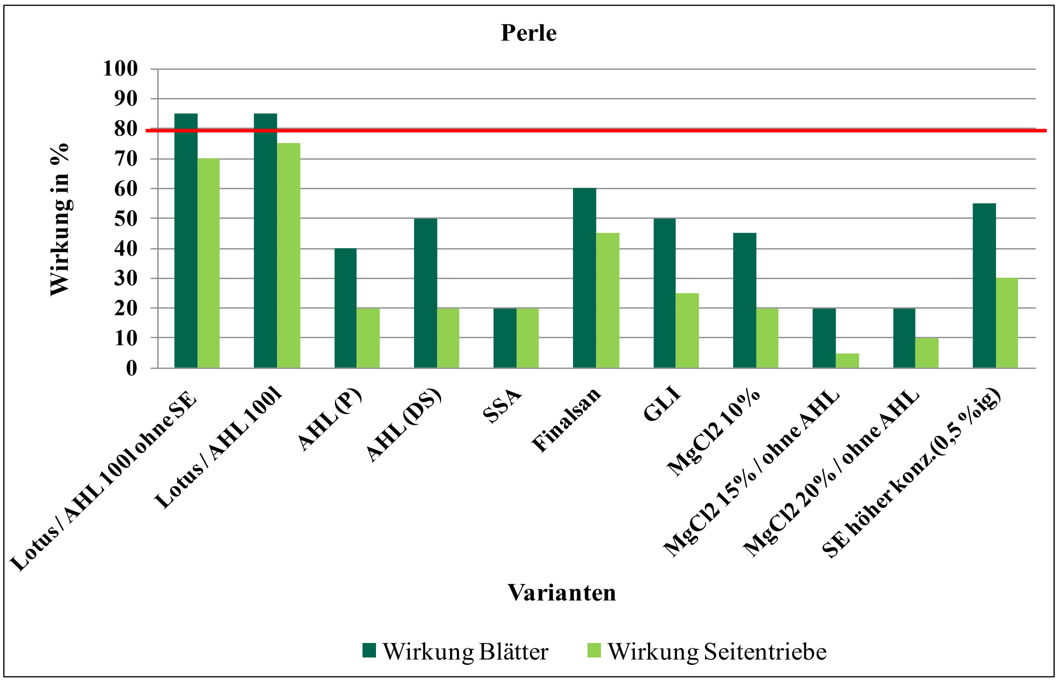


Fig. 5.7: Efficacy on Perle

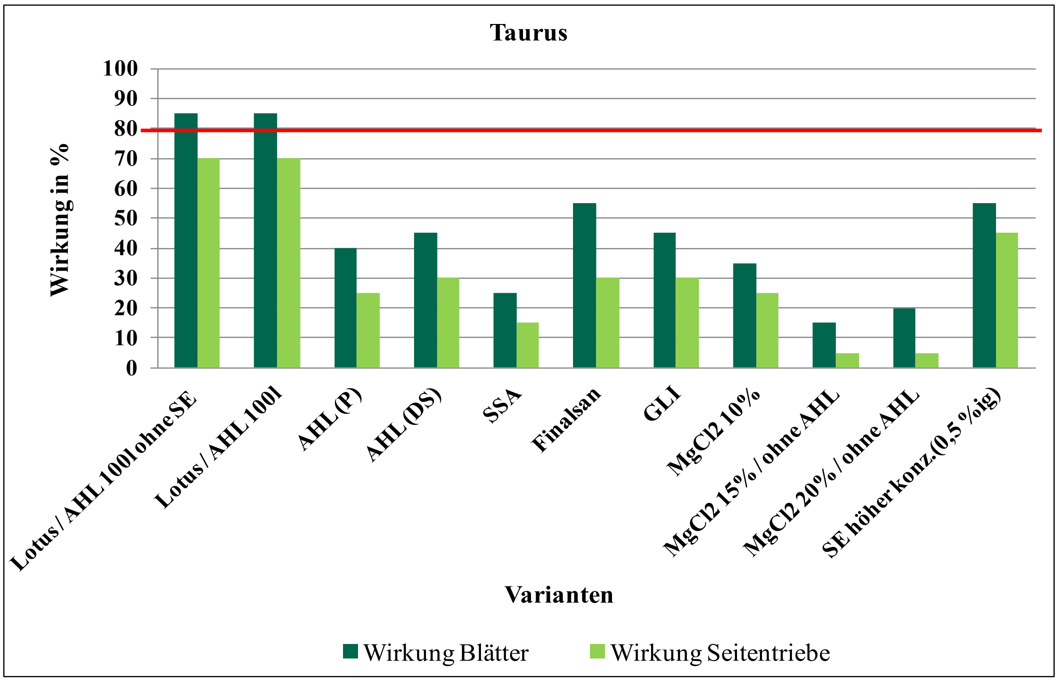


Fig. 5.8: Efficacy on Taurus

A comparison of the assessment results shows the same trend for the different variants with all three test cultivars. The effect on Perle and Taurus was only slightly less than on Herkules. What is clear, however, is the fact that the variants containing the herbicide Lotus produced the best results. Only these variants produced the desired 80 % (red line) desiccation of leaves and laterals. The relatively pronounced caustic effect of the UAN (D.S.) variant was identifiable but insufficient. The result obtained with ammonium sulphate was very poor on account of the dry weather. Finalsan did intensify the effect of the stripping solution but would need to be licensed for use in hop-growing. It would also be too costly if used in a higher concentration. The wetting agent GLI intensified the effect only moderately. No additional effect was obtained with a 10 % magnesium chloride solution or with the 15 % and 20 % magnesium chloride variants containing no UAN. Higher trace-element concentrations increased the spray's effectiveness slightly but led to oversupply symptoms if spraying had been followed by rain.

5.3.2.2 Trial design, Part 2, of 13.05.11

Tolerance tests were performed on Saphir, Magnum and Taurus in the Rohrbach breeding yard. New variants were defined on the basis of the findings from the first trial. A new 30 % magnesium chloride solution was also available, which is used by growers of organic potatoes to kill the haulm.
Magnesium chloride ($MgCl_2$) is converted into plant-available magnesium chloride (MgO) via the factor 0.423. GLI was used as wetting agent. The spray mixtures, which were applied at a dose rate of 400 l/ha, also contained the micronutrient fertilisers zinc (0.3 %) and boron (0.2 %). During the assessment, superficial burns on the treated sections of the bines were also recorded. Tab. 5.5 shows the exact mixing ratios of the sprays.

Explanation of variants I to VI:

I. Untreated control

II. Mixture used by hop farmers, which includes Lotus

III. 33 % UAN solution + 66 % $MgCl_2$ solution, no additional water; micronutrients did not dissolve!

IV. 50 % UAN solution + 50 % $MgCl_2$ solution, no additional water; micronutrients did not dissolve!

V. 100 % $MgCl_2$ solution

VI. 50 % $MgCl_2$ + 50 % water

Tab. 5.5: Trial design, Part 2, showing dose rates and nutrient amounts per ha

Variante	Aufwandmenge 400 l/ha	Nährstoffe/ha	Variante	Aufwandmenge 400 l/ha	Nährstoffe/ha
I	unbehandelt		IV	200 l AHL 200 l $MgCL_2$ (30 %ig) 1,2 kg Zinksulfat 0,8 kg Borsalz 1 % GLI	**72 kg N** **25 kg MgO** **Zn+B nicht lösl.**
II	80 ml Lotus 133 l AHL 266 l Wasser 1,2 Zinksulfat 0,8 kg Borsalz 1 % GLI	**48 kg N** **209 g Zn** **170 g B**	V	400 l $MgCL_2$ (30 %ig)	**51 kg MgO**
III	133 l AHL 266 l $MgCL_2$ (30 %ig) 1,2 kg Zinksulfat 0,8 kg Borsalz 1 % GLI	**48 kg N** **34 kg MgO** **Zn+B nicht lösl.**	VI	200 l $MgCL_2$ (30 %ig) 200 l Wasser	**25 kg MgO**

Part 2 results

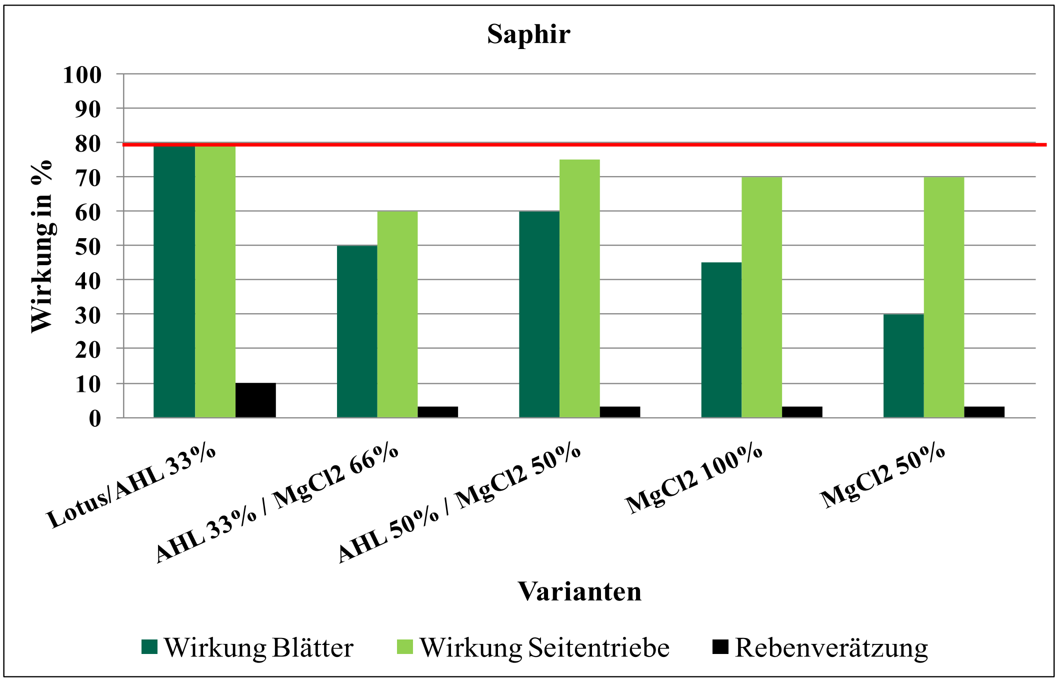


Fig. 5.9: Efficacy and superficial bine burns on Saphir

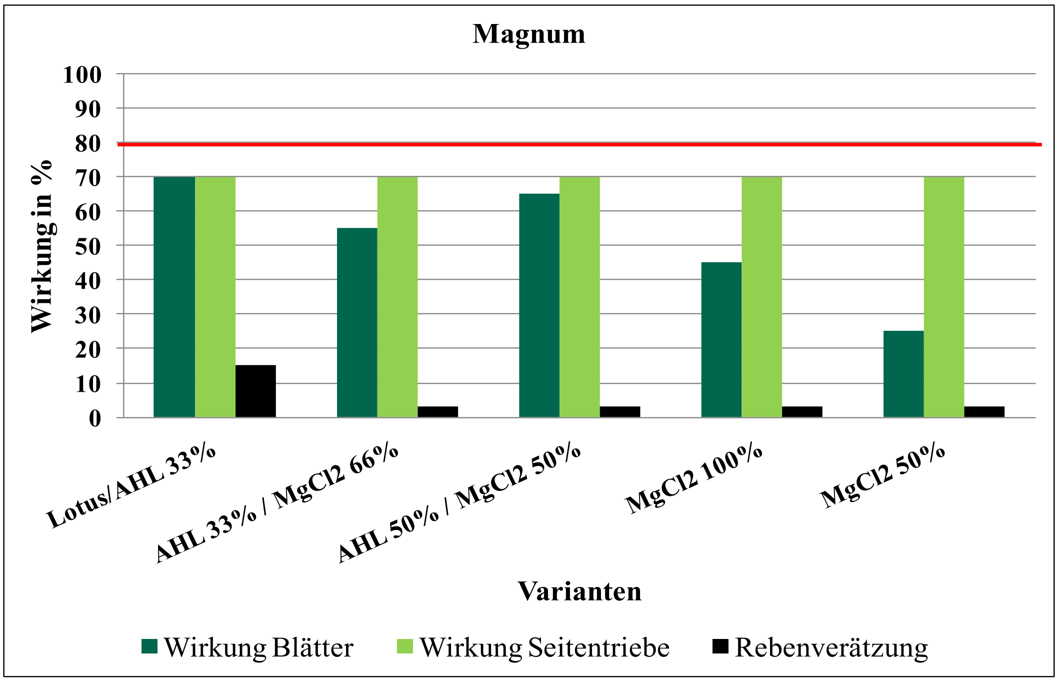


Fig. 5.10 : Efficacy and superficial bine burns on Magnum

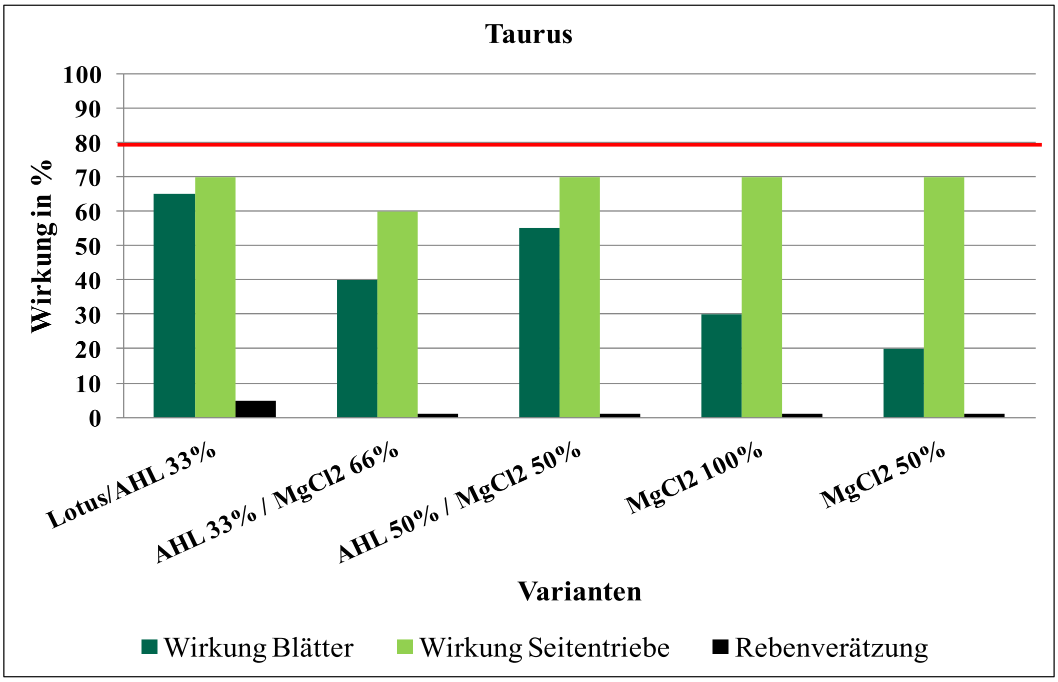


Fig 5.11.: Efficacy and superficial bine burns on Taurus

As in the first trial, results were poorest with the Taurus variety. None of the Lotus-free spray variants produced satisfactory degrees of leaf desiccation. However, all the spray variants were highly effective on all three cultivars with regard to killing off the lateral shoots, especially the shoot tips. During spraying, small droplets accumulated at the shoot tips and led to pronounced desiccation. This is due to the consistency of the spray liquid, which was made more viscous and stickier by the addition of magnesium chloride solution.

5.3.2.3 Trial design, Part 3, of 18.05.11

The combination of UAN and magnesium chloride produced a satisfactory result in the second trial. The aim of the third trial was to test whether this result can be improved still further by adding various wetting agents to the spray mixtures. The trial was carried out on Taurus because lack of efficacy is most easily identifiable with this variety. The spray mixtures were applied at a dose rate of 400 l/ha as in the preceding trials. A mixture of 50 % UAN and 50 % $MgCl_2$ was used as the standard spray solution. The addition of zinc and boron necessitated vigorous stirring because the solution was so saturated. One variant was again formulated as a standard Lotus spray mixture for comparison purposes, and one variant was formulated without UAN so as to permit testing of a nitrogen-free spray mixture. This variant was made up of 50 % $MgCl_2$ solution, 50 % water and some Lotus.

Part 3 results

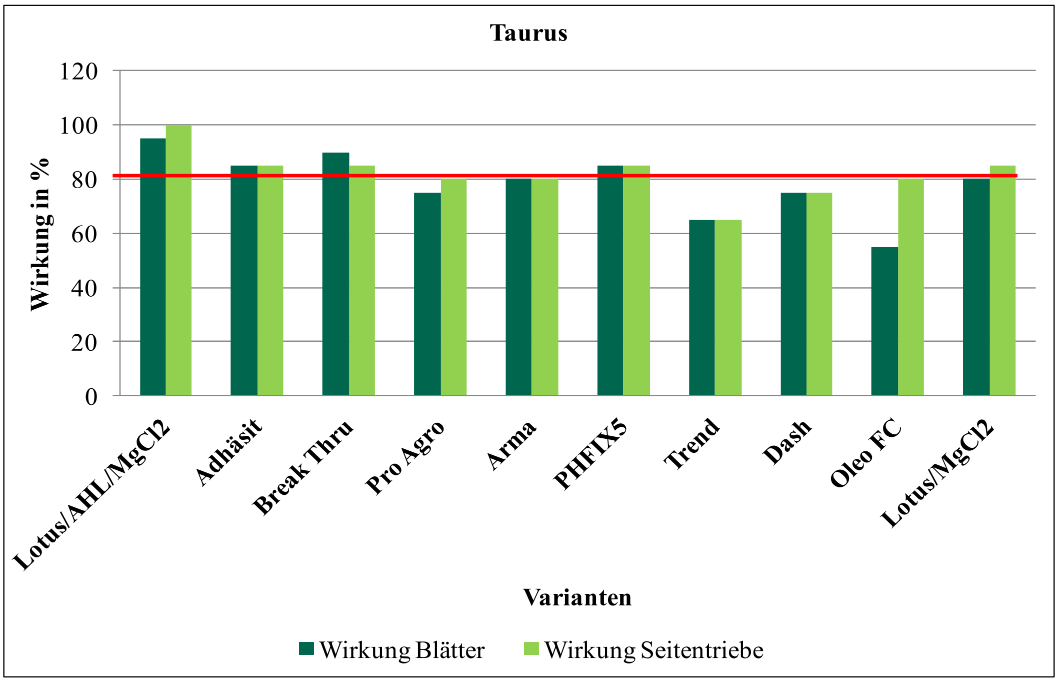


Fig. 5.12: Efficacy on Taurus

Prior to hop stripping, heavy rain had fallen and been followed by intense sunshine. Weather conditions were thus ideal for stripping and a good caustic effect was anticipated. The mixture comprising Lotus, UAN and $MgCl_2$ produced an almost perfect result. However, the variants that did not contain Lotus were also very effective. The wetting agents Adhäsit, Pro Agro, Arma and PHFIX 5 were equally good, while Trend, Dash and Oleo FC were slightly less effective. What was remakable, however, was the rapid and good effect achieved with the wetting agent Break Thru. The leaves and laterals of the hop bines showed signs of wilting after only one hour. The speed with which the spray solution takes effect, thanks to Break Thru, makes for less weather dependence. Furthermore, on conclusion of the assessment, this product showed the best result of all the Lotus-free variants. The combination of Lotus and $MgCl_2$ solution, without UAN, is a nitrogen-free alternative but needs to be tested for its effectiveness and compatibility with other cultivars in a further trial year.

5.3.2.4 Trial design, Part 4, of 24.05.11

Herkules and a cultivar in the Rohrbach breeding yard were selected for the last trial with initial-hop-stripping formulations. Alzchem provided a new fertiliser solution to be tested for its caustic effect. The fertiliser was an ammonium nitrate solution (AN solution) with a nutrient content of 6 % NH_4-N and 6 % NO_3-N. This solution was tested in three different concentrations. The hop-stripping mixture containing UAN and $MgCl_2$ solution, which was newly recommended in 2011, was also tested. Quickdown combined with the wetting agent Toil served as the comparative variant. All the other spray variants, which were again applied at a dose rate of 400 l/ha, contained the wetting agent Break Thru and additions of the micronutrients boron (0.2 %) and zinc (0.3 %).

Explanation of variants I to VII:

I. Untreated control
II. 50 % AN solution
III. 66 % AN solution
IV. 75 % AN solution
V. Quickdown + Toil as wetting agent
VI. 33 % water, 33 % UAN solution, 33 % $MgCl_2$ solution
VII. 33 % water, 33 % UAN solution, 33 % $MgCl_2$ solution and Adhäsit

Tab. 5.6: Trial design, Part 4, showing dose rates and nutrient amounts per ha

Variante	Aufwandmenge 400 l/ha	Nährstoffe/ha	Variante	Aufwandmenge 400 l/ha	Nährstoffe/ha
I	unbehandelt				
II	200 l Wasser 200 l AN 200 ml Break Thru 1,2 kg Zinksulfat (0,3 %) 0,8 kg Borsalz (0,2 %)	24 kg N 209 g Zn 170 g B	V	400 l Wasser 107 ml Quickdown 266 ml Toil 1,2 kg Zinksulfat (0,3 %) 0,8 kg Borsalz (0,2 %)	209 g Zn 170 g B
III	133 l Wasser 266 l AN 200 ml Break Thru 1,2 kg Zinksulfat (0,3 %) 0,8 kg Borsalz (0,2 %)	32 kg N 209 g Zn 170 g B	VI	133 l Wasser 133 l $MgCL_2$-Lösung 133 l AHL 200 ml Break Thru 1,2 kg Zinksulfat (0,3 %) 0,8 kg Borsalz (0,2 %)	48 kg N 17 kg MgO 209 g Zn 170 g B
IV	100 l Wasser 300 l AN 200 ml Break Thru 1,2 kg Zinksulfat (0,3 %) 0,8 kg Borsalz (0,2 %)	36 kg N 209 g Zn 170 g B	VI	133 l Wasser 133 l $MgCL_2$-Lösung 133 l AHL 200 ml Break Thru 400 ml Adhäsit 1,2 kg Zinksulfat (0,3 %) 0,8 kg Borsalz (0,2 %)	48 kg N 17 kg MgO 209 g Zn 170 g B

Part 4 results

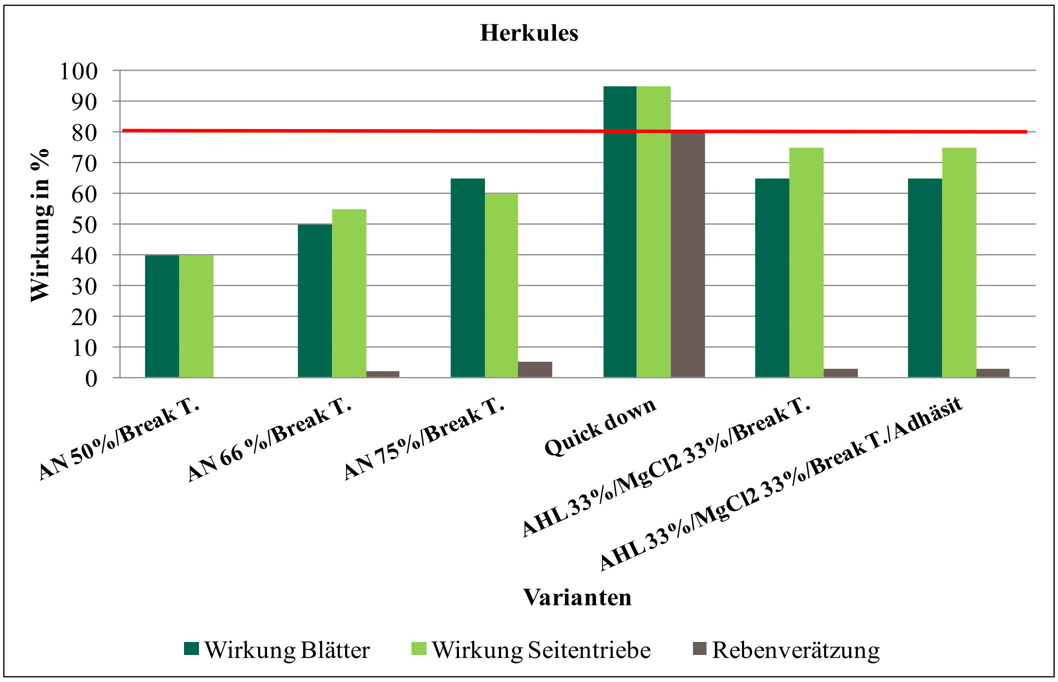


Fig. 5.13: Efficacy and superficial bine burns on Taurus

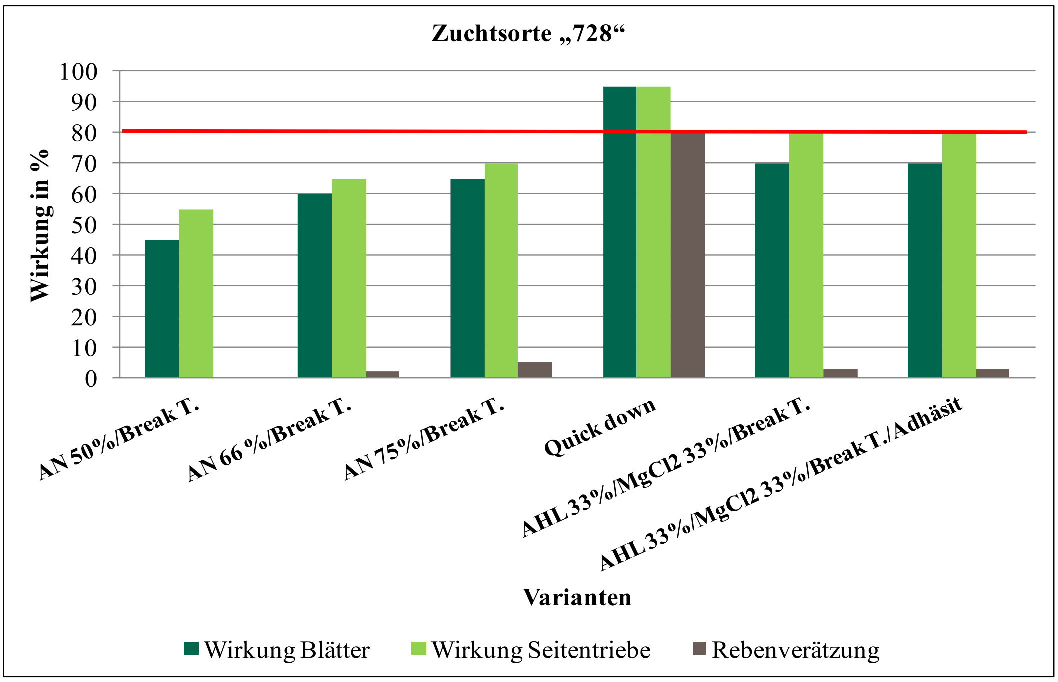


Fig. 5.14: Efficacy and superficial bine burns on the "728" cultivar

The spray variants produced almost the same stripping results with both cultivars. The degree of dessication increased with increasing concentrations of AN solution. However, the desired degree of 80 % leaf and lateral dessication was not achieved. By contrast, the nutrient solution currently used by hop growers for stripping purposes produced satisfactory results. The use of Adhäsit to supplement Break Thru as a wetting agent did not increase stripping efficacy.

The herbicide Quickdown was extremely effective but also caused burns on around 80 % of the treated bine surface. As the bines were not yet sufficiently lignified at the time of spraying, the burns destroyed vascular bundles. The clearly visible constrictions caused considerabe growth depressions during the rest of the vegetative season, and these, too, were clearly visible right up to harvesting time.

5.3.3 Discussion

Initial tentative trials at the Hüll Hop Research Centre have shown that the caustic effect of UAN can be intensified by combining it with various nutrient solutions and wetting agents. The new 12 % ammonium nitrate solution did not meet expectations in the trial. The intention is to conduct further tests with the solution in its currently available form (15 %). The addition of $MgCl_2$ solution intensified the caustic effect, especially at the shoot tips. Approx. 30 % water should, however, always be added to the nutrient solutions so as enable additions of zinc and boron, which are important micronutrients at this stage of development, to dissolve.

The wetting agent with the best results was Break Thru. Good stripping results with spray mixtures containing nutrient solutions can only be achieved if stripping is preceded by rain followed by intense sunshine, and no further rain falls until the spray has taken effect. Experience has shown the necessity of generating very fine droplets during spraying in order to obtain uniform wetting of leaves and laterals.

In the case of Quickdown, it is essential to wait until the hop plants have reached the top of the trellis before they are sprayed. This will eliminate the risk of damage to the plant via burns on the bines.

5.4 Field trials with follow-up hop-stripping formulations

5.4.1 Initial situation, problem and objective

Experience with initial hop stripping has shown that the caustic effect of herbicides can be intensified by combining them with nutrient solutions. Since unwanted grass spread, e.g. annual meadow grass or grass sorghum, has increased greatly in recent years, many farmers combine the contact herbicide Reglone with UAN (= AHL) or systemic grass herbicides such as Aramo. By doing so, these farmers ignore the fact, however, that the dessication caused by Reglone prevents the plant from absorbing a systemic herbicide. The overall weed- and grass-control effect may decrease as a result. The aim of the trials was to combine a number of active agents and nutrient solutions and assess the combinations for plant tolerance and effectiveness.

5.4.2 Methods

In 2010 and 2011, follow-up hop-stripping trials were set up in which spraying was conducted with a plant-base spray boom. Two TurboDrop nozzles (TD 80-04) were fitted to each side of the spray boom. The forward speed was approx. 4 km/h at an operating pressure of 6 to 9.5 bar depending on the dose rate. In post-treatment assessments, the percentage of dessicated leaf-surface area was recorded. The percentage of lateral shoot tips and ground shoots killed was also recorded, as well as superficial burns on the treated sections of the bines. Assessment was performed for all spray-mixture variants 14 days after application.

Trial design, Part 1, of 22.07.2010

The follow-up hop-stripping spray mixtures shown in the table were tested in 2010 on Taurus at the Wolnzach location. The standard dose rate was set at 400 l/ha. The wetting agent Adhäsit (0.1 %), which in recent years has proved very effective in these sprays, was used in all variants except Quickdown. Tab. 5.7 lists the formulations used and the amounts of nutrients applied in kg/ha.

Explanation of variants I to VI:

Untreated control: after every other pole, a patch was left untreated

I. Standard Reglone application of 1.67 l/ha

II. Reglone reduced to 1.2 l/ha + 25 % (=100 l) UAN to intensify the effect

III. Standard Quickdown application + Toil

IV. Standard Reglone application of 1.67 l/ha + Aramo 0.67 l/ha

V. Aramo 0.67 l/ha with a reduced volume of water (150 l)

VI. Aramo 0.67 l/ha

Tab. 5.7: Trial design, Part 1, showing dose rates and nutrient amounts per ha

Variante	Aufwandmenge 400 l/ha	Nährstoffe/ha	Variante	Aufwandmenge 400 l/ha	Nährstoffe/ha
I	1,67 l Reglone 0,4 l Adhäsit		IV	1,67 l Reglone 0,67 l Aramo 0,4 l Adhäsit	
II	1,2 l Reglone 100 l AHL 0,4 l Adhäsit	**36 kg N**	V	0,67 l Aramo 0,15 l Adhäsit bei 150 l/ha	
III	100 ml Quickdown 250 ml Toil		VI	0,67 l Aramo 0,4 l Adhäsit	

Part 1 results

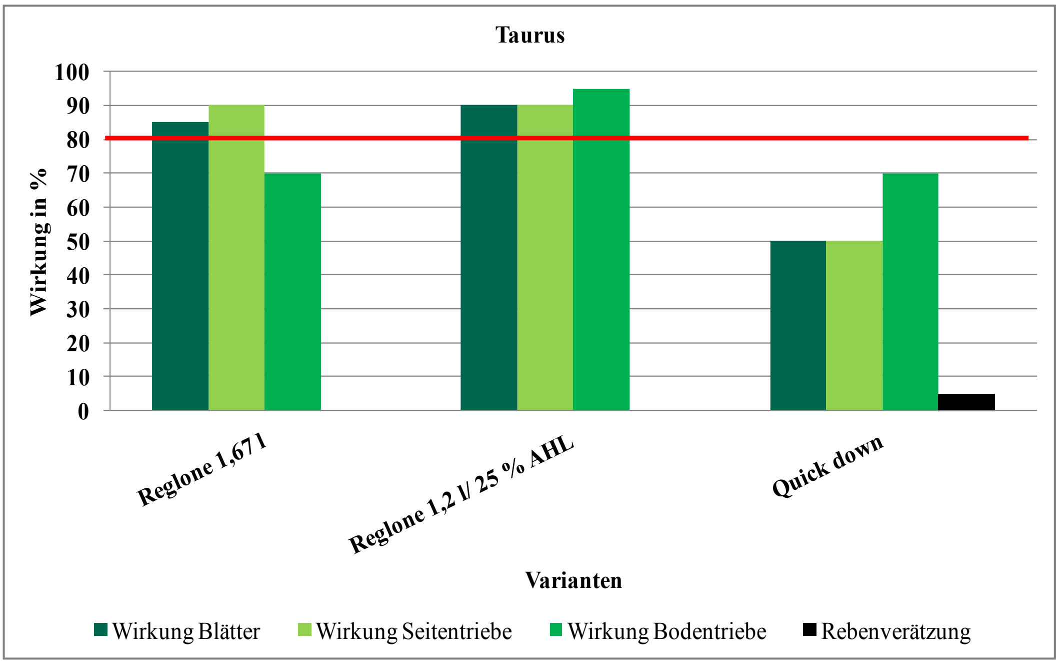


Fig. 5.15: Efficacy on Taurus

The standard variant with a dose rate of 1.67 l/ha Reglone produced a good caustic effect. More than 80 % of both the leaves and the laterals were desiccated, although approx. 30 % of the ground shoots survived. The second variant, containing 25 % UAN but a reduced amount of Reglone, was extremely effective. The effective killing of lateral and ground shoots is typical of this combination but, as has already been observed in field crops, untreated parts of the plant were found to have taken up Reglone's active agent, i.e. the active agent was transported acropetally in the vascular bundles. In this case, the active agent was merely shifted into the next internodes of the laterals. For inexplicable reasons, Quickdown produced a very poor result.

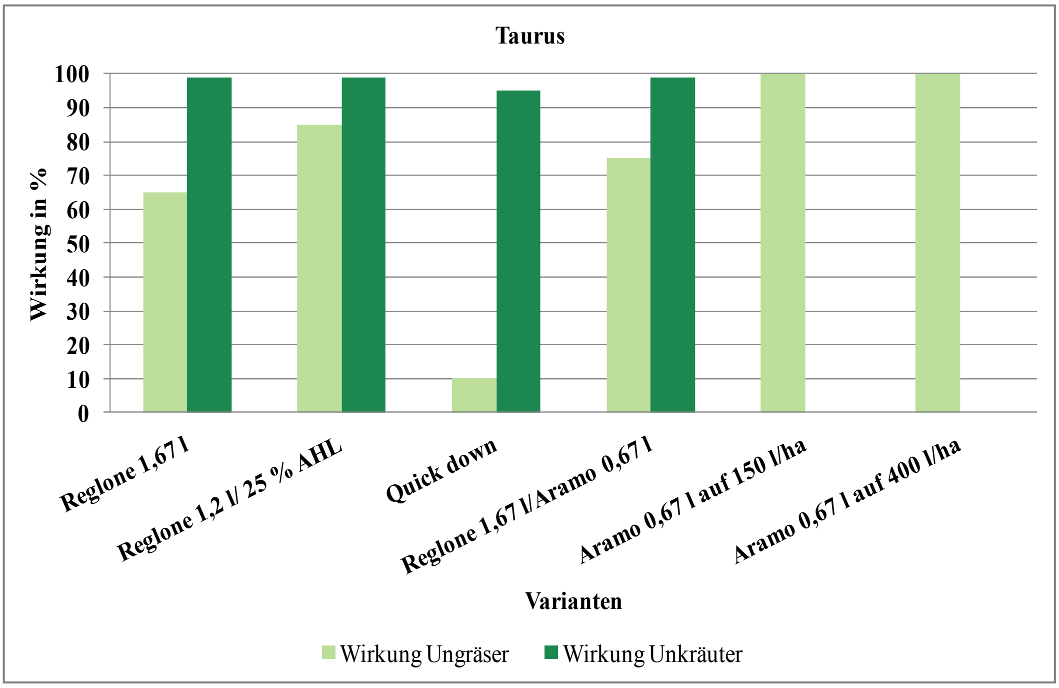


Fig. 5.16: Effect on weeds and grass on the hilled rows

As far as the effect on weeds and unwanted grass is oncerned, the Reglone/UAN variant produced a very good result. Quickdown's poor degree of effectiveness against grasses was clearly evident, and combining Aramo with Reglone was of no advantage with respect to grass control. On the contrary, rapid leaf desiccation prevented Aramo from taking full effect. This is evidenced by the 100 % effect of Aramo when used on its own. It should be noted that Aramo took effect much more quickly when applied with the reduced volume of water, i.e. 150 l/ha.

Trial design, Part 2, of 20.07.2011

Further trials with follow-up hop-stripping formulations were commenced in 2011, the aim being to test the potency and compatibility of various combinations. All variants were applied at a dose rate of 500 l/ha. New variants were defined on the basis of the findings from the preceding hop stripping trials. Tab. 5.8 shows the exact mixing ratios of the sprays.

Explanation of variants I to VI:

Untreated control: after every other pole, a patch was left untreated

I. Standard Reglone application of 1.67 l/ha + Adhäsit
II. Reglone reduced to 1.0 l/ha + 25 % (=100 l) UAN to intensify the effect + Adhäsit
III. Standard Quickdown application + Toil
IV. Weed control with U 46 M-Fluid, 0.33 l/ha + Adhäsit
V. Nitrogen-free hop stripping: 50 % $MgCl_2$ + 50 % water + 80ml Lotus + Break Thru
VI. Nutrient solution recommended for initial hop stripping in 2011: 33 % water, 33 % UAN, 33 % $MgCl_2$ + Break Thru

Tab. 5.8: Trial design, Part 2, showing dose rates and nutrient amounts per ha

Variante	Aufwandmenge 500 l/ha	Nährstoffe/ha	Variante	Aufwandmenge 500 l/ha	Nährstoffe/ha
I	1,67 l Reglone 0,5 l Adhäsit		IV	0,33 l U 46 M-Fluid 0,5 l Adhäsit	
II	1,0 l Reglone 100 l AHL 400 l Wasser 0,5 l Adhäsit	**36 kg N**	V	80 ml Lotus 250 l $MgCl_2$ (30 %ig) 250 l Wasser 250 ml Break Thru	**32 kg MgO**
III	100 ml Quickdown 250 ml Toil		VI	165 l AHL 165 l $MgCL_2$ (30 %ig) 165 l Wasser 250 ml Break Thru	**59 kg N** **21 kg MgO**

Part 2 results

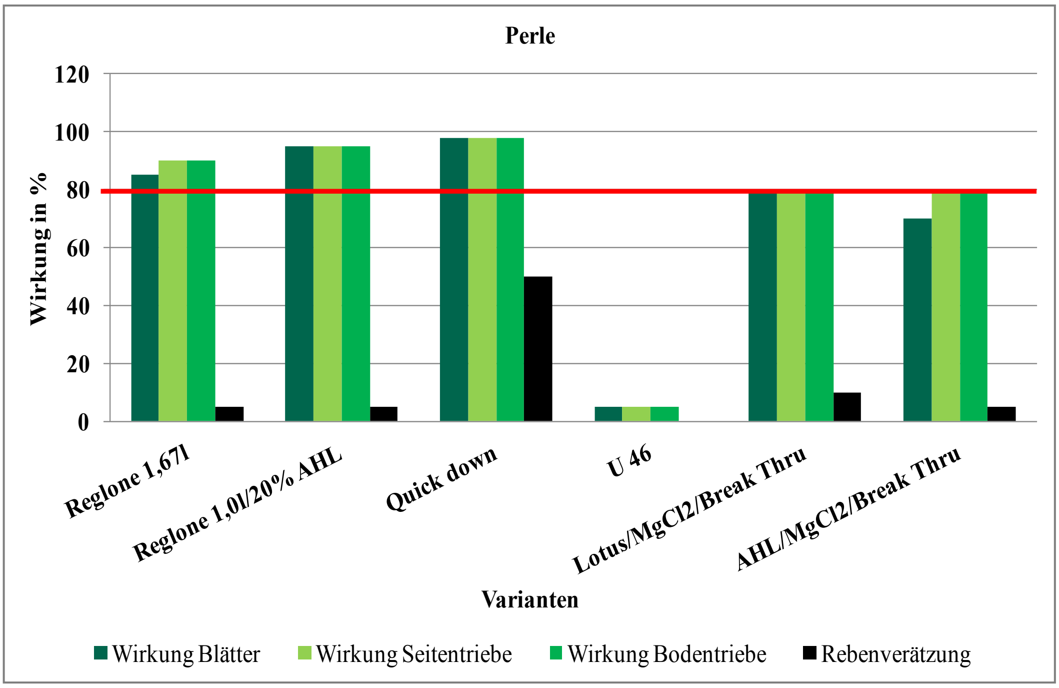


Fig. 5.17: Efficacy and superficial bine burns on Perle

As in 2010, the standard Reglone variant was very effective. The second variant, containing UAN, produced an excellent result despite the strong reduction in the Reglone dose rate to 1.0 l/ha. Once again, however, Reglone transport in the vascular bundles could be observed. Quickdown was also highly effective. Despite dark burns on approx. 50 % of the treated bine surface, the plants showed no visible signs of having been adversely affected. As expected, U 46 M-Fluid had practically no effect. Both the nitrogen-free variant containing Lotus and the Lotus-free nutrient solution produced a satisfactory result.

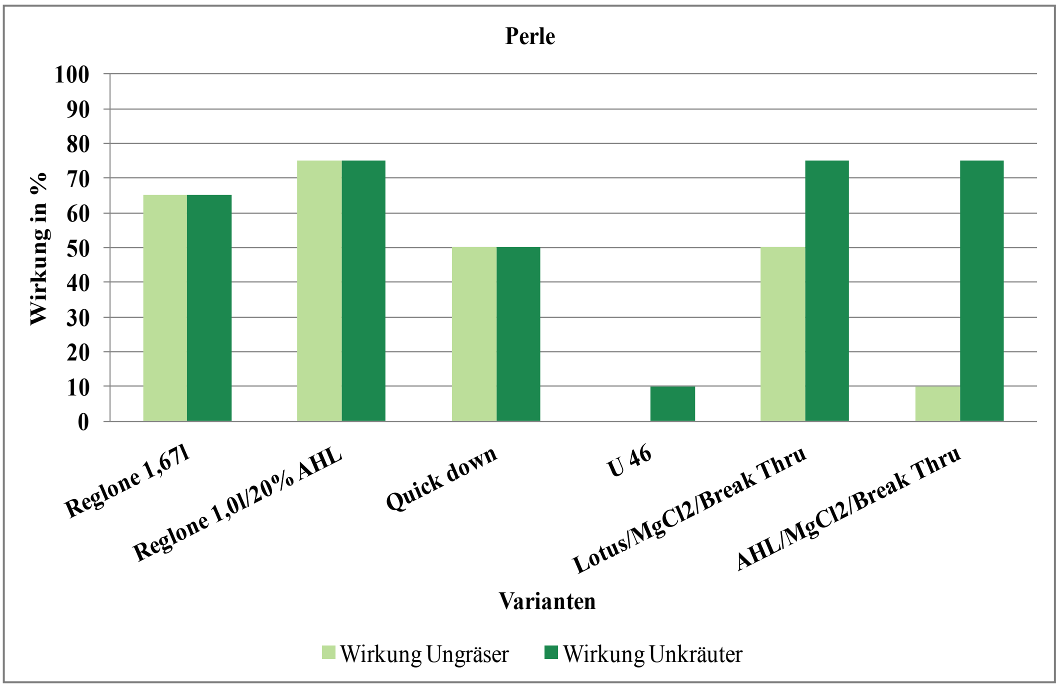


Fig. 5.18: Effect on weeds and grass on the hilled rows

As in 2010, the Reglone/UAN combination was highly effective against unwanted grasses. Quickdown produced its familiar poor result with grass. In the concentration applied, U 46 M-Fluid had no effect either. The variant containing nutrient solutions unfortunately has only a limited effect on grass, although a satisfactory result is obtained for weeds.

Discussion

Tentative trials at the Hüll Hop Research Centre with follow-up hop-stripping formulations have shown that the caustic effect of Reglone can be intensified by the addition of UAN. However, the active agent is transported upwards in the vascular bundles and can damage the hop plants in adverse weather conditions. Further tolerance trials are necessary to test whether the addition of UAN will enable a reduction in Reglone dosage. Quickdown is ideal as a follow-up hop-stripping herbicide but is particularly poor against grass. If herbicides such as Aramo or U 46 M-Fluid are to be effective, it is essential to use them in the recommended concentration, i.e. to use the right amount of water. The advice to farmers not to use these systemic herbicides together with contact herbicides still holds, because the immediate contact effect hinders the necessary transfer of the systemic herbicide into the rhizome. The use of nutrient solutions is also possible for the follow-up hop-stripping measure but these do not produce the reliable and good result obtained with Reglone.

5.5 Disinfection of hop bine choppings by means of hot rotting

5.5.1 Objective

Hop wilt disease is caused by the soil-borne *Verticillium albo-atrum* fungus. Genetic analyses have shown that not only mild but also lethal fungal races have established themselves in the Hallertau growing region. One conspicuous feature of this region is the fact that the greatest yield losses occur in the hop yards to which green bine choppings have been returned during the harvest for many years. The return of non-hygienised hop-bine remains enriched the population of *V. albo-atrum* in the soil. Evidence was obtained in earlier trials that if the bine choppings are stored in piles, the heat generated during the rotting process destroys the *Verticillium* fungus. The aim of the trial was to increase the temperature of bine choppings temporarily piled in the field by covering the piles with plastic sheeting and thereby to kill off the fungus at the edges of the piles.

5.5.2 Methods

To this end, the temperatures of temporary piles of bine choppings were logged in 2010 at a commercial hop farm where bine choppings have to be returned to the field daily due to lack of storage space. To simulate unfavourable conditions, two 30-m³ loads of bine choppings were dumped on the same day at the edge of a wood (trees to the east, no sunshine). Load 1 was left uncovered and load 2 was covered with plastic sheeting (black/white, 150 µm, black side up). Three data loggers were inserted horizontally into the eastern side of each pile at a height of 80 cm above the ground and to depths of 10 cm, 50 cm and 90 cm from the edge of the piles. The data loggers recorded the temperature and relative humidity at 60-minute intervals from 22.09 to 26.10.2010. The graph shows the averaged daily temperatures in °C and the rainfall recorded at the nearby Hüll weather station.

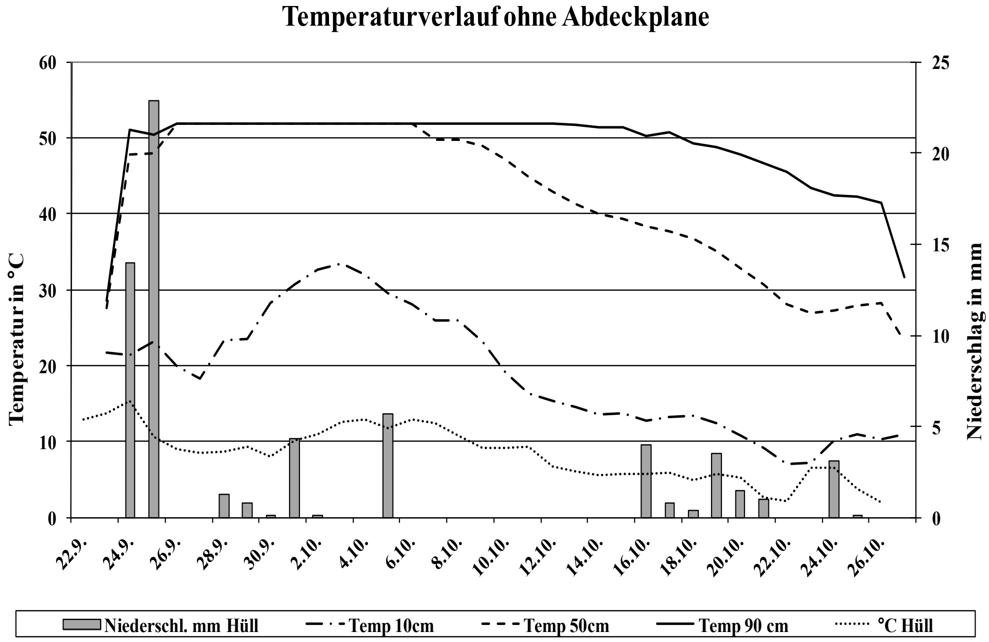


*Fig. 5.19: Temperatures measured 10, 50 and 90 cm from the edge of the **uncovered** pile and rainfall measured at the Hüll weather station*

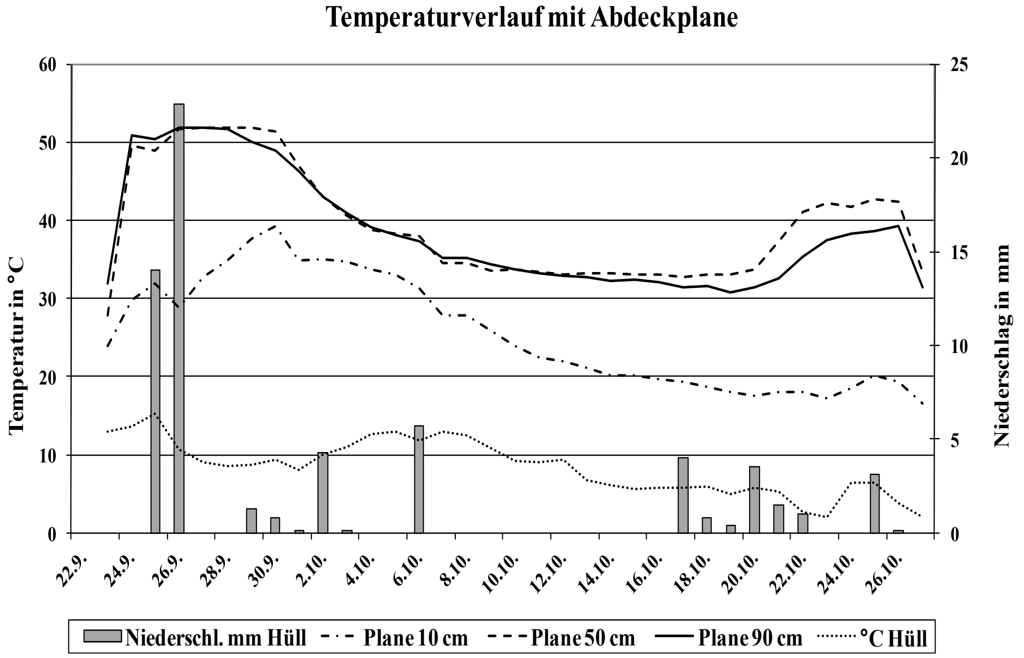


*Fig. 5.20: Temperatures measured 10, 50 and 90 cm from the edge of the **plastic-covered** pile and rainfall measured at the Hüll weather station*

5.5.3 Results and discussion

The graphs show relatively similar temperature rises at the relevant distances from the edge of both the pile with and the pile without a plastic covering. What was surprising at first glance was the early drop in temperature (after only 5-6 days) at all three measuring points in the load covered with plastic sheeting. The explanation may lie in the fact that the supply of oxygen becomes depleted sooner if a pile is covered, causing the microorganisms responsible for generating heat to die. The approx. 10 °C rise in temperatrure at depths of 50 and 90 cm in the covered pile during the last week of the trial is presumably due to the development of anaerobic bacteria. The compost was spread immediately after the data loggers had been removed, making it impossible to carry out a bacterial analysis after the data read-out. According to Bundesgütegemeinschaft Kompost e.V., it takes 7 days at 40 °C and 3 hours at 50 °C to disinfect compost containing *Verticillium albo-atrum*. If these findings are combined with the results of the trial, it can be seen that adequate disinfection of bine choppings can only be assumed as from a depth of 50 cm from the edge of the pile. This was evidenced in both trial piles (with and without plastic sheeting). The trial also showed that the temperature in the edge zones was probably insufficient to reliably kill the fungus.

The labour- and cost-intensive measure of using plastic-sheeting coverings thus fails to produce the desired results. Plan to repeat the trial after the 2011 harvest using conical piles of bine choppings failed when the bine choppings were sold and taken away at short notice to a cropping farm.

5.6 Savings in plant-protective consumption through use of sensors during row treatment

5.6.1 Objective

In order to combat primary downy mildew infections and pests such as flea beetles and alfafa snout beetles in hops, plant protectives are applied to the shoots via 1-3 nozzles from both sides of each row before and after stripping and training of the plants (BBCH Code 11 - 19). The volume of water required per row treatment is 300 - 400 l/ha. On account of the wide within-row spacing (1.4 – 1.6 m) and the limited ground cover provided by the emerging and trained shoots, 80 – 90 % of the spray solution ends up on the ground in the case of continuous row treatment. Plant-protective volumes and the environmental impact could be reduced, without compromising effectiveness, by switching off the spray fan between hop plants.

5.6.2 Methods

To determine the potential savings in consumption, an appliance for sensor-controlled application of plant-protectives via watering was modified by replacing the nozzle unit for watering by 2 -3 flat-pattern spray nozzles. With the nozzles mounted vertically (for use after training), the hop bines can be sprayed to a height of 1.5 m.

As the tractor moves forward, the optical sensor detects the training wire or the hop plant and opens the nozzles via pneumatic valves. The nozzle delay and opening times can be set on the control unit as a function of the tractor's forward speed.

The saving in plant-protective consumption achieved via sensor-controlled spot or intermittent spraying rather than continuous band spraying was determined in two trial series conducted in the Hüll Hop Research Centre's breeding yard on 19th April, 2011 (prior to stripping and training) and on 2nd May, 2011 (after stripping and training).


Fig. 5.21 and Fig. 5.22: Conventional practice of continuous row treatment


Fig. 5.23 and Fig. 5.24: Sensor-controlled application technique for initial spraying (19.04.2011) up to 40 cm in height



Fig. 5.25, Fig. 5.26 and Fig. 5.27: Sensor-controlled application technique for follow-up spraying (02.05.2011) up to 1.5 m in height

5.6.3 Results

In the first trial, on 19th April, 2011, the 5 - 40 cm shoots emerging from the crowned hop plants were band-sprayed from each side via 2 flat-pattern spray nozzles. Switching off the sprayer between plants by means of sensors reduced spray-solution, and thus plant-protective, consumption by 61.7 % compared with continuous row treatment.

At the second spraying date, after stripping and training, the hop bines were already 1.5 m high. Three flat-pattern spray nozzles were accordingly fitted to a vertical spray bar and switched off between the training wires by sensors. The saving in spray solution and plant protective was 55.2 % in this case.

No visible differences in leaf wetting were observed between band treatment and sensor-controlled spray application. An efficacy trial was not performed.

5.7 Testing of possible control methods for drip irrigation

5.7.1 Objective

In numerous trials conducted not only in drought years but also in years when rain was plentiful and yields were high, distinctly higher yields were obtained with the irrigated than with the non-irrigated trial variants. This shows that a steady water supply is crucial for constant yield levels at any one location, not only rainfall volumes.

Drip irrigation is thought to ensure optimal plant development by keeping the soil optimally moist around the tap root and providing an adequate water supply to the plant during stressful weather conditions without leaching nutrients from the soil into the groundwater.

To guarantee this, measuring methods and parameters are needed to identify a crop's water requirement at any one time and to control the irrigation system accordingly.

5.7.2 Possible methods of assessing soil moisture and the water requirement of hop plants

As part of an irrigation trial, various measuring methods were used to assess the water requirment of hop plants growing in sandy soil with a useful field capacity (UFC) of 11 vol. % and a location-dictated tap-root depth of up to 40 cm. At this location, the reaction of the plant to a variety of water volumes applied via drip irrigation can be researched extremely well on account of the low UFC and the high yields that can be obtained if the water supply is adequate. Growth and yield depressions are very quickly visible here if water is lacking. At the same time, drip irrigation has made it possible in recent years to obtain yields that demonstrate the genetic yield potential of cultivars.

5.7.2.1 Measurement of soil moisture tension via:

Tensiometers

Soil-moisture measurements provide information about the force with which the water is bound in the soil, i.e. its availability to plants. In the field, tensiometers have proved suitable for measuring soil moisture tension directly. A tensiometer consists of a water-filled plexiglass tube to the bottom of which a ceramic or clay cup is attached and to the top a manometer. The water in the tensiometer is in contact with the soil water via the pores in the cup, which is buried in the soil at a defined depth. If the soil becomes dryer because water is evaporating or being extracted by the plant, the soil moisture tension rises; a partial vacuum equal to the soil moisture tension is created in the tensiometer and is displayed in mbar or cbar via the manometer. Tensiometers have the disadvantage that, under severe drought conditions, the water column in the tensiometer cavitates, i.e. breaks suction, as from approx. 800 mbar, a moisture tension reached very quickly with hops.

Watermark sensors

Watermark gypsum-block sensors were used in the trial to measure and record water moisture tension. Two electrodes embedded within the sensor convert the measured resistance into soil moisture tension. This maintenance-free sensor operates up to 2000 mbar. All the values measured in the individual trial variants were continuously recorded, stored and evaluated via a Watermark Monitor datalogger.

Installing the tensiometers and Watermark sensors in the trial

Since the measurement of soil moisture tension is a spot measurement and soil moisture levels differ naturally on account of heterogeneous soil and varying plant-root growth, three tensiometers or 3 Watermark sensors were used in each trial variant.

The sensors were installed in the hilled rows at the cutting level. They were positioned precisely in the centre of the row between two hop plants, immediately beside the drip point in the irrigation hose. Commencement of irrigation was a function of soil-moisture tension, the value of which was obtained by averaging the readings from the 3 installed sensors. In addition to these sensors in the hilled row, 3 sensors were installed 30 cm below the cutting level. The effects of irrigation were observed by means of the lower sensors via the change in soil moisture.

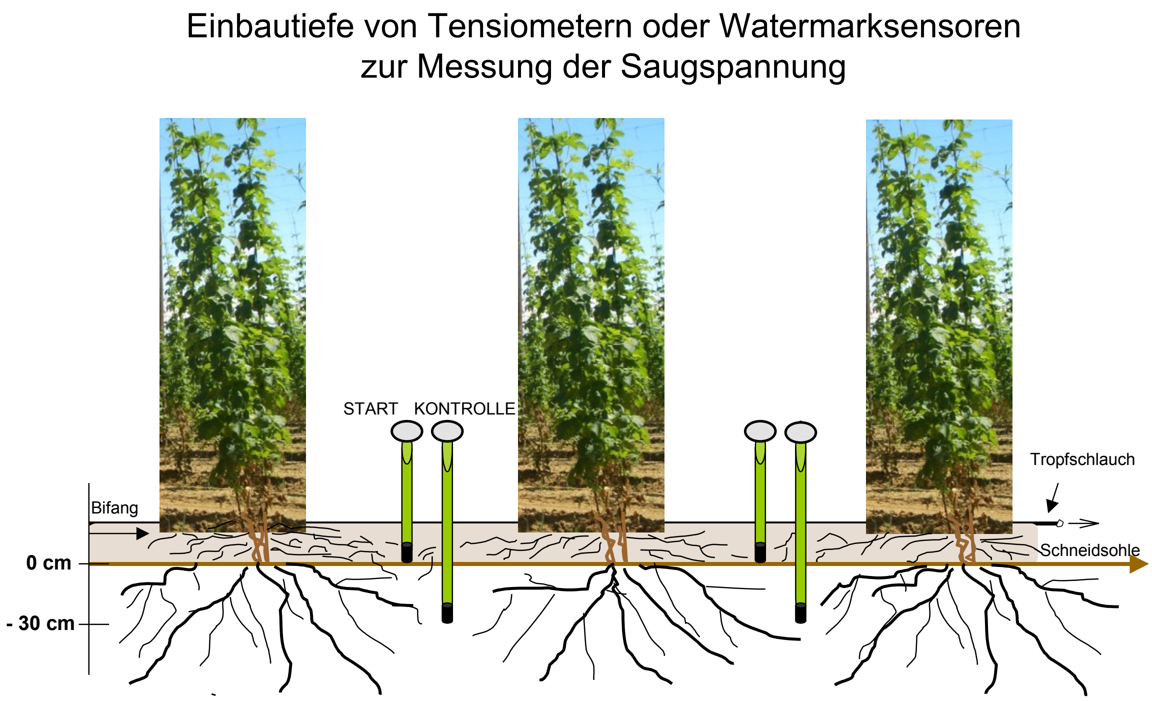


Fig. 5.28: Arrangement of tensiometers and Watermark sensors in the irrigation trial

5.7.2.2 Calculating the required amount of irrigation with the HyMoHop water balance model

The HyMoHop water balance model was developed and programmed by Dr. Rötzer in 2004-2005. HyMoHop calculates potential and actual evaporation, interception, drainage, soil water content and required irrigation volume from meteorological data in daily steps. The long-term aim is to offer hop farmers an irrigation recommendation scheme via an internet application. The purpose of the irrigation trial was to test the model and devise the fundamentals of a more refined version. Commencement of irrigation was scheduled as a function of computed soil moisture and differed from trial plot to trial plot. Irrigation volumes and timing thus differed according to whether irrigation was scheduled as from 70 %, 80 % or 90 % UFC.

5.7.3 Results

Measuring soil moisture tension with tensiometers or Watermark sensors is a means of measuring and assessing soil moisture directly in the plant's main root zone. Soil moisture tensions in the main root zone of hops with an adequate water supply range from 150 to 500 mbar, depending on the type of soil. Within this measuring range, highly reproducible values are obtained with both conventional tensiometers and Watermark sensors.

The described installation and the positioning of tensiometers or sensors at different depths constitute an inital approach to selective irrigation control. The soil moisture tension measured by the upper sensors is a guide for deciding when to irrigate. The values measured by the lower sensors allow the irrigation effect to be monitored. Measuring soil moisture tension has the advantage that measured values can be applied elsewhere and compared. Defined optimum ranges apply to all types of soil, provided the sensors are installed in the same way.

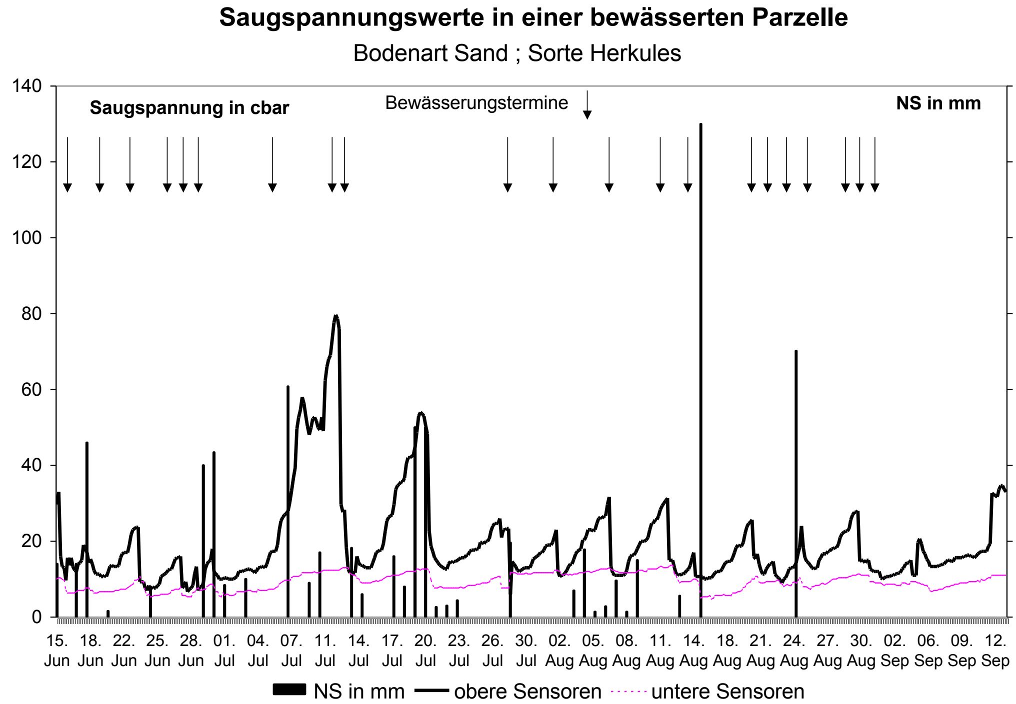


Fig. 5.29: Soil moisture tensions in an irrigated plot

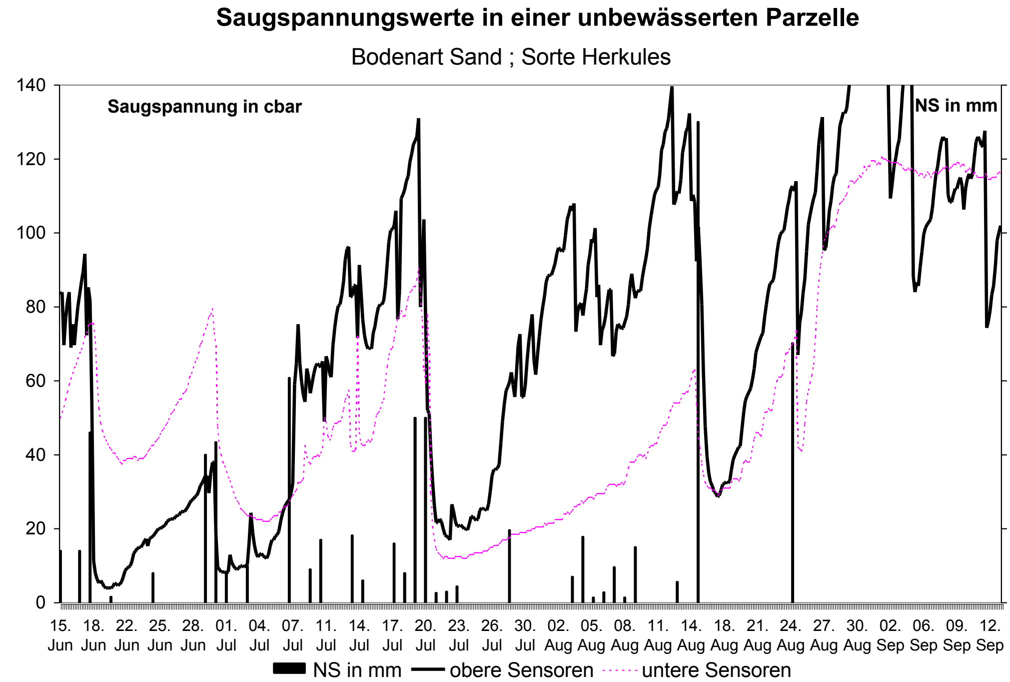


Fig. 5.30: Soil moisture tensions in a non-irrigated plot

Fig. 5.29 and Fig. 5.30 show soil moisture in the form of soil moisture tension in the hilled row and in the main root zone 30 cm below the cutting level. The soil moisture deficit in the case of the non-irrigated variant as compared with the irrigated variant is very well illustrated by the high soil water tensions obtained for the non-irrigated variant. It is also evident that, despite high rainfall in July, the soil in the hilled rows of the non-irrigated plot kept drying out very quickly. The reason for this is the non-uniform distribution of rain over the plot surface. The hilled rows are partially screened from rain by the dense growth and rich foliage of the hop bines. In addition, a lot of water is extracted by the root mass of the hop plants. In the irrigated plots, by contrast, fluctuations in soil moisture tensions were reduced and kept at a low level.

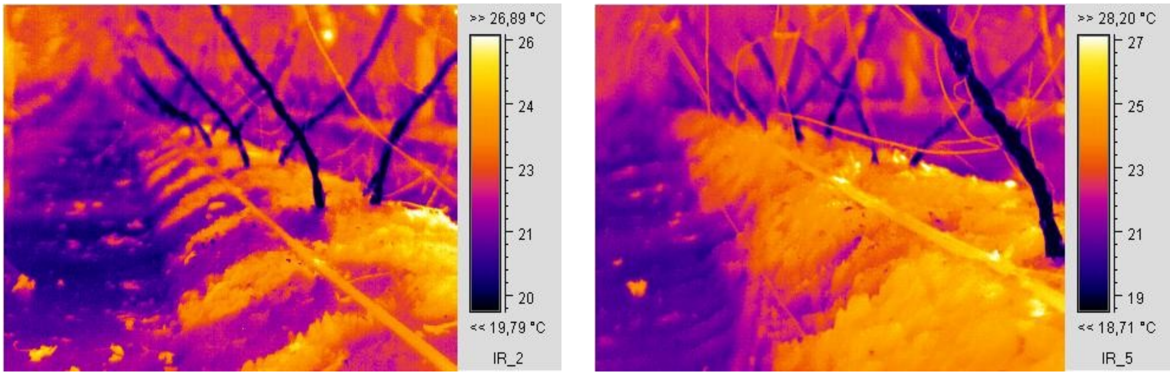


Fig. 5.31: Thermal images of an irrigated (left) and non-irrigated plot (right)

The thermal images confirm the severe drying out of the hilled row. The zones thoroughly moistened by drip irrigation are clearly identifiable (left-hand picture). Additional reasons for the big difference in soil moisture between the hilled row and the tractor aisles are the relative lack of lateral water movement in the sandy soil and the near absence of roots in the aisles, this being a consequence of the location.

For the first time, an attempt was made to calculate the irrigation volumes required by hops with the EDP HyMoHop water balance model. The basis of this approach is the climatic water balance (cwb), in which the irrigation requirement is calculated from the product of potential evaporation (according to Penman) multiplied by the plant-specific kc factor, minus the natural rainfall. The plant-specific kc factor is the ratio of current to potential evaporation. Since the various hop cultivars differ significantly from one another, e.g. in stature, root mass, leaf surface area, yield level and growing season, refining the model will necessitate closer definition of a kc factor not only for hop crops in general but for each individual hop variety or groups of comparable varieties. This was evident from the differences in soil moisture tension and gravimetrically determined soil water content obtained for the Perle, Magnum and Herkules cultivars at the same location, under the same weather conditions and using the same irrigation volumes at the same times.

Outlook

Building on the findings obtained so far, research on the irrigation requirement of hop crops will be continued as part of the DBU-financed irrigation project "Optimization of irrigation management in hop growing" (DBU = Deutsche Bundesstiftung Umwelt, a federal German foundation supporting environmental projects). The intention is to correlate physiological measurements on hop plants with soil moisture measurements in order to draw conclusions as to when best to irrigate. This information will be used later to develop a selective irrigation management system.

5.8 LfL projects within the Production and Quality Initiative

As part of a production and quality offensive on behalf of agriculture in Bavaria, the Bavarian State Research Center for Agriculture has launched a programme to collect, record and evaluate representative yield and quality data for selected agricultural crops from 2009 to 2013. For the hops department of the Institute for Crop Science and Plant breeding, this work is being undertaken by its advisory service partner Hallertau Hop Producers' Ring. The aims of the hop projects are described briefly below, and the 2011 results summarized.

5.8.1 Annual survey, examination and evaluation of post-harvest hop quality data

"Alpha-Express"

During the 2011 harvest, 600 freshly harvested hop samples were analysed on the day of harvesting for alpha-acid content. These daily measurements provide insight into harvest maturities of the various hop cultivars, allowing recommendations to be made concerning optimum harvesting times.

Neutral Quality Assessment Procedure (NQF) results

Quality data collected within the framework of the NQF provide valuable information on the hop quality of the year in question and point to production-related errors or incorrect treatment of harvested hops.

In 2011, for example, a high proportion of cones were again found to be tainted or damaged.

Assessment of diseases and pests and assignment to infection categories reveal cultivar-specific differences in resistance and regional differences in infestation levels, and also enable the effectiveness of plant protectives to be judged. The 2011 results showed infestation levels in line with the crop year weather. The abundance of summer rain, for example, led to increased levels of downy mildew and botrytis infestation.

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

Representative, real-time and accurate assessments of and investigations into disease and pest infestations are necessary in order to provide advice and develop control strategies. Results are provided by the Hop Producers' Ring, which monitors aphid, spider-mite and virus infestation.

5.8.3 Maintenance of Adcon weather stations for forecasting downy mildew in hop crops

Within this project, it is the task of the Hop Producers' Ring to set up, service and operate Adcon weather stations at the seven downy-mildew forecasting locations in the hop-growing regions (five in the Hallertau region, one in Spalt and one in Hersbruck). Weather-related data have to be evaluated daily and a probability index for downy-mildew outbreak calculated. This index is needed at the LfL's three scientific-test sites for comparing secondary downy-mildew control according to the previous early-warning model with control according to the Adcon weather model.

In 2011, trials continued with the index-based control thresholds, which had been raised in 2010 and take the distinction between "prior to flowering" and "post flowering" into account.

The 2011 figures showed that the number of treatments recommended for tolerant varieties by the previous early-warning model was two fewer at the Aiglsbach trial location than the number of treatments recommended by the Adcon model, despite the index threshold for the latter having been raised. For the susceptible Hersbrucker spät cultivar, by contrast, the Adcon model recommended one spray application fewer.

At the Eschenhart trial location, the number of treatments recommended by Adcon for Hallertauer Magnum in 2011 was no higher than that for the plot treated as per the early warning model.

In Speikern (Hersbruck), only 3 treatments were recommended by the early-warning model for the tolerant Spalter Select cultivar in 2011, compared with 5 treatments according to the Adcon model. For the susceptible Hersbrucker cultivar, the early-warning model also recommended one spray application fewer.

Cone samples from the comparative plots at the scientific-test locations were again examined for downy-mildew infestation after harvesting. The weighted average level of infestation was found to be slightly higher for the Hersbrucker cultivar in Aiglsbach and in Speikern than in the plot treated according to the early-warning model.

5.9 Advisory and training activities

Besides applied research on production techniques for hop cultivation, the Hop Cultivation/ Production Techniques work group (IPZ 5a) processes trial results for practical application and makes them directly available to hop farmers by way of special consultations, training and instruction sessions, workshops, seminars, lectures, print media and the internet. The work group is also responsible for organising and implementing the downy mildew warning service and updating the relevant data, cooperating with the hop organisations and providing training and expert support for its joint service provider, the Hop Producers' Ring.

The group's training and advisory activities in 2011 are summarized below:

5.9.1 Written information

- The 2011 "Green Pamphlet" on Hops – Cultivation, Varieties, Fertilisation, Plant Protection and Harvest – was updated jointly with the Plant Protection work group following consultation with the advisory authorities of the German states of Baden-Württemberg, Thuringia, Saxony and Saxony-Anhalt. 2640 copies were distributed by the LfL to the national offices for food, agriculture and forestry (ÄELF) and research facilities, and by the Hallertau Hop Producers' Ring to hop growers.
- 40 of the 57 faxes sent in 2011 by the Hop Producers' Ring to 1102 recipients contained up-to-the-minute information from the work group on hop cultivation and spray warnings.
- Updated information was likewise made available at irregular intervals for the German Weather Service's weather data fax.
- 3,396 soil-test results obtained within the context of the N_{min} nitrogen fertilisation recommendation system were checked for plausibility and approved for issue to hop-growers.
- Advice and specialist articles for hop-growers were published in 2 circulars issued by the Hop Producers' Ring and in 7 monthly issues of the magazine "Hopfen Rundschau".
- 250 field records on the 2011 hop harvest were evaluated by two working groups with the "HSK" recording and evaluation program and returned to farmers in written form.

5.9.2 Internet and Intranet

Warnings and advice, specialist articles and papers were made available to hop-growers via the internet.

5.9.3 Telephone advice and message services

- The downy-mildew warning service, provided jointly by the WG Hop Cultivation/Production Techniques (Wolnzach) and the WG Plant Protection in Hop Growing (Hüll) and updated 75 times during the period from 10.05.2011 to 23.08.2011, was available via the answerphone (Tel. 08442/9257-60 and 61) or via the internet.
- Consultants from the WG Hop Cultivation/Production Techniques answered around 2,800 special questions by telephone or provided advice in one-to-one consultations, some of them on site.

5.9.4 Talks, conferences, guided tours, training sessions and meetings

- 9 training sessions for consultants from the Hop Producers' Ring
- Weekly note swapping with the Ring experts during the vegetation period
- 9 meetings on hop cultivation, organised jointly with the offices for food, agriculture and forestry (ÄELF)
- 54 talks
- Poster exhibition at the IHGC Scientific Congress in Lublin, Poland, and at the HopFa tradeshow held during the Gallimarkt fair in Mainburg.
- 15 guided tours through trial facilities for hop growers and the hop industry
- 7 conferences, trade events and seminars

5.9.5 Basic and advanced training

- Setting of a Master's examination topic and assessment of 2 work projects for the examination
- 12 lessons for hop-cultivation students at the Pfaffenhofen School of Agriculture
- 1-day course during the summer semester at the Pfaffenhofen School of Agriculture
- Exam preparation and examination of agricultural trainees focusing on hop cultivation, 3 sessions
- 1 information event for pupils at Pfaffenhofen vocational school
- One "BiLa" seminar (educational programme for farming) on hop growing, in 4 evening sessions
- Participation in exam preparation and competence test for users of plant protectives, specifically for hop farm women
- 6 meetings with the "Business Management for Hop Growers" working group

6 Plant protection in hops

LLD Bernhard Engelhard, Dipl. Ing. agr. (until 03/2011)

LD Johann Portner, Dipl. Ing. agr. (provisionally as of 04/2011)

6.1 Pests and diseases in hops

6.1.1 Flea beetles and aphids

Flea beetle outbreaks immediately after bud break right up to training are becoming more and more of a problem. Some of the young hop shoots are so badly damaged by the beetles that further upward growth is prevented and effective treatment is necessary. Isolated cases of a summer generation occurred again in 2011 as from early August, which resulted in chewed cones. Selective control of hop flea beetles in August is currently impossible.

2011 witnessed extreme and concentrated aphid migration, with counts of up to 45 winged aphids per leaf. Thereafter, the infestation soon died down and there were altogether few problems with hop aphids and common spider mites. In many cases what is known as 'precautionary spraying' was performed to avoid all risks.

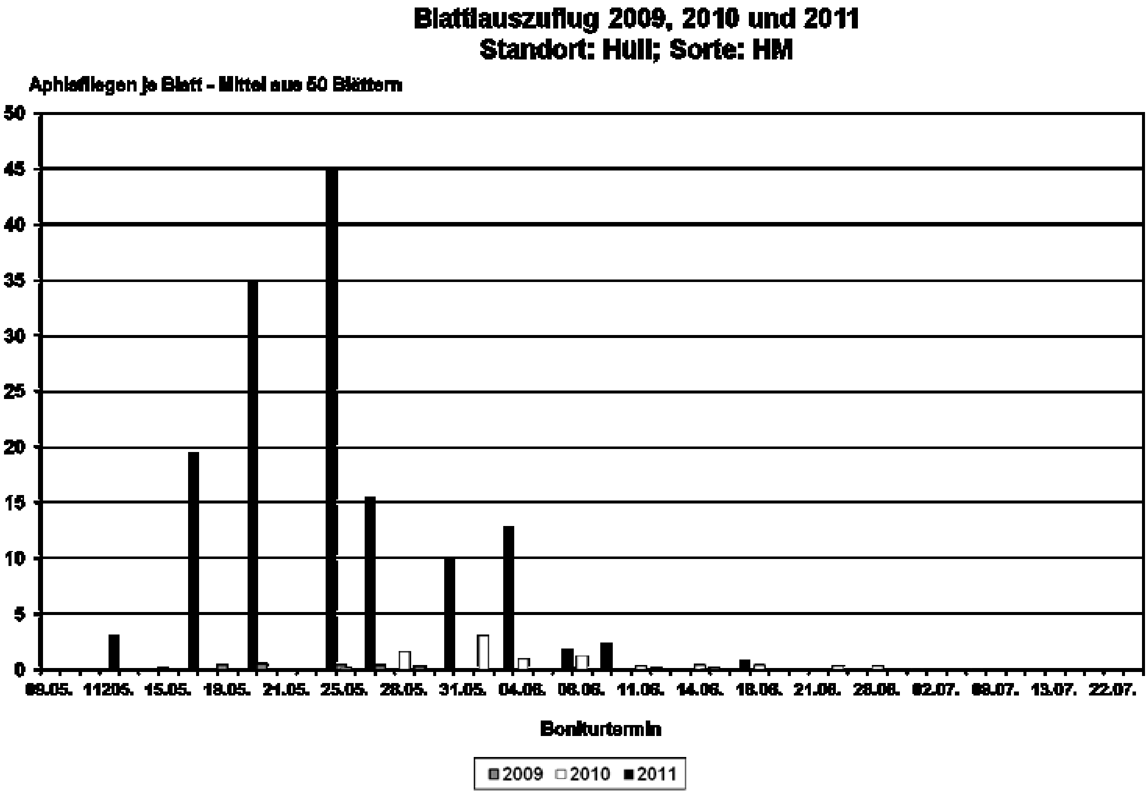


Fig. 6.1: Aphid migration

6.1.2 Downy mildew

Tab. 6.1: Downy and powdery mildew warning service

Fax-No.	Date	Primary downy mildew	Spray warnings for cultivars			Powdery mildew
			Susceptible	All	Late	
4	13.05.	x	Treatment of primary downy mildew infection, especially in areas affected by hail in 2010			
to	until	x				
17	01.06.	x				
19	06.06.			x		All
24	14.06.		Only hail-damaged areas			
26	16.06.		x			
32	27.06.		x			
38	06.07.			x		Susceptible
45	15.07.		x			
53	27.07.			x		
57	02.08.		x			
62	09.08.		x	x		Susceptible
71	23.08.				x	
No. of spray warnings			4	4	1	3

6.2 Development of integrated methods of plant protection against the alfafa snout beetle (*Otiorhynchus ligustici*) in hops: egg production

Objective

This project is part of the joint project "Erarbeitung von integrierten Pflanzenschutzverfahrengegen Bodenschädlinge" *(Development of integrated methods of plant protection against soil pests)*, in which another five institutes are working on integrated and alternative control methods for soil pests, in particular soil-dwelling snout beetles and wireworms. Three-year field trials were set up in the Hallertau region to test the efficacy of entomopathogenic nematodes (EPN) and fungi (EPP). The small number of alfafa snout larvae and irregular occurrence of adult beetles did not permit any conclusions to be drawn. In addition to testing the efficacy of EPN and EPP, a biotest devised by GLAZER & LEWIS (2000) had been planned but could not be performed, again because of the small numbers of L2 and L3 larvae on bait plants in the field (red clover). Instead, the method devised by VAN TOL & GWYNN (2004) was used. This involved breeding beetles in order to obtain eggs and thus ensure a defined initial infestation for pot trials. In 2010, the number of eggs/individual laid by beetles that had been fed red clover was compared with the number laid by lucerne-fed beetles. In 2011, the comparison was carried out with red clover and hops.

Methods

For the purpose of egg production, beetles were collected from Hallertau hop fields in early April of each trial year and divided up among eight containers. Five beetles were put into each container.

Four containers were supplied with red clover for the beetles to feed on, and four with lucerne (2010) or hops (2011). The relative humidity in the containers was kept at 85 % so as to prevent the eggs from drying out. The feed plants were renewed weekly and the eggs collected and counted at the same time.

Results and discussion

Egg-laying commenced at the beginning of April in each case and ended, for the clover and lucerne variants, in mid-July. The main egg-laying period was from late April until mid-June. The egg-laying period of the beetles fed on hops lasted longer, peaking in late May and mid-July and stretching on into September. Egg counts were high. The hop variant was also characterised by delayed mortality following egg-laying, whereas the mortality rate among the clover and lucerne-fed beetles rose sharply on conclusion of egg-laying. The beetles fed on red clover laid an average of 421 eggs/beetle in 2010, and those fed on lucerne an average of 291 eggs/beetle. Egg counts for *O. Ligustici* that had been fed on lucerne were thus lower (df = 1; F = 9.9492; P = 0.0197). In 2011, the average number of eggs laid by the red-clover variant was 1,001 eggs/beetle, while the beetles fed on hops laid 1,467 eggs/adult insect. Feeding the beetles on hops thus resulted not only in a longer egg-laying period and delayed mortality but also an increase in the number of eggs laid per beetle (df = 1; F = 30,7153; P = 0,0014). The choice of feed plant thus had a marked effect on egg-laying by *O. ligustici*. The reduced egg counts for beetles fed lucerne rather than red clover in 2010 may be attributable to the specific composition of the plant material of these two types of legume. The increased egg count witnessed in the case of the hop variant compared to the red-clover variant in 2011 may have been due to the progressive transition of the red clover to generative growth. The hops, by contrast, were always harvested at the vegetative growth stage. In 2012, potential influencing factors will be included in the trial.

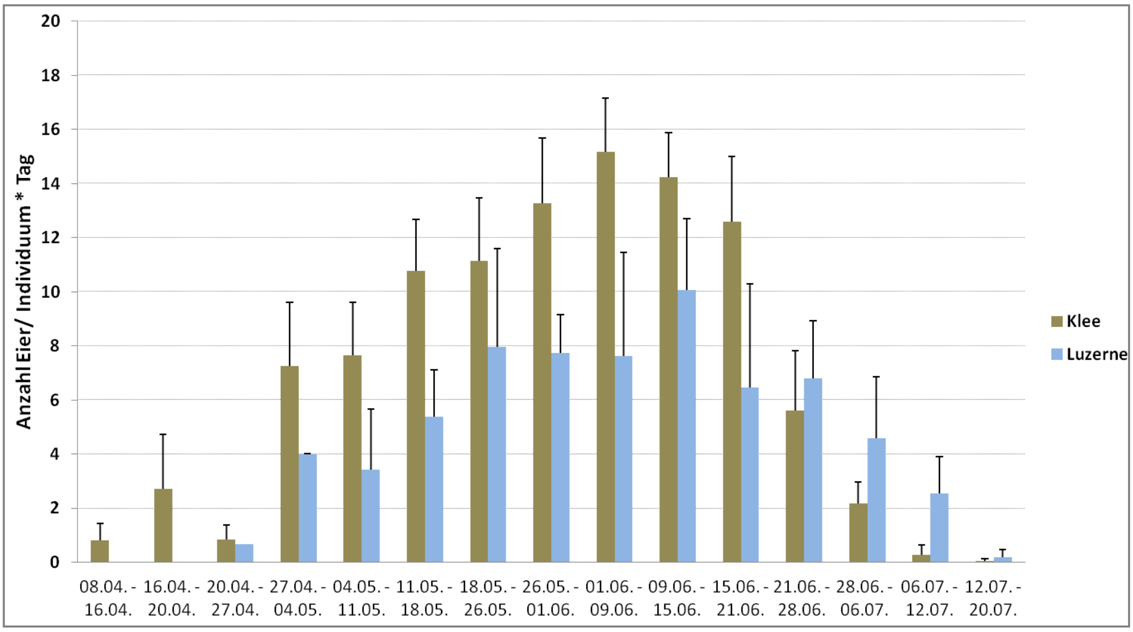


Fig. 6.2: Number of eggs/beetle/day in 2010 by O. Ligustici kept in containers and fed on red clover or lucerne

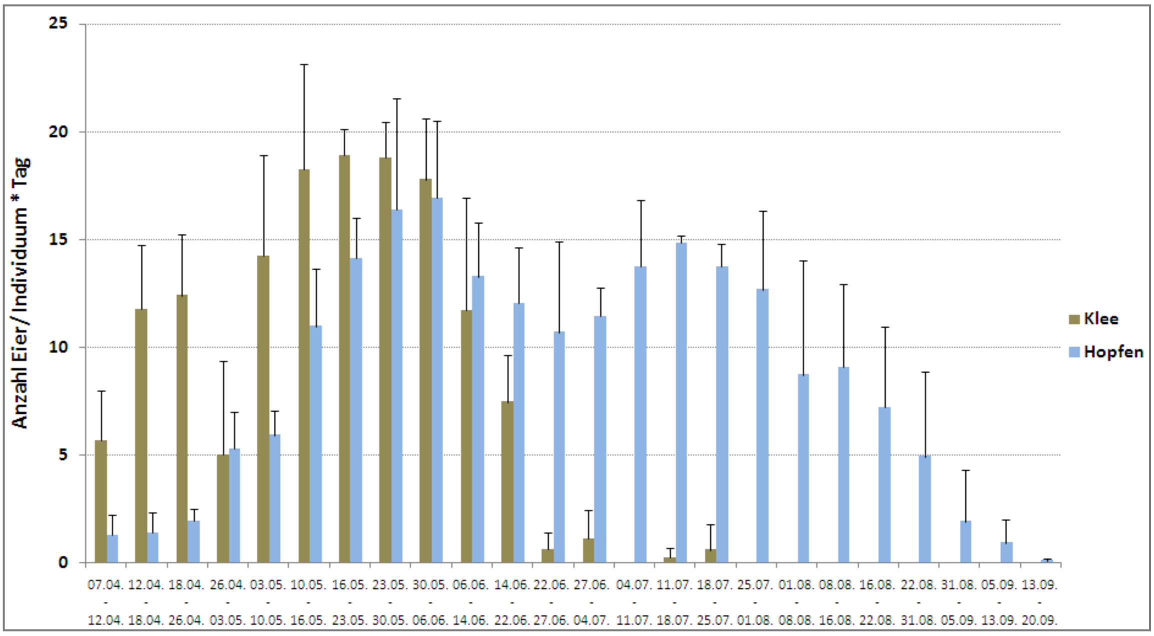


Fig. 6.3: Number of eggs/beetle/day in 2011 by O. Ligustici kept in containers and fed on red clover or hops

7 Hop quality and analytics

ORR Dr. Klaus Kammhuber, Dipl. Chemiker

7.1 General

Within the Hops Dept. (IPZ 5) of the Institute for Crop Science and Plant Breeding, the IPZ 5d work group (WG Hop Quality and Analytics) performs all analytical studies required to support the experimental work of the other Work Groups, especially Hop Breeding Research. The hop plant has three groups of value-determining components: the bitter compounds, essential oils and polyphenols, ranked in order of importance. The bitter compounds consist of the alpha and beta acids. Alpha-acid content, as a measure of hop bittering potential, is by far the most economically important quality characteristic of hops. The alpha acids give beer its typical hop bitter taste and ensure both biological stability and good foaming stability. The antimicrobial characteristics of beta acids make them interesting for alternative fields of use, e.g. as preservatives in the food industry. They are already being successfully employed to replace formalin in sugar processing and ethanol production.

The essential oils are responsible for hop scent and aroma. They are gaining more and more importance in the craft brewers' scene, as craft brewers require hops with special aromas, some of them not typical of hops. They are known collectively as flavour hops.

Because of the sedative effects of essential oils, pharmaceutical products are being made from hops in combination with valerian. Hops has a similar effect to the sleep hormone melatonin and valerian a similar effect to adenosine.

Numerous publications attest to the positive health-giving properties of the polyphenols, which act as anti-oxidants and can scavenge free radicals. The hop plant is very rich in polyphenols.

Xanthohumol, in particular, has attracted a lot of publicity in recent years because of its significant anti-carcinogenic potential, although the latest studies have shown that its bioavailability in the human organism is not especially high. 8-prenylnaringenin, trace amounts of which are found in hops, is regarded as one of the most potent phyto-oestrogens and is responsible for the slightly oestrogenic effect of hops. Although this effect had been known for centuries, the responsible substance was not discovered until 10 years ago.

Currently the breweries face a huge glut of hops, making it very important to tap alternative uses. They can be found in the food industry, as well as in the fields of medicine and wellness.

7.2 Component optimisation as a breeding goal

7.2.1 Requirements of the brewing industry

95 % of hop output is used in the brewing industry, which will remain by far the largest purchaser of hops in the future, too. As far as hopping is concerned, breweries follow two extremely different philosophies.

The aim of the first approach is to obtain alpha-acids as cheaply as possible, with variety and growing region being irrelevant. The aim of the second is to cultivate beer diversity through a variety of hop additions and products, with importance still being attached to varieties and regions and costs playing no role. However, overlaps can be found between these two extremes.

The requirements of the brewing and hop industries regarding the composition of the hop components are constantly changing. All parties agree, however, on the need to breed hop varieties with the highest possible α-acid levels that remain as stable as possible from year to year. A low cohumolone content as a quality parameter has declined in significance. For downstream and beyond-brewing products, even high-alpha varieties with a high cohumolone content are in demand.

The role of the essential oils in beer brewing is a never-ending story. The essential oils in hops consist of more than 300 different substances. The olfactory and aroma impression must be seen as an integral, synergistic quality. Some substances are perceived more strongly, others blot each other out. Key substances must be defined, however, so that aroma quality can also be characterised analytically. Myrcene tends to be regarded as indicative of an unpleasant, resinous aroma and linalool of a pleasant, flowery aroma. The goal is to breed aroma cultivars with various combinations of hop oils in order to guarantee product diversity. Key substances for hop aroma include linalool, humulene, caryophyllene and myrcene. Craft brewers, in particular, are interested in purchasing hops with very distinct aromas, even exotic aromas such as mandarine, melon, mango or currant. The way in which aroma is imparted to beer is also highly dependent on technological factors such as late hopping or, best of all, dry hopping.

Polyphenols contribute towards the bitter taste imparted by hops (harmony and quality of the bitterness) and also possess some functional health benefits. One of the goals of hop breeding will be to achieve higher levels of low-molecular polyphenols such as xanthohumol, the prenylflavonoids and phenolic carboxylic acids.

7.2.2 Alternative uses

A mere 5 % of hop output is used for alternative purposes (Fig. 7.1).

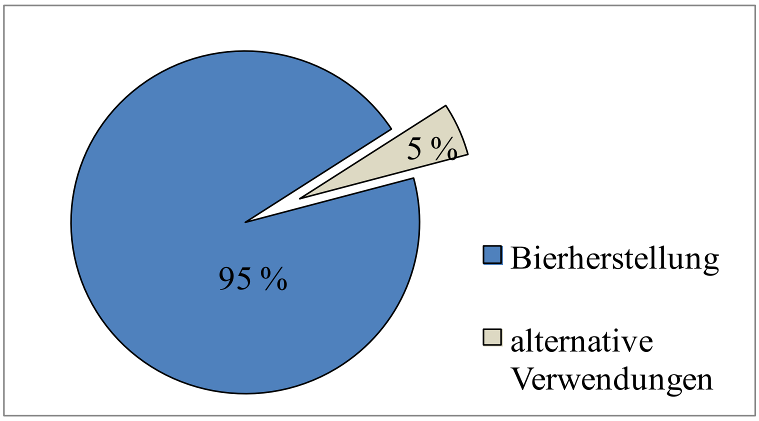


Fig. 7.1: Uses of hops

Both the hop cones and the remainder of the plant can be used. The shives (woody core of the stem) have good insulating properties and are very stable mechanically; they are thus suitable for use as loose-fill insulation material and in composite thermal-insulation mats. Shive fibres can also be used to make moulded parts such as car door panels. As yet, no large-scale industrial applications exist, however.

As far as the cones are concerned, the antimicrobial properties of the bitter substances are especially suited to alternative uses. Even in catalytic amounts (0.001-0.1 wt. %), the bitter substances have antimicrobial and preservative properties in the following order of importance: iso-α-acids, α-acids, β-acids. They destroy the pH gradient at the cell membranes of bacteria, which can no longer absorb any nutrients and die. Iso-α-acids in beer even provide protection against heliobacter pylori, a bacterium that triggers stomach cancer. The ß-acids are especially effective against bacteria such as listeriae and clostridiae and also have a strong inhibitory effect on the growth of Mycobacterium tuberculosis. This property can be exploited by using the bitter substances in hops as natural biocides wherever bacteria need to be kept under control. In sugar processing and ethanol profuction, it is already established practice to replace formalin with β-acids. Other potential applications that exploit the antimicrobial activity of hop β-acids include their use as preservatives in the food industry (fish, meat, milk products), the sanitation of biogenic waste (sewage sludge, compost), removal of mould, improvement of the smell and hygiene of pet litter, control of allergens, and use as an antibiotic in animal food. In future, considerable demand for hops for use in such areas can be expected. Increased β-acid content is therefore one of the breeding goals in Hüll. Currently, the record is about 20 %, and there is even a breeding line that produces β-acids alone and no α-acids.

The hop plant boasts a wide variety of polyphenolic substances and is thus also of great interest for the areas of health, wellness, dietary supplements and functional food. With a polyphenol content of up to 8 %, the hop plant is very rich in these substances. Work is being done on increasing xanthohumol content. A breeding line containing 1.7 % xanthohumol is already available. Other prenylated flavonoids, such as 8-prenylnaringenin, occur only in trace amounts in hops. The oligomeric proanthocyanidins (up to 1.3 %), glycosidically bound quercetin (up to 0.2 %) and kaempferol (up to 0.2 %) are substances with very strong antioxidative potential. Aroma hops generally have a higher polyphenol content than bitter hops. If specific components are desired, Hüll can react at any time by selectively breeding for the required substances in collaboration with Hop Quality and Analytics.

7.3 Differentiating the world hop range with the help of low-molecular polyphenols

This project is being funded by the Bavarian State Ministry for Food, Agriculture and Forestry in the amount of € 20,000. Tab. 7.1 shows the composition of the polyphenols in hops.

Tab. 7.1: Composition of hop polyphenols and their concentrations in hops

Substances and substance groups	Concentrations
Phenolic carbon acids	
1) Benzoic acid derivatives	< 0.01 %
2) Cinnamic acid derivatives	0.01 – 0.03 %
Flavonoids	
3) Xanthohumol	0.20 – 1.70 %
4) 8-,6- prenylnaringenin	< 0.01 %
5) Quercetin glycoside	0.05 – 0.23 %
6) Kaempferol glycoside	0.02 – 0.24 %
7) Catechins and epicatechins	0.03 – 0.30 %
8) Oligomeric proanthocyanidins	0.20 – 1.30 %
9) Acylphloroglucinol derivatives (multifidols)	0.05 – 0.50 %
Higher-molecular substances	
10) Catechin tanning agents and tannins	2.00 – 7.00 %

Polyphenols occur as bioactive substances in almost all plants. They are responsible for colour and flavour and also help promote resistance to disease and pests. In higher-molecular form, they act as tanning agents. Although they are a very heterogeneous group of substances, the polyphenols share a common structural element: an aromatic ring with at least 2 hydroxyl groups. As they themselves can be very easily oxidized, they act as strong anti-oxidants.

All polyphenols share elements of a common biosynthetic pathway. The main step is conversion of the amino acid phenylalanine to cinnamic acid. This reaction is catalysed by the enzyme PAL (phenylalaninammoniumlyase). This enzyme can be blocked by nitrate. This explains why over-fertilisation with nitrogen leads to lower polyphenol levels in plants and thus to reduced resistance to diseases. Flavonoids are a sub-group of polphenols and were discovered by Nobel Prize Winner for Medicine Albert Szent-Györgyi Nagyropolt in the 1930s. Initially, he labelled them 'vitamin P', as they were capable of exerting an influence on the permeability of blood vessels. Later on, they were given the name 'flavonoids', as they are derived from the structure of flavone (Fig. 7.2).

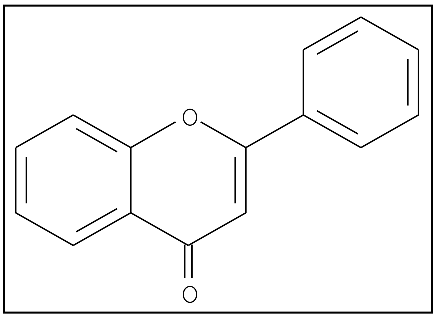


Fig. 7.2: Structure of flavone

I. McMurrough and C. F. Sumere (Lit. 1,2) were the first scientists to analyse the low-molecular polyphenols in hops via HPLC and perform basic research on these substances. Quercetin and kaempferol do not occur in free form in hops but only in glycosidically bound forms. The sugar can be removed via hydrolysis and quercetin and kaempferol quantitatively determined. This method had already been used to analyse the total world hop range (Lit. 3). In this project, however, the glycosides also had to be taken into account. A further group of substances that are of pharmacological interest due to their anti-inflammatory properties is that of the acylphloroglucinol derivatives (multifidols, Lit. 4). The term 'multifidols' comes from the tropical plant *Jatropha multifida*, which contains these compounds in its sap. Fig. 7.3 shows the chemical structures. Multifidol glucoside itself has structure A. Hops mainly contain the B compound, but also A and C in small concentrations.

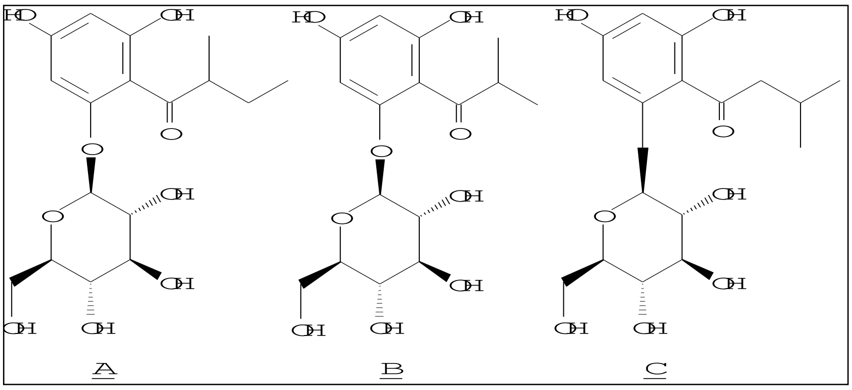


Fig. 7.3: Chemical structures of the multifidols

Lit.: 1) McMurrough I., Hennigan, G., P., Loughrey, J.: "Quantitative Analysis of Hop Flavonols Using High Performance Liquid Chromatography", J. Agric. Food Chem. 1982, 10, 1102-1106 2) Van Sumere, C., F., Vande Casteele, K., Hutsebaut, M., Everaert, E., De Cooman, L., Meulemans, W.: "RP-HPLC Analysis of Flavanoids and the Biochemical Identification of Hop Cultivars", EBC-Monograph XIII, 146-175, 1987 3) Kammhuber, K.: "Quercetin & Kämpferol", Hopfenrundschau International, 2006/2007, 52-55 4) Bohr, G.; Gerhäuser , C.; Knauft, J.; Zapp, J.; Becker, H.: "Anti-inflammatory Acylphloroglucinol Derivatives from Hops (Humulus lupulus)", J. Nat. Prod., 2005, 68, 1545-1548

The exact chemical names are:

A = 1-(2-methylbutyryl)phloroglucinol-glucopyranoside (multifidol)
B = 1-(2-propanoyl)phloroglucinol-glucopyranoside
C = 1-(3-methylbutyryl)phloroglucinol-glucopyranoside

Work first focussed on devising suitable methods of sample preparation and optimum HPLC differentiation. For sample preparation purposes, the hops are extracted using an acetone:water mixture (3:1) and the polar substances then shaken with hexane to remove them. The EC 125/2 NUCLEODURSphinx RP, 3 µm from Macherey and Nagel has proved very suitable as a separation column. The following gradient system is used for UHPLC analysis:

Eluent A: add water to 100 ml methanol and 3 ml 85% H_3PO_4 to make up 1 l solution

Eluent B: add water to 700 ml methanol and 3 ml 85% H_3PO_4 to make up 1 l solution

Eluent C: methanol

Linear gradient:	Detection wave lengths:
0 min.: 100 % A	Benzoic acid derivatives: 250 nm
5 min.: 100 % A	Cinnamic acid derivatives: 280 nm
30 min.: 70 % A, 30 % B	Catechins: 280 nm
55 min.: 10 % A, 90 % B	Quercetin,
56 min.: 100 % C	Kaempferol glycosides: 350 nm
60 min.: 100 % C	Multifidol glucoside: 280 nm
61 min.: 100 % A	

The most suitable polyphenols for cultivar differentiation are the quercetin and kaempferol glycosides; the other phenolic components are less cultivar specific. Quercetin and kaempferol glycosides have an absorption maximum of 350 nm and the multifidol glucosides of 280 nm. The decision was therefore taken to measure at wavelengths 350 nm and 280 nm in order to obtain maximum selectivity and sensitivity. Fig. 7.4 shows a chromatogram at wavelength 280 nm, which is ideal for measuring the multifidol glucosides. Fig. 7.5 shows the chromatograms of the Opal, Hersbrucker Spät, Herkules and Zeus cultivars at 350 nm, which differ clearly in their flavonoid composition.

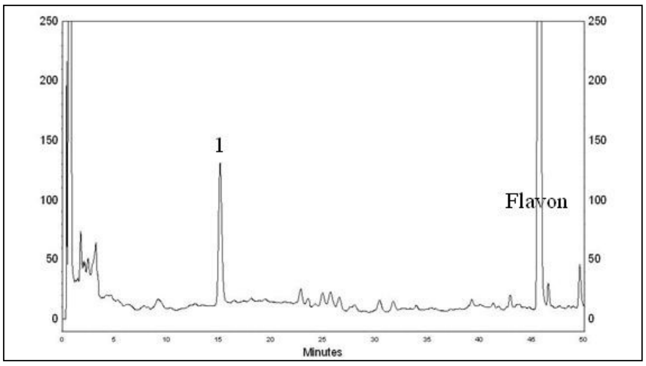


Fig. 7.4: Chromatogram of the flavonoids at 280 nm

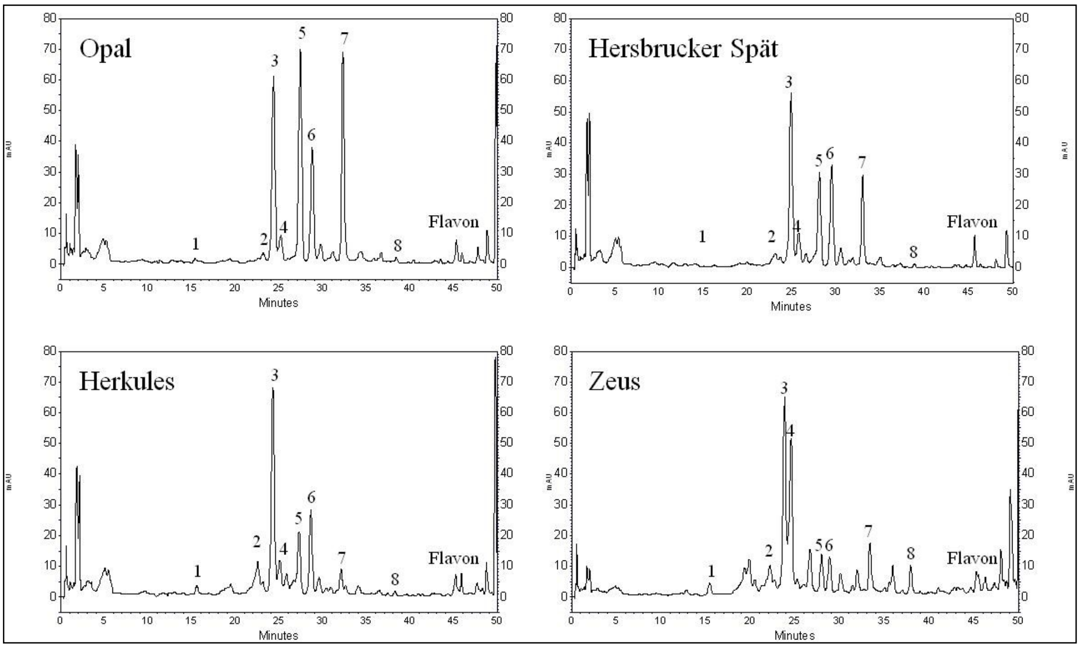


Fig. 7.5: HPLC chromatogram of the flavonoid glycosides of Opal, Hersbrucker Spät, Herkules and Zeus at 350 nm

The substance flavone (Fig. 7.2) serves as the standard, as it does not occur in hops and separates the polar from the non-polar substances. The non-polar bitter substances, xanthohumol and the prenylated naringenines, are eluted only after flavone. The main substances of interest in this research work were those that exceeded flavone in polarity. In collaboration with Dr. Coelhan of Munich Technical University (TUM), all main substances were identified via mass spectrometry. The substances quercetin-3-galactoside, quercetin-3-glucoside and kaempferol-3-glucoside (astragaline) were also verified with pure substances. Substance 1 was positively identified as 1-(2-propanoyl) phloroglucinol-glucopyranoside B. The chemical structures are compiled in Fig. 7.6.

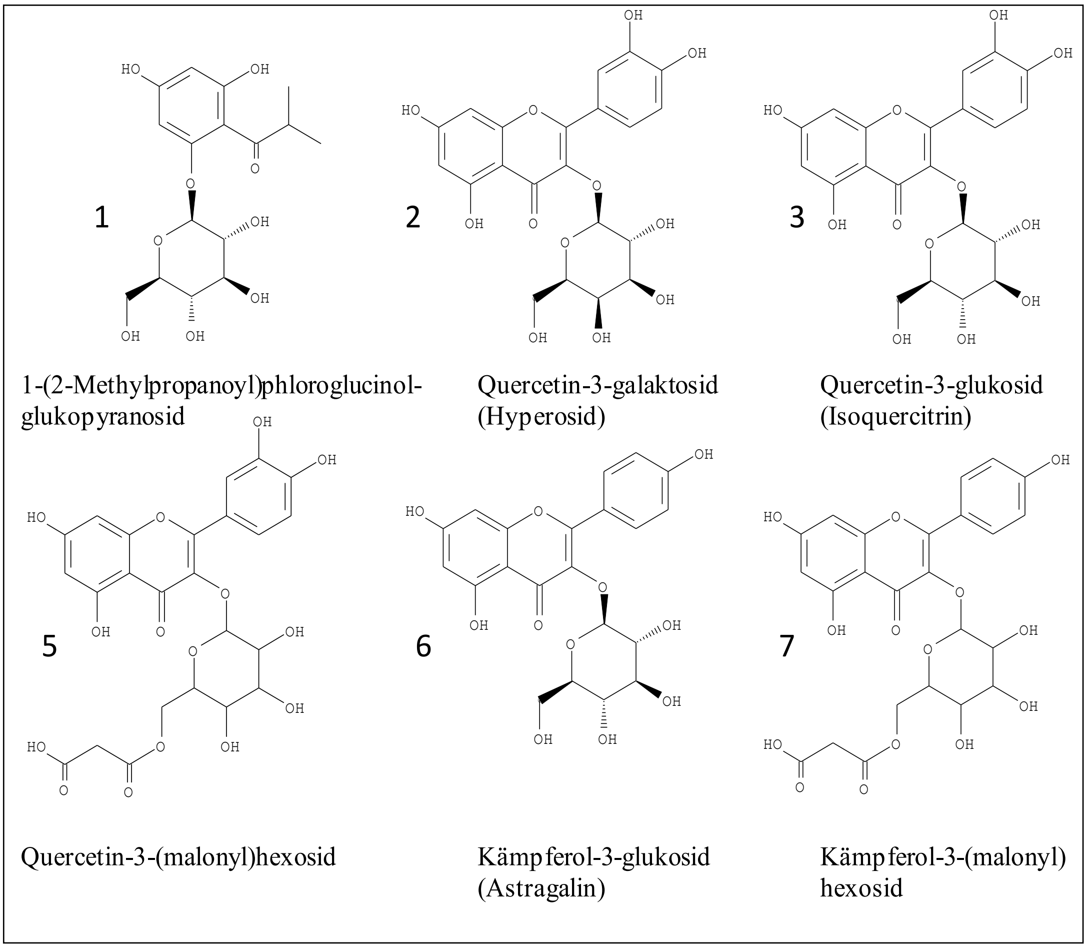


Fig. 7.6: Chemical structures of the identified substances

The methods thus developed were used to examine almost the entire world hop range available in Hüll (121 different cultivars from 17 countries) from crop years 2009 and 2010; the 2011 crop is still being analysed. Many cultivars, especially the landrace cultivars, differ only very slightly, but a number of cultivars differ greatly in their flavonoid composition. A principal-component analysis was performed on the basis of the eight substances identified in order to visualize similarities and differences. SAS 9.1 was the software programme used. Tab. 7.2 shows the first three principal components and Fig. 7.7 the graph. Each dot in the graph represents a hop cultivar. The closer the dots are clustered together, the greater the similarity between the cultivars. The further apart the dots are, the more the cultivars differ. Most of them lie within the plotted ellipse. The plotted lines show the contribution of the various characteristics to the principal-component analysis.

Tab. 7.2: World hop range and PCA values (2009 and 2010 crops)

Cultivar	PCA 1	PCA 2	PCA 3	Cultivar	PCA 1	PCA 2	PCA 3
Admiral	1.1682	-0.5349	1.0614	Hall. Gold	0.1733	-1.1510	-0.9658
Agnus	2.3061	-0.5189	0.9039	Hall. Magnum	2.8912	1.0239	0.4025
Ahil	2.2231	-0.2418	-1.2286	Hall. Merkur	1.3086	0.7450	0.3580
Alliance	-1.9321	-1.4778	1.3508	Hall. Taurus	2.2465	0.8289	-0.9431
Alpharoma	-2.2172	-0.7703	1.3347	Hall. Tradition	1.0473	-1.1677	-1.5281
Apolon	0.6569	0.3291	-0.9330	Hallertauer Mfr.	-0.5632	-2.0694	-0.1420
Aquila	1.5885	3.0754	1.5011	Harmony	1.3107	-0.3659	-0.0423
Aromat	0.0367	-1.5485	-0.5999	Herald	0.3043	-0.1575	-1.2075
Atlas	-0.6711	2.1336	-0.1297	Herkules	1.5148	1.5725	-1.8072
Aurora	-0.2010	-1.6635	0.6439	Hersbrucker Pure	-0.2882	-1.1079	0.3737
Backa	1.2217	1.1048	0.0661	Hersbrucker Spät	-3.0965	0.7484	1.0776
Belgischer Spalter	0.0865	-0.1480	-0.7276	Horizon	-0.4303	-0.7081	0.8742
Blisk	0.9699	1.1906	-0.5516	Hüller Anfang	-0.6423	-2.1060	-0.3398
Boadicea	-1.1622	0.6009	-0.7538	Hüller Aroma	-0.5397	-1.6429	-0.2945
Bobek	0.7563	-1.3901	-0.3582	Hüller Bitter	-0.6432	0.4300	0.2369
Bor	0.7966	-0.3426	-1.0197	Hüller Fortschritt	-1.2859	-1.7462	0.3518
Bramling Cross	-2.0159	2.6388	-0.6440	Hüller Start	-0.9317	-2.2770	0.1523
Braustern	0.8084	-1.2310	-0.7422	Japan C 730	-0.6456	0.0283	1.7829
Brewers Gold	2.3456	0.9341	0.0525	Japan C 845	1.6744	-0.0063	-2.4914
Brewers Stand	-0.8525	2.9484	0.1179	Kirin 1	-0.5663	4.3001	-0.6098
Buket	-0.4146	-1.4976	1.1649	Kirin 2	-0.6803	4.5611	-0.4765
Bullion	0.5911	0.8128	-0.4729	Kitamidori	0.4046	0.2743	-1.8071
Cascade	0.7359	-0.0825	-0.5093	Kumir	0.4719	-0.7643	0.2004
Chang Bei 1	-1.5525	-0.8015	0.6504	Lubelski	1.0551	-1.3945	-0.4113
Chang Bei 2	-1.5555	-0.4521	0.6733	Malling	-2.1140	1.0422	0.2514
College Cluster	-2.9899	2.4738	0.6321	Marynka	-0.9812	2.6990	0.1190
Columbus	0.9282	3.0808	-1.2409	Mt. Hood	-0.2745	-0.8995	0.5223
Comet	1.1808	0.5673	-0.1616	Neoplanta	-1.0720	-1.1345	1.0980
Crystal	-2.9592	1.1544	0.8979	Neptun	4.6159	0.0358	5.2798
Density	-1.8294	2.5229	-0.8132	New Zealand Hallertauer	-1.3090	1.0854	-0.0906
Diva	-0.8184	-0.9396	-0.7198	Northern Brewer	3.9825	-0.3649	1.4789
Early Choice	-1.0962	-0.9869	-0.7157	Nugget	-1.2975	-0.3105	0.8997
Eastern Gold	-0.7137	4.3263	-0.1320	Olympic	-1.3420	-0.2178	0.7355
Eastwell Golding	-0.9016	-0.4953	-0.2306	Opal	-2.0242	-1.4161	0.5223
Emerald	1.9226	-0.4544	-2.5513	Orion	1.2338	-0.4060	-1.7365
Eroica	0.5112	2.9135	-1.2670	Pacific Gem	-2.2264	0.9394	1.5129
Estera	-1.4200	0.6819	-0.0872	PCU 280	0.8562	-0.9419	-0.6114
First Gold	-0.9611	-0.5190	-0.2654	Perle	2.3792	-0.4904	-3.0422
Fuggle	-0.4894	0.5915	0.4451	Phoenix	-0.8352	-0.8661	0.8535
Galena	2.0862	2.0949	-1.5645	Pilgrim	-0.6419	-0.7377	-0.9443
Ging Dao Do Hua	-0.7069	4.1741	-0.3927	Pilot	-2.0300	0.1094	-0.2576
Glacier	-1.4959	-1.4693	-0.0567	Pioneer	-1.7790	0.7577	0.3629
Golden Star	-0.6494	4.3068	-0.4637	Premiant	1.3224	-0.6696	-0.6105
Granit	-0.3470	1.0616	0.3112	Pride of Kent	-1.6595	-1.9667	0.3066
Green Bullet	-1.7257	-0.5629	0.9473	Pride of Ringwood	-1.7599	1.7763	0.4951

Cultivar	PCA 1	PCA 2	PCA 3	Cultivar	PCA 1	PCA 2	PCA 3
Progress	-0.8397	2.9648	0.6149	Toyomidon	2.5675	0.1553	-0.3233
Rubin	-1.7520	-1.0825	0.5508	Urozani	-0.0948	-0.9667	1.1646
Saazer	-0.1950	-1.6743	0.5515	USDA 21055	-1.5491	3.8642	-0.3581
Saphir	-1.3506	-1.3976	-0.3865	Vojvodina	-0.8368	-1.7339	0.0174
Serebrianker	-0.7182	-1.9525	1.0076	WFG	0.9388	-1.4671	-0.6445
Sirem	0.9910	-1.4713	-0.7268	Williamette	-2.2056	1.2095	0.0951
Sladek	0.8235	-0.7533	-1.0480	Wye Northdown	0.7422	-0.6856	-1.5281
Smaragd	-1.8402	-1.1527	0.3351	Wye Target	0.8986	-0.6559	0.7886
Spalter	-0.0589	-1.8434	0.3222	Wye Viking	-0.0075	-0.6130	0.4524
Spalter Select	-0.8540	-1.8748	0.0160	Yeoman	-0.5796	-1.1030	0.1024
Sterling	-1.6244	-0.0231	0.7788	Zatecki	-0.6515	0.8889	0.1565
Sticklebrackt	-2.1959	2.0770	0.9805	Zenith	-1.0167	-1.5939	0.2939
Strisselspalter	-3.1147	1.3959	0.9958	Zeus	0.1323	3.6007	-0.3090
Super Alpha	-1.5729	1.0136	0.9513	Zitic	1.3728	-0.5409	-2.1116
Talisman	1.1639	-0.7823	-0.7213	Zlatan	0.5318	-1.4985	-0.2262
Tettnanger	0.0549	-1.5640	0.1947				

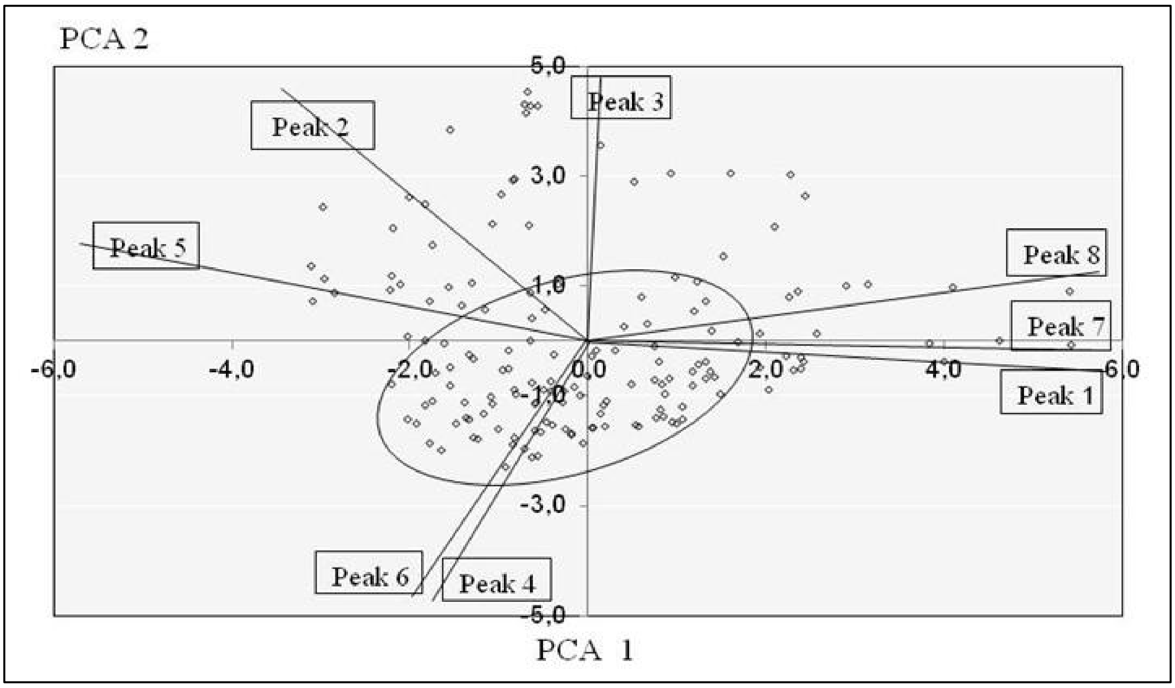


Fig. 7.7: Principal-component analysis of the world hop range

Cluster analysis is another method that can be used to arrange objects on the basis of their degree of similarity. In hierarchical cluster analysis, objects are grouped together step by step in hierarchical clusters based on similarity. An attempt was made to group the world hop cultivars in 20 clusters according to the similarity of their flavonoid composition. The choice of clusters is arbitrary; 10 or 15 clusters could also have been chosen. Tab. 7.3 shows the world hop range grouped according to clusters. Fig. 7.8 shows a dendogram depicting the relative similarities of the clusters.

Tab. 7.3: Assignment of world hop range to 20 clusters

Cluster 1
Admiral
Agnus
Aromat
Belgischer Spalter
Bobek
Bor
Braustern
Cascade
Diva
Hall. Gold
Harmony
Herald
Kumir
Lubelski
PCU 280
Pilgrim
Pioneer
Saazer
Saphir
Sirem
Sladek
Spalter
Spalter Select
Talisman
Tettnanger
WFG
Wye Northdown
Wye Target
Zlatan

Cluster 2
Aurora
Buket
Early Choice
Eastwell Golding
Emerald
First Gold
Glacier
Hall. Tradition
Hallertauer Mfr.
Hersbrucker Pure
Hüller Anfang
Hüller Aroma
Hüller Fortschritt
Hüller Start
Opal
Orion
Perle
Pride of Kent
Rubin
Smaragd
Urozani
Vojvodina
Wye Viking
Yeoman
Zenith
Zitic

Cluster 3
Boadicea
Estera
Fuggle
Hüller Bitter
New Zealand Hallertauer
Williamette
Zatecki

Cluster 4
Eastern Gold
Ging Dao Do Hua
Golden Star
Kirin 1
Kirin 2

Cluster 5
Ahil
Blisk
Brewers Gold
Comet
Hall. Magnum
Hall. Taurus
Herkules
Japan C 845
Kitamidori
Northern Brewer
Premiant
Toyomidori

Cluster 6
Crystal
Hersbrucker Spät
Malling
Pacific Gem
Strisselspalter

Cluster 7
Columbus
Eroica
Galena
Zeus

Cluster 8
Backa

Cluster 9
Chang Bei 2
Japan C 730
Nugget
Olympic
Sterling

Cluster 10
Horizon
Mt. Hood
Pilot

Cluster 11
Neptun

Cluster 12
Aquila

Cluster 13
Granit

Cluster 14
Atlas
Bramling Cross
Density
Marynka
USDA 21055

Cluster 15
Apolon
Hall. Merkur

Cluster 16
Brewers Stand
Pride of Ringwood
Progress

Cluster 17
Alliance
Alpharoma
Chang Bei 1
Neoplanta
Phoenix
Serebrianker

Cluster 18
Green Bullet

Cluster 19
Bullion

Cluster 20
College Cluster
Sticklebrackt
Super Alpha

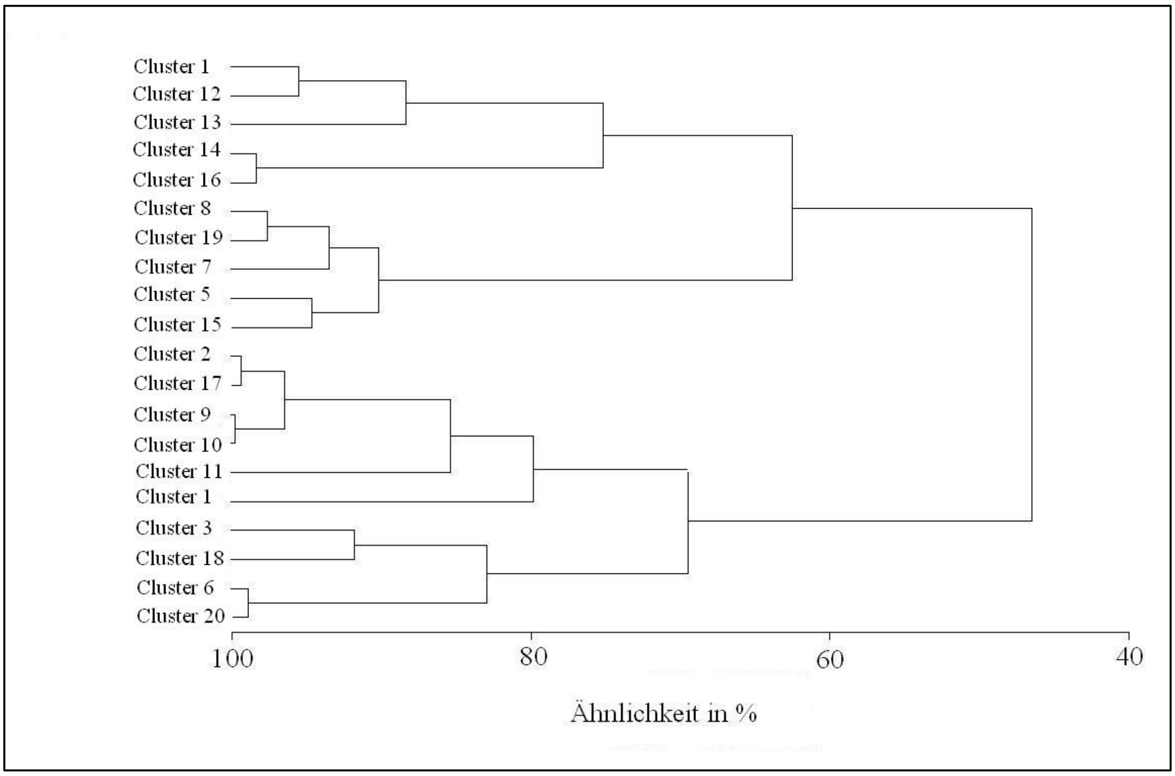


Fig. 7.8: Dendogram of cluster analysis of world hop range

7.4 World hop range (2010 crop)

This analysis is performed every year. The aim is to determine the quality- and variety-specific components of the available domestic and foreign hop varieties when they are grown under the conditions prevailing at Hüll. Tab. 7.4 shows the results for the 2010 harvest. It may be helpful in classifying unknown hop varieties. The oil analyses were performed via headspace gas chromatography. The individual oil components are quoted in relation to beta-caryophyllene.

Tab. 7.4: World hop range 2010

Variety	Myr-cene	2-M.-iso butyrate	Sub. 14b	Sub. 15	Lina-lool	Aroma-dedrene	Unde-canon	Humu-lene	Farne-sene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	Cadi-nene	Selina-diene	Gera-niol	α-acids	ß-acids	ß/α	Cohu-mulone	Colu-pulone
Admiral	5835	582	17	35	33	0	10	271	10	8	4	1	16	0	2	17.3	6.2	0.36	33.7	64.0
Agnus	2720	79	1	5	7	0	7	139	0	5	5	4	13	0	1	10.7	7.0	0.65	38.2	58.9
Ahil	2683	278	21	2	11	8	11	189	39	8	7	4	17	0	2	8.5	4.6	0.54	31.1	56.7
Alliance	645	64	1	2	13	0	7	305	7	8	6	5	17	0	0	5.4	3.1	0.57	28.8	53.7
Alpharoma	1446	124	28	5	7	0	16	319	19	11	6	3	21	0	3	8.1	3.7	0.46	32.0	55.2
Apolon	1780	52	29	3	16	0	8	197	28	7	8	5	14	0	3	5.6	4.3	0.77	32.0	52.5
Aquila	2368	70	4	72	24	22	27	24	0	14	72	83	12	93	4	5.0	2.8	0.56	45.2	72.9
Aromat	2430	19	6	8	43	0	18	325	21	11	10	5	19	0	5	2.7	4.1	1.52	25.1	43.7
Atlas	1777	633	19	4	16	0	11	197	31	9	12	8	17	0	7	5.6	2.9	0.52	31.6	58.7
Aurora	2961	81	1	24	24	0	32	265	32	6	5	3	16	0	0	9.0	4.2	0.47	22.9	48.0
Backa	1534	219	3	10	15	0	11	283	22	10	6	5	20	0	1	10.4	6.4	0.62	37.6	58.9
Blisk	2074	280	23	5	21	0	10	218	45	8	6	3	15	0	3	8.3	4.2	0.51	32.7	57.5
Bobek	7901	207	11	97	47	0	33	258	48	7	1	1	12	0	2	6.5	5.8	0.89	26.8	47.8
Bor	2550	100	3	45	7	0	8	298	0	7	3	1	15	0	1	11.3	5.7	0.50	24.9	50.9
Bramling Cross	1872	133	6	5	38	0	24	293	0	12	8	3	24	4	5	5.2	3.2	0.62	30.8	56.7
Braustern	2389	88	2	32	6	0	5	261	0	7	4	2	16	0	1	10.7	5.8	0.54	27.1	52.1
Brewers Gold	2506	202	12	15	9	0	6	145	0	5	8	7	12	0	1	7.5	4.6	0.61	42.6	66.5
Brewers Stand	12588	663	45	48	43	33	29	58	0	68	83	73	126	96	7	7.1	5.0	0.70	25.8	45.8
Buket	3279	171	3	63	18	0	13	241	27	8	2	1	16	0	1	10.1	5.3	0.52	25.9	51.1
Bullion	1541	202	16	14	10	0	4	134	0	6	9	7	14	0	1	6.9	4.8	0.70	37.2	54.1
Cascade	3268	298	30	10	15	0	31	240	20	13	25	24	28	0	4	6.1	4.9	0.80	34.5	51.9
Chang bei 1	1359	106	4	3	29	0	23	280	12	11	28	25	25	22	3	5.6	5.2	0.93	29.3	47.8

Variety	Myr-cene	2-M.-iso butyrate	Sub. 14b	Sub. 15	Lina-lool	Aroma-dedrene	Unde-canon	Humu-lene	Farne-sene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	Cadi-nene	Selina-diene	Gera-niol	α-acids	ß-acids	ß/α	Cohu-mulone	Colu-pulone
Chang bei 2	1247	11	4	3	28	0	24	264	16	9	21	18	19	23	2	4.7	5.3	1.13	22.7	43.4
College Cluster	459	130	13	5	6	0	4	145	0	5	9	7	11	0	1	6.3	2.2	0.35	23.8	55.5
Columbus	4621	213	14	13	11	4	7	139	0	15	14	10	32	11	1	13.3	5.2	0.39	41.0	64.1
Comet	929	72	10	12	10	0	6	9	0	2	39	39	4	11	1	9.0	4.5	0.50	31.2	52.8
Crystal	652	17	4	4	16	31	18	202	0	12	36	37	15	62	1	4.2	8.1	1.93	27.1	41.5
Density	2047	164	7	5	42	0	30	295	0	11	11	6	20	0	6	4.3	2.9	0.67	28.6	54.6
Early Choice	1938	84	1	34	6	0	8	232	0	7	47	51	14	0	1	3.3	1.8	0.55	21.7	55.9
Eastwell Golding	1160	62	2	6	10	0	6	294	0	7	5	5	16	0	1	7.3	4.8	0.66	26.8	51.0
Emerald	880	60	4	11	5	0	11	325	0	8	4	2	17	0	1	8.2	4.9	0.60	26.7	50.5
Eroica	2545	378	42	65	2	5	7	164	0	6	7	5	14	0	2	9.6	6.5	0.68	37.1	56.1
Estera	1250	119	2	5	16	0	8	286	18	8	4	2	17	0	1	4.7	3.9	0.83	27.4	50.7
First Gold	5346	539	5	19	21	3	17	241	19	7	95	133	20	0	1	8.7	4.3	0.49	33.9	57.9
Fuggle	775	98	5	5	12	0	11	247	10	7	5	2	17	0	1	4.9	3.4	0.69	31.1	50.5
Galena	2933	374	47	92	2	16	13	166	0	7	7	4	15	0	1	9.3	7.0	0.75	40.5	62.6
Ging Dao Do Hua	1877	607	6	4	24	0	20	296	0	20	59	53	47	0	4	6.1	5.3	0.87	39.2	55.0
Glacier	3577	107	9	5	35	0	23	296	0	8	7	4	18	0	0	6.4	8.8	1.38	13.6	39.0
Golden Star	3691	1236	4	6	27	0	15	279	0	20	50	45	48	0	4	6.3	4.9	0.78	37.1	56.1
Granit	756	37	5	5	5	6	16	193	0	6	13	11	13	0	1	8.6	5.5	0.64	28.9	50.2
Green Bullet	3629	258	18	7	20	0	22	305	0	9	12	7	17	0	3	7.9	5.1	0.65	33.5	59.3
Hallertauer Gold	1527	73	20	5	17	0	10	308	0	7	5	3	16	0	2	7.5	5.5	0.73	23.0	44.4
Hallertauer Magnum	4991	143	31	21	7	4	6	302	0	6	4	3	13	0	1	15.1	7.0	0.46	27.7	50.6
Hallertauer Merkur	3183	183	13	7	16	3	5	300	0	7	5	3	15	0	1	14.4	6.8	0.47	22.4	45.8
Hallertauer Mfr.	326	59	1	1	18	0	11	320	0	10	6	3	20	0	0	3.6	4.8	1.33	20.5	37.9

Variety	Myr-cene	2-M.-iso butyrate	Sub. 14b	Sub. 15	Lina-lool	Aroma-dedrene	Unde-canon	Humu-lene	Farne-sene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	Cadi-nene	Selina-diene	Gera-niol	α-acids	ß-acids	ß/α	Cohu-mulone	Colu-pulone
Hallertauer Taurus	7988	160	19	16	34	0	13	275	0	7	63	65	17	0	2	17.7	5.4	0.31	24.1	50.2
Hallertauer Tradition	920	143	10	3	22	0	17	316	0	8	6	3	18	0	0	6.5	5.3	0.82	24.3	45.9
Harmony	4451	49	7	15	23	0	16	267	0	7	71	97	19	0	2	8.8	8.1	0.92	18.9	36.3
Herald	5124	434	4	103	10	0	26	221	0	5	29	40	14	0	0	10.8	4.6	0.43	37.7	59.1
Herkules	8789	390	92	131	11	0	19	293	0	6	5	4	17	0	2	18.2	6.4	0.35	37.7	55.4
Hersbrucker Pure	1642	98	1	8	27	12	32	201	0	10	33	38	18	52	1	5.4	2.9	0.54	22.6	42.9
Hersbrucker Spät	956	107	7	5	35	24	18	191	0	16	56	53	19	75	2	3.3	7.8	2.36	15.2	32.8
Hüller Anfang	265	89	7	1	17	0	8	322	0	10	7	5	23	0	0	2.6	5.2	2.00	20.2	41.7
Hüller Aroma	496	80	4	2	22	0	7	347	0	9	6	2	22	0	0	3.9	4.5	1.15	26.8	46.8
Hüller Bitter	1110	195	32	4	26	21	21	166	0	56	64	55	92	83	3	4.7	4.0	0.85	26.5	47.1
Hüller Fortschritt	586	50	9	2	21	0	9	331	0	8	6	2	21	0	0	3.6	5.0	1.39	25.0	44.6
Hüller Start	292	74	2	2	13	0	14	348	0	10	7	4	25	0	0	2.6	4.0	1.54	23.4	43.3
Jap. C 730	937	18	11	32	19	0	27	168	18	6	8	4	12	0	3	5.1	3.7	0.73	30.2	52.7
Jap. C 845	886	20	4	10	3	0	4	303	6	4	4	2	16	0	1	12.2	5.0	0.41	23.9	50.5
Kirin 1	1916	620	5	5	18	0	13	301	0	20	45	41	40	0	3	6.2	4.8	0.77	40.2	58.2
Kirin 2	1876	792	7	4	21	0	16	301	0	23	67	61	53	0	4	6.2	5.3	0.85	42.1	56.2
Kitamidori	850	19	4	11	2	0	4	301	9	9	4	2	17	0	1	11.1	4.5	0.41	25.4	41.8
Kumir	2106	81	4	14	19	0	8	300	6	7	3	1	16	0	1	9.9	5.7	0.58	23.9	47.3
Late Cluster	10794	641	38	51	47	17	51	50	4	68	77	65	126	57	5	6.1	4.5	0.74	32.2	51.8
Lubelski	1135	17	5	4	32	0	18	322	26	11	9	5	21	0	3	3.8	6.2	1.63	22.3	41.4
Malling	1367	113	3	6	23	0	10	264	19	9	6	3	18	0	1	3.0	3.5	1.17	22.4	47.0
Marynka	3644	211	4	32	8	7	7	146	87	6	4	3	12	0	1	9.5	4.7	0.49	25.2	50.4
Mt. Hood	150	23	10	1	6	0	10	279	0	10	7	3	19	0	0	4.3	5.4	1.26	22.7	43.8

Variety	Myr-cene	2-M.-iso butyrate	Sub. 14b	Sub. 15	Lina-lool	Aroma-dedrene	Unde-canon	Humu-lene	Farne-sene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	Cadi-nene	Selina-diene	Gera-niol	α-acids	ß-acids	ß/α	Cohu-mulone	Colu-pulone
Neoplanta	1413	73	2	18	6	0	6	216	19	7	3	1	16	0	1	8.0	4.8	0.60	31.3	56.7
Neptun	2017	84	30	6	11	0	4	222	0	7	6	3	17	0	1	13.9	5.5	0.40	24.1	44.5
Northern Brewer	2045	69	2	26	6	0	5	272	0	7	4	3	16	0	1	10.4	5.7	0.55	26.3	51.0
Nugget	2191	118	3	13	11	3	6	184	0	4	8	8	11	0	1	12.1	5.3	0.44	30.7	53.9
NZ Hallertauer	4040	160	4	38	22	0	12	183	24	9	24	24	15	37	3	7.5	8.1	1.08	33.9	49.7
Olympic	2573	151	4	16	11	6	5	183	0	4	8	7	10	0	0	14.3	4.8	0.34	27.7	57.3
Opal	1538	34	14	13	24	0	10	252	0	8	3	7	18	19	1	8.7	6.7	0.77	13.8	30.8
Orion	1492	130	5	7	15	0	9	249	0	8	4	2	17	0	1	9.0	4.7	0.52	29.1	53.7
Outeniqua	2066	49	2	3	5	9	13	250	0	9	52	50	19	0	1	12.8	5.3	0.41	30.4	59.4
PCU 280	1761	48	1	15	4	0	3	281	0	6	3	2	15	0	1	10.9	5.3	0.49	26.8	53.9
Perle	844	60	2	15	4	0	8	302	0	8	4	3	17	0	1	6.5	4.1	0.63	30.2	55.6
Phoenix	2963	199	2	12	7	0	7	246	15	7	54	73	19	0	1	11.6	5.6	0.48	26.6	48.6
Pilgrim	6841	528	6	116	10	0	22	274	0	6	71	97	19	0	2	8.4	4.0	0.48	37.2	58.5
Pioneer	5696	400	3	245	8	3	29	230	0	6	34	47	18	0	1	10.4	4.2	0.40	36.1	58.9
Premiant	2002	81	4	9	19	0	8	298	6	7	4	2	16	0	1	8.1	5.3	0.65	25.1	47.5
Pride of Kent	1525	54	1	4	24	0	7	321	0	8	5	2	18	0	1	6.7	3.4	0.51	25.9	54.4
Pride of Ringwood	2686	105	4	2	7	0	19	27	0	6	119	122	12	0	1	9.0	6.3	0.70	32.7	56.5
Progress	8403	739	54	38	47	19	38	40	0	74	90	80	135	116	6	7.3	4.5	0.62	26.2	48.2
Rubin	2719	238	36	9	11	0	8	253	0	10	73	74	19	1	3	13.5	4.6	0.34	27.6	58.6
Saazer	1438	9	2	5	30	0	26	305	22	10	7	3	20	0	4	2.7	4.4	1.63	23.8	40.9
Saphir	1964	49	5	20	23	7	29	181	0	7	19	23	14	23	3	3.7	7.1	1.92	12.6	40.7
Serebrianker	458	126	3	3	34	0	13	202	0	15	61	57	22	0	2	1.4	5.1	3.64	37.4	41.5
Sirem	680	14	7	5	40	0	25	339	14	15	6	2	25	0	2	4.3	5.7	1.33	27.4	44.4

Variety	Myr-cene	2-M.-iso butyrate	Sub. 14b	Sub. 15	Lina-lool	Aroma-dedrene	Unde-canon	Humu-lene	Farne-sene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	Cadi-nene	Selina-diene	Gera-niol	α-acids	ß-acids	ß/α	Cohu-mulone	Colu-pulone
Sladek	1965	86	4	13	20	0	7	307	8	8	4	2	17	0	1	9.0	5.2	0.58	21.9	46.5
Smaragd	2651	38	13	20	21	0	10	284	0	7	7	14	17	13	2	7.9	6.2	0.78	14.9	30.2
Southern Promise	713	156	6	9	1	0	17	284	0	10	19	17	18	22	1	6.1	5.5	0.90	26.3	53.8
Southern Star	1378	76	6	2	4	0	13	286	29	10	4	2	18	0	1	11.1	6.2	0.56	36.1	60.8
Spalter	1272	8	2	5	28	0	20	300	27	9	7	3	19	0	3	2.3	4.7	2.04	25.8	43.1
Spalter Select	5189	152	17	8	70	28	24	177	47	9	34	43	16	53	0	4.0	4.4	1.10	24.0	42.7
Sterling	1876	86	3	14	10	6	6	188	0	3	8	7	11	0	0	12.9	5.0	0.39	27.1	54.3
Sticklebract	6676	675	26	27	9	0	18	169	23	7	52	56	13	0	3	11.3	7.3	0.65	41.2	65.2
Strisselspalter	1157	64	6	6	18	24	12	184	0	9	31	39	15	41	0	4.0	7.7	1.93	17.8	34.8
Südafrika	508	31	1	1	4	0	15	287	0	9	78	78	21	0	2	4.0	4.3	1.08	32.6	51.3
Super Alpha	5329	422	24	17	29	0	16	276	0	6	5	3	15	0	1	9.4	5.2	0.55	29.7	57.1
Talisman	2136	88	2	32	6	0	6	257	0	7	6	4	16	0	1	9.4	5.6	0.60	27.0	50.0
Tettnanger	1175	11	1	4	25	0	18	307	26	9	6	3	19	0	3	3.3	5.5	1.67	21.3	39.0
Toyomidori	1508	208	15	46	10	0	19	220	0	2	13	9	39	12	2	10.0	4.8	0.48	33.9	61.2
Urozani	1452	21	3	5	62	0	21	271	23	11	25	22	20	27	3	3.5	6.4	1.83	24.3	43.7
USDA 21055	4421	415	6	155	7	0	3	116	43	6	15	16	14	0	2	12.1	5.5	0.45	34.7	60.8
Vojvodina	1945	78	2	22	6	0	10	274	6	7	5	3	16	0	2	7.6	4.2	0.55	28.3	53.3
WFG	906	24	4	5	23	0	20	319	24	12	7	2	25	0	3	4.6	5.5	1.20	26.7	45.7
Willamette	1117	100	1	5	11	0	9	236	20	7	5	2	15	0	1	3.9	3.4	0.87	34.6	53.0
Wye Challenger	2770	230	4	31	17	0	19	276	9	7	52	68	18	0	0	6.1	5.1	0.84	25.2	45.2
Wye Northdown	2392	101	3	8	16	0	5	251	0	7	5	3	15	0	1	8.8	7.0	0.80	28.4	47.8
Wye Target	2735	201	4	11	26	8	16	191	0	17	12	7	36	8	2	10.5	4.4	0.42	34.7	67.6
Wye Viking	3836	218	7	33	18	0	15	209	37	8	48	49	16	0	1	5.8	5.1	0.88	28.2	47.9

Variety	Myr-cene	2-M.-iso butyrate	Sub. 14b	Sub. 15	Lina-lool	Aroma-dedrene	Unde-canon	Humu-lene	Farne-sene	γ-Muu-rolene	ß-Seli-nene	α-Seli-nene	Cadi-nene	Selina-diene	Gera-niol	α-acids	ß-acids	ß/α	Cohu-mulone	Colu-pulone
Yeoman	2127	144	9	10	6	0	5	235	0	7	40	51	17	0	1	12.8	5.9	0.46	27.0	51.8
Zatecki	1196	90	2	11	17	0	7	266	17	9	4	1	18	0	1	5.1	4.7	0.92	25.2	46.9
Zenith	1572	45	2	10	16	0	9	282	0	8	84	94	17	0	1	9.3	4.2	0.45	23.4	48.9
Zeus	3449	186	13	11	9	0	7	141	0	16	14	9	34	12	0	12.6	5.0	0.40	39.4	61.3
Zitic	1374	7	2	8	8	3	12	312	8	8	3	1	17	0	2	8.1	6.1	0.75	27.7	47.9
Zlatan	1286	29	7	6	39	0	27	323	19	13	9	4	23	0	2	4.5	5.3	1.18	27.6	46.8

Essential oils = relative values, ß-caryophyllene=100, α- and ß-acids in % l, analogues in % of α- or ß-acids

7.5 Quality assurance in α-acid determination for hop supply contracts

7.5.1 Ring analyses of the 2011 crop

Since 2000, hop supply contracts have included a supplementary agreement concerning α-acid content. The contractually agreed price applies provided the α-acid content is within what is termed a 'neutral' range. If it is above or below this range, the price is marked up or down, respectively. The specification compiled by the working group for hop analysis (AHA) describes precisely how samples are to be treated (sample division and storage), lays down which laboratories carry out post-analyses and defines the tolerance ranges permissible for the analysis results. In 2011, the IPZ 5d Work Group once again assumed responsibility for organizing and evaluating the ring tests used to verify the quality of the alpha-acid analyses.

The following laboratories took part in the 2011 ring tests:

- Hallertauer Hopfenveredelungsgesellschaft (HHV), Au/Hallertau plant
- NATECO$_2$ GmbH & Co. KG, Wolnzach
- Hopfenveredlung St. Johann GmbH & Co. KG, St. Johann
- Hallertauer Hopfenveredelungsgesellschaft (HHV), Mainburg plant
- Hallertauer Hopfenverwertungsgenossenschaft (HVG), Mainburg
- Agrolab GmbH, Oberhummel
- Thuringia State Research Centre for Agriculture(TLL)
- Hops Dept. of the Bavarian State Research Centre for Agriculture, Hüll

The ring tests commenced on 6th September 2011 and ended on 11th November 2011, as this was the period during which most of the hop lots were examined in the laboratories. In all, ten ring tests were conducted (ten weeks). Sample material was kindly provided by Mr. Hörmansperger (Hop Producers' Ring). To ensure maximum homogeneity, each sample was drawn from a single bale. Every Monday, the samples were ground with a hammer mill in Hüll, divided up with a sample divider, vacuum-packed and taken to the various laboratories. The laboratories then analysed one sample daily on each of the following weekdays. A week later, the results were sent back to Hüll and evaluated there. A total of 38 samples were analysed in 2011.

The evaluations were passed on to the individual laboratories as quickly as possible. Fig. 7.9 shows a sample evaluation as a model example of a ring-test evaluation. The laboratory numbers (1-7) do not correspond to the above list. The outlier test was calculated as per DIN ISO 5725. Cochran's test was applied for inter-laboratory assessment and Grubb's test for intra-laboratory assessment.

No. 29: HHE (26.10.2011)

Laboratory	KW		Mean	s	cvr
1	4.61	4.68	4.65	0.049	1.1
2	4.61	4.66	4.64	0.035	0.8
3	4.56	4.56	4.56	0.000	0.0
4	4.60	4.69	4.65	0.064	1.4
5	4.53	4.53	4.53	0.000	0.0
6	4.50	4.56	4.53	0.042	0.9
7	4.59	4.58	4.59	0.007	0.2

Mean	4.59
sr	0.037
sL	0.045
sR	0.058
vkr	0.81
vkR	1.27
r	0.10
R	0.16
Min	4.50
Max	4.69

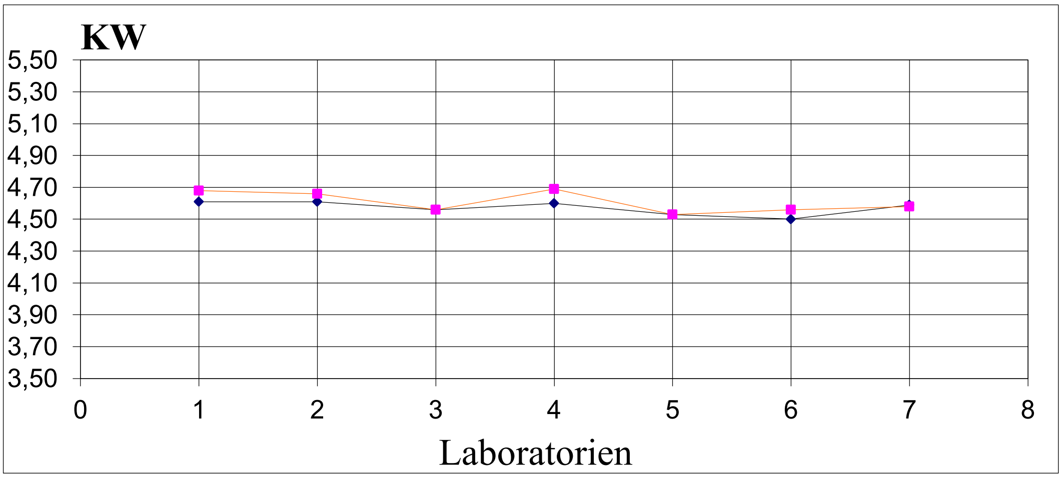


Fig. 7.9: Ring-test evaluation

The 2011 outliers are compiled in Tab. 7.5.

Tab. 7.5: 2011 outliers

	Cochran		Grubbs	
Sample	α = 0.01	α = 0.05	α = 0.01	α = 0.05
12	1	1		
14	1	1		
23				1
33		1		1
Total:	2	3		2

Tab. 7.6 shows the tolerance limits (critical difference values (CD), Schmidt, R., NATECO$_2$, Wolnzach) derived from the Analytica-ECB of the European Brewery Convention (EBC 7.4, conductometric titration) and outliers from 2000 to 2011.

Tab. 7.6: Tolerance limits set by EBC 7.4 and outliers from 2000 to 2011

	Up to 6.2 % α-acids	6.3 % - 9.4 % α-acids	9.5 % - 11.3 % α-acids	From 11.4 % α-acids
Crit. diff. (CD)	+/-0.3	+/-0.4	+/-0.5	+/-0.6
Range	0.6	0.8	1.0	1.2
Outliers in 2000	0	3	0	3
in 2001	2	1	0	2
in 2002	4	4	2	4
in 2003	1	1	1	0
in 2004	0	0	0	4
in 2005	1	0	1	3
in 2006	2	0	1	0
in 2007	1	0	0	0
in 2008	2	0	0	6
in 2009	3	2	0	4
in 2010	0	0	0	1
in 2011	1	0	0	1

In 2011, two results were outside the permissible tolerance limits. Fig.7.10 shows all the analysis results for each laboratory as relative deviations from the mean (= 100 %), differentiated according to alpha-acid contents of <5 %, ≥ 5 % and <10 %, and also ≥ 10 %. The chart clearly reveals whether a laboratory tends to arrive at values that are too high or too low.

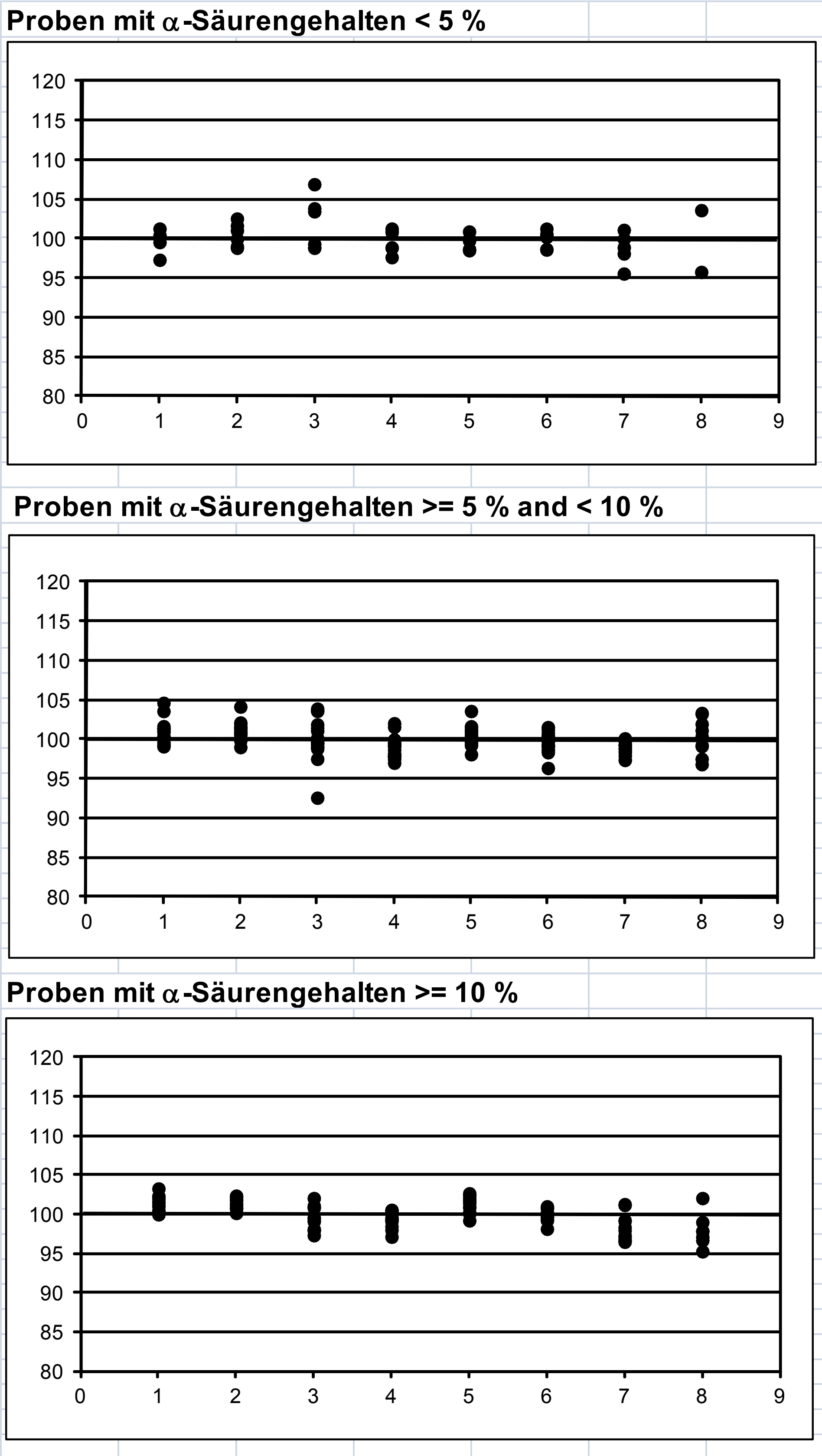


Fig.7.10: Analysis results of laboratories relative to the mean

The Hüll laboratory is number 5.

7.5.2 Evaluation of post-analyses

Since 2005, post-analyses have been performed to confirm the results of the ring tests. The post-analyses are evaluated by the IPZ 5d Work Group, which passes on the results to the laboratories involved, the Hop Growers' Association and the German Hop Trade Association. Each of the laboratories conducting ring tests selects three samples weekly that are then analysed by three other laboratories according to the AHA specification. The result of the initial ring test is confirmed if the post-analysis mean and initial ring-test result are within the specified tolerance limits (Table 7.). Tab. 7.7 shows the 2011 results. Since 2005, all initial test results have been confirmed.

Tab. 7.7: 2011 post-analyses

Sample designation	Initial test laboratory	Initial test result	Post-analysis 1	2	3	Mean	Result confirmed
KW 36 HHT	HHV Au	7.3	7.2	7.2	7.5	7.30	yes
KW 36 HPE 1	HHV Au	10.7	10.5	10.6	10.9	10.67	yes
KW 36 HPE 2	HHV Au	11.1	10.9	11.0	11.1	11.00	yes
KW 37 HTU	NATECO2 Wolnzach	15.7	15.8	15.9	15.9	15.87	yes
KW 37 HPE	NATECO2 Wolnzach	9.0	9.1	9.2	9.3	9.20	yes
KW 37 HHM	NATECO2 Wolnzach	14.7	14.9	15.0	15.0	14.97	yes
HHM 1 - KW 38	HVG Mainburg	15.5	15.4	15.6	15.8	15.60	yes
HHM 2 - KW 38	HVG Mainburg	15.5	15.3	15.4	15.6	15.43	yes
HPE - KW 38	HVG Mainburg	11.2	11.0	11.1	11.1	11.07	yes
KW 39 HZE	HHV Au	13.1	12.9	13.2	13.3	13.13	yes
KW 39 HMR	HHV Au	15.7	15.3	15.7	15.9	15.63	yes
KW 39 HHM	HHV Au	15.2	14.9	15.3	15.3	15.17	yes
QK 11/003135 EHM	NATECO2 Wolnzach	15.8	15.9	15.9	16.0	15.93	yes
QK 11/0031356 HHS	NATECO2 Wolnzach	17.9	18.2	18.2	18.3	8.23	yes
QK 11/003134 EHM	NATECO2 Wolnzach	13.9	13.7	13.8	14.0	13.83	yes
HPE-KW 41	HVG Mainburg	10.3	10.0	10.0	10.1	10.03	yes
HHS *1*-KW 41	HVG Mainburg	18.8	18.6	18.6	18.9	18.70	yes
HHS 2-KW 41	HVG Mainburg	17.5	17.2	17.3	17.4	17.30	yes
KW 42 HPE	HHV Au	8.5	8.6	8.6	8.8	8.67	yes
KW 42 HHM	HHV Au	14.0	13.9	14.0	14.2	14.03	yes
KW 42 HTU	HHV Au	16.8	16.7	6.8	16.9	16.80	yes
KW 43 QK 4095 HTU	NATECO2 Wolnzach	17.1	17.0	17.1	17.3	17.13	yes
KW 43 QK 4097 HHM	NATECO2 Wolnzach	16.8	16.5	16.7	16.8	16.67	yes
KW 43 QK 4101 HHM	NATECO2 Wolnzach	14.1	13.7	14.0	14.3	14.00	yes
HPE-KW 44	HVG Mainburg	10.3	10.1	10.3	10.3	10.23	yes
HHM-KW 44	HVG Mainburg	13.5	13.2	13.3	13.6	13.37	yes
HTU-KW 44	HVG Mainburg	17.7	17.4	17.5	17.9	17.60	yes

7.6 Production of pure alpha acids and their ortho-phenylendiamine complexes for monitoring and calibrating the HPLC standards

In the autumn of 2010, the AHA working group introduced the new international calibration extract ICE 3. It was the task of the Hüll laboratory to produce the ultra-pure α-acids (>98 %) required for calibrating and monitoring the extract as a standard. The stability of the calibration extract is checked twice a year by the laboratories. The ortho-phenylenediamine complex is first prepared from a CO_2 extract with a high α-acid content by reaction with ortho-phenylenediamine (Fig. 7.11).

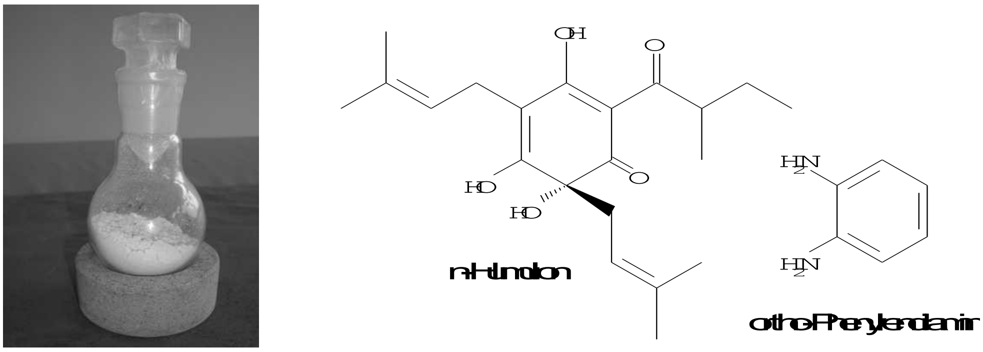


Fig. 7.11: Ortho-phenylendiamine complex and its chemical structure

This complex can be purified by multiple re-crystallization. The pure α-acids are then released from the complex. The complex itself has been found to be very stable and to be suitable for use as a standard for ICE calibration.

7.7 Analytical characterisation of "flavour hops"

Hitherto hops were divided up into bitter and aroma varieties. Bitter varieties have a high alpha-acid content and aroma varieties are characterised by a fine aroma. In the craft brewers' scene, however, a new term has emerged for characterizing hop varieties: "flavour hops". They are hops whose aroma profiles are very different to those of conventional hops. In some cases, their aromas are exotic and untypical of hops, mostly tending towards fruity and citrus-like notes: such hops may nevertheless boast a high alpha-acid content. Experienced flavour and aroma experts can describe hop aromas in great detail. Subdivision into seven aroma descriptions is nevertheless very helpful for characterising hop varieties. The aroma profiles and chemical substances responsible for them are shown in Tab. 7.8. Probably even more substances can be added to round off the descriptions.

Tab. 7.8: Description of hop aromas and pertinent aroma components

Fruity	**Floral**	**Citrus-like**	**Herbs/Vegetable**
Isobutyl isobutyrate	Linalool	Lemon/limes	α-pinene
Isoamyl acetate	2-decanone	Citronellol	ß-phellandrene (*)
2-methylbutyl isobutyrate	2-undecanone	Citral (*)	ß-pinene
2-methylbutyl-2-metylbutyrate	Tridecanone	p-Cymen (*)	ß-selinene
Enanthic acid methylester	Pentadecanone	Citronellal (*)	α-selinene
Methyl-6-methylheptanoate	Geraniol		Cadinene
2-nonanone	Farnesol (*)		Selinadiene
4-decenoic acid methylester	Nerol (*)		
4,8-decadienoic acid, methyles-	Geranyl acetate		
Spice/Wood	**Grass, Hay**	**Off-Flavour**	
Myrcene	Hexanal (*)	Dimethylsulfide	
α-copaene (*)			
ß-caryophyllene			
Humulene			
Caryophyllenoxide			
Eudesmol (*)			
(*) these components will be additionally included in analytics			

If the results of oil-component analysis via headspace gas chromatography are compiled as in Tab. 7.8, the individual hop varieties can be compared very effectively in terms of their aroma profiles. Fig. 7.12 provides a comparison of a number of hop varieties with breeding lines. The analytical results are in line with the sensory evaluation. Breeding line 2007/019/008 has by far the most powerful aroma.

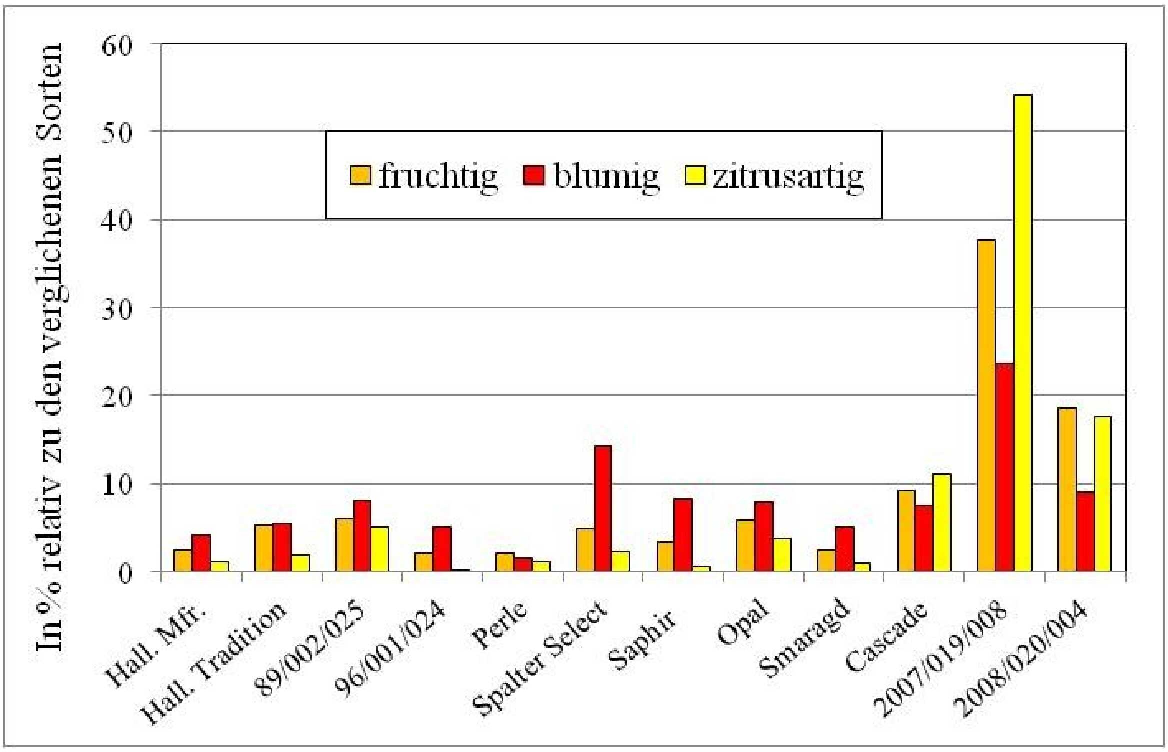
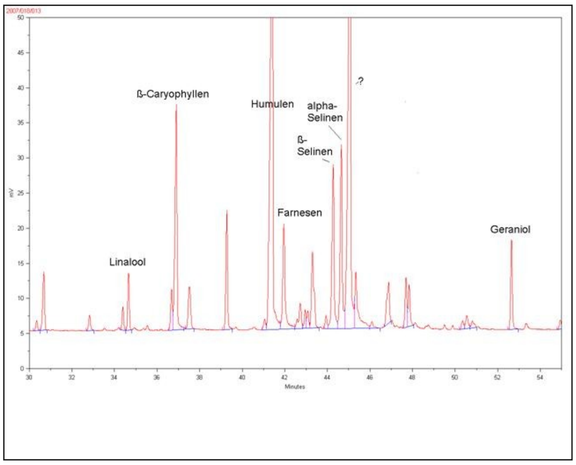


Fig. 7.12: Aroma profiles of hop varieties and breeding lines

The oil spectra of the flavour hops are in some cases quite different to those of traditional hops. New substances not yet identified via mass spectrometry also occur (Fig. 7.13).

Breeding line 2007/018/013



Breeding line 2008/059/003

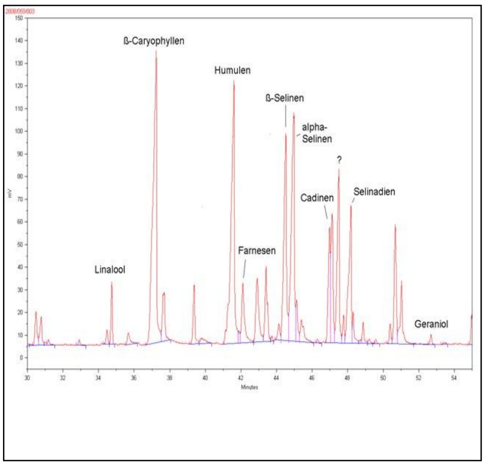


Fig. 7.13: New aroma components of flavour hops

An unknown substance, accounting for more than 5% of total oil content, elutes after beta- and alpha-selinene from breeding line 2007/018/013. Another unknown substance, which elutes between cadinene and selinadiene from breeding line 2008/059/003, is already very evident in the Smaragd and Opal varieties.

7.8 Monitoring of varietal authenticity

IPZ 5d has a statutory duty to provide administrative assistance to the German food control authorities by monitoring varietal authenticity.

Varietal authenticity checks for German food authorities (District Administrator’s Offices)	29
Complaints	0

8 Publications and specialist information

8.1 Overview of PR activities

	Number		Number
Practice-relevant information and scientific articles	40	Guided tours	68
LfL publications	4	Exhibitions and posters	5
Press releases	1	Basic and advanced training sessions	21
Radio and TV broadcasts	2	Final-year university-degree theses	-
Conferences, trade events and seminars	14	Participation in working groups	16
Talks	64	Awards	2
Foreign guests	312		

8.2 Publications

8.2.1 Practice-relevant information and scientific articles

Drofenigg, K., Zachow, C., Berg, G., Radišek, S., Seigner, E., Seefelder, S. (2011): Development of a rapid molecular in-planta test for the detection of *Verticillium* pathotypes in hops and strategies for prevention of wilt. Proceedings of the Scientific Commission, International Hop Growers` Convention, Poland, ISSN 1814-2192, 98-100.

Engelhard, B., Weihrauch, F. (2011): Nachhaltige Optimierung der Bekämpfung von Blattläusen (*Phorodon humuli*) im Hopfen (*Humulus lupulus*) durch Bekämpfungsschwellen und Züchtung Blattlaus-toleranter Hopfensorten. Abschlussbericht des Forschungsprojektes im Auftrag der Deutschen Bundesstiftung Umwelt, Osnabrück. 46 pp.

Kammhuber, K. (2011): Differentiation of the world hop collection by means of the low molecular polyphenols. Proceedings of the Scientific Commission, International Hop Growers` Convention, Poland, ISSN 1814-2192, 61-64.

Kammhuber, K. (2011): Ergebnisse von Kontroll- und Nachuntersuchungen für Alphaverträge der Ernte 2010, Hopfen-Rundschau, Nummer 8, August 2011, 217-218

Lutz, A., Kammhuber, K., Hainzlmaier, M., Kneidl., J., Petzina, C., Wyschkon, B. (2011): Bonitierung und Ergebnisse für die Deutsche Hopfenausstellung 2011. Hopfenrundschau 62 (11), 316-319.

Lutz, A., Kneidl, J., Seefelder, S., Kammhuber, K., and Seigner, E. (2011): Trends in hop breeding – new aroma and bitter qualities at the Hop Research Centre Huell. Proceedings of the Scientific Commission, International Hop Growers` Convention, Poland, ISSN 1814-2192, 14.

Niedermeier, E. (2011): Pflanzenstandsbericht. Hopfen Rundschau 62 (5), 138.

Niedermeier, E. (2011): Pflanzenstandsbericht. Hopfen Rundschau 62 (6), 160.

Niedermeier, E. (2011): Pflanzenstandsbericht. Hopfen Rundschau 62 (7), 187.

Niedermeier, E. (2011): Pflanzenstandsbericht. Hopfen Rundschau 62 (8), 218.

Niedermeier, E. (2011): Pflanzenstandsbericht. Hopfen Rundschau 62 (9), 259.

Oberhollenzer, K., Seigner, E., Lutz, A., Eichmann, R., Hückelhoven, R. (2011): Resistance mechanisms of different hop genotypes to hop powdery mildew. Proceedings of the Scientific Commission, International Hop Growers` Convention, Poland, ISSN 1814-2192, 21-24.

Portner, J. (2011): Aktuelle Hopfenbauhinweise. Hopfenbau-Ringfax Nr. 2; 4; 7; 9; 11; 12; 13; 14; 15; 16; 17; 18; 19; 20; 21; 22; 23; 24; 25; 26; 29; 30; 31; 32; 33; 35; 36; 37; 40; 41; 42; 43; 45; 46; 47; 52; 53; 54; 56; 57

Portner, J. (2011): Nährstoffvergleich bis 31. März erstellen! Hopfen Rundschau 62 (3), 78.

Portner, J. (2011): Nmin-Untersuchung in Hopfen und anderen Ackerkulturen; Hopfen Rundschau 62 (3), 81.

Portner, J. (2011): Gezielte Stickstoffdüngung des Hopfens nach DSN (Nmin). Hopfen Rundschau 62 (3), 81-82.

Portner, J., Brummer, A. (2011): Nmin-Untersuchung 2011. Hopfen Rundschau 62 (5), 125-126.

Portner, J. (2011): Zwischenfruchteinsaat im Hopfen für KuLaP-Betriebe spätestens am 30. Juni! Hopfen Rundschau 62 (5), 142.

Portner, J. (2011): Zwischenfruchteinsaat im Hopfen für KuLaP-Betriebe spätestens bis 30. Juni vornehmen! Hopfen Rundschau 62 (6), 161.

Portner, J. (2011): Peronosporabekämpfung. Hopfen Rundschau 62 (6), 162.

Portner, J. (2011): Kostenfreie Rücknahme von Pflanzenschutz-Verpackungen PAMIRA 2011. Hopfen Rundschau 62 (8), 198.

Portner, J. (2011): Rebenhäcksel bald möglichst ausbringen! Hopfen. Rundschau 62 (8), 212.

Portner, J., Dr. Kammhuber, K. (2011): Fachkritik zur Moosburger Hopfenschau 2011. Hopfen Rundschau 62 (10), 282-286.

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Portner, J. (2011): Fortbildungsveranstaltungen; KuLaP-Förderung; Flächenzu- und abgänge melden. Hopfenring-Information v. 04.11.2011, 1-2.

Portner, J. (2011): Hopfentechnologie aus der Hallertau beispiellos – Hop Technology from the Hallertau peerless. Hopfenrundschau – International Edition of the German Hop Growers Magazine 2011/2012, 52-56.

Schwarz, J., Engelhard, B., Lachermaier, U., Weihrauch, F. (2011): Efficacy of entomopathogenic nematodes and fungi on larvae of Alfalfa snout weevil *Otiorhynchus ligustici* in semi-field trials in hops. DgaaE-Nachrichten 25 (2): 70

Schwarz, J., Engelhard, B., Lachermaier, U., Weihrauch, F. (2011): Efficacy of entomopathogenic nematodes and fungi on larvae of alfalfa snout weevil *Otiorhynchus ligustici* in semi-field trials in hops. In: Herz, A., Ehlers, R.-U. (eds), Report on the 29th Annual Meeting of the Working Group "Beneficial Arthropods and Entomopathogenic Nematodes": 80-81. Journal of Plant Diseases and Protection 118 (2): 80-85

Seefelder, S., Drofenigg, K., Seigner, E., Niedermeier, E., Berg, G., Javornik, B., Radisek, S. (2011): Investigations about occurrence and characterization of different strains of hop wilt (*Verticillium* ssp.) to develop a control strategy against this pathogen. Proceedings 33rd Congress European Brewery Convention.

Seefelder, S.,Drofenigg, K., Seigner, E., Niedermeier, E., Berg, G., Javornik, B., Radišek, S. (2011): Studies of *Verticillium* wilt in hops. Proceedings of the Scientific Commission, International Hop Growers` Convention, Poland, ISSN 1814-2192, 97.

Seigner, E. (2011): Welthopfensortenliste des Internationalen Hopfenbaubüros 2010. Hopfenrundschau 62 (1),12-20.

Seigner, E. (2011): Bericht zur Tagung der Wissenschaftlichen Kommission des IHB in Lublin, Poland. http://www.lfl.bayern.de/ipz/hopfen/10585/sc_2011_kurzbericht.pdf

Seigner, E. (2011): Report on the meeting of the Scientific Commission of the I.H.G.C. in Poland. http://www.lfl.bayern.de/ipz/hopfen/10585/sc_2011_report_english.pdf

Seigner, E. (2011): Hop stunt viroid monitoring. Hopfenrundschau 62 (5), 125.

Seigner, E. (2011): Hopfenforscher der LfL zum Wissensaustausch in Poland. Hopfenrundschau 62 (7), 184-185.

Seigner, E. (2011): Hopfenforscher zum Wissensaustausch in Poland – Hop Researchers meet in Poland for Information Exchange. Hopfenrundschau – International Edition of the German Hop Growers Magazine 2011/2012, 46-47.

Strumpf, T., Engelhard, B., Weihrauch, F., Riepert, F., Steindl, A. (2011): Erhebung von Kupfergesamtgehalten in ökologisch und konventionell bewirtschafteten Böden. Teil 2: Gesamtgehalte in Böden deutscher Hopfenanbaugebiete. Journal für Kulturpflanzen 63 (5): 144-155

Weihrauch, F. (2011): The significance of Brown and Green Lacewings as aphid predators in the special crop hops (Neuroptera: Hemerobiidae, Chrysopidae). Abstracts, DgaaE Entomology Congress from 21-24 March 2011 in Berlin: 196

Weihrauch, F., Schwarz, J. (2011): Monitoring of click beetles with the use of pheromone traps in hop yards of the Hallertaand In: Ehlers, R.-U., N. Crickmore, J. Enkerli, I. Glazer, M. Kirchmair, M. Lopez-Ferber, S. Neuhauser, H. Strasser, C. Tkaczuk & M. Traugott (eds), Insect Pathogens and Entomopathogenic Nematodes. Biological Control in IPM Systems. IOBC wprs Bulletin 66: 548

Weihrauch, F., Schwarz, J., Sterler, A. (2011): Downy mildew control in organic hops: How much copper is actually needed? Proceedings of the Scientific Commission of the International Hop Growers´ Convention, Lublin, Poland, 19-23 June 2011: 76-79

8.2.2 LfL publications

Name	Work Group	LfL publications	Title
Engelhard, B., Lutz, A., Seigner, E.	IPZ 5	LfL-Information (LfL publication)	Hopfen für alle Biere der Welt (Hops for all the beers in the world)
Engelhard, B., Kammhuber, K., Lutz, A., Lachermeier, U., Bergmaier, M.	IPZ 5	LfL-Schriftenreihe (LfL publication series)	Blattentwicklung und Ertragsaufbau wichtiger Hopfensorten (Leaf area development and distribution of cone formation of important hop cultivars)
Engelhard, B., Portner, J., Seigner, E., Lutz, A., Schwarz, J., Seefelder, S., Kammhuber, K., Weihrauch, F.	IPZ 5	LfL-Information (LfL publication)	Annual Report 2010 Special Crop: Hops
Portner, J.	IPZ 5a	"Grünes Heft" ("Green Leaflet")	Hops 2011

8.2.3 Press releases

Author(s), work group	Title
Seigner, E., IPZ 5c	Hofenforscher der LfL zum Wissensaustausch in Poland (LfL hop researchers meet in Poland to share expertise)

8.2.4 Radio and TV broadcasts

Name /WG	Date of broadcast	Topic	Title of programme	Station
Münsterer, J./ IPZ 5a	10.05.2011	Auswirkungen der aktuellen Trockenheit auf Hopfen (Effects of current aridity on hops)		IN TV
Portner, J., Seigner, E. IPZ 5a/c	01.08.2011	Angewandte Forschung am Beispiel des Hopfenforschungszentrums Hüll (Applied research as illustrated by the Hüll Hop Research Centre)	Bayernmagazin	Bavarian TV (Bayern1)

8.3 Conferences, talks, guided tours and exhibitions

8.3.1 Conferences, trade events and seminars

Organized by	Date/Venue	Topic	(No. of) participants
Münsterer, J. IPZ 5a	17.01.2011 Wolnzach	Seminar: Neueste Erkenntnisse zur Hopfentrocknung (Recent findings concerning hop drying)	34 hop growers
Münsterer, J. IPZ 5a	18.01.2011 Wolnzach	Seminar: Optimale Konditionierung von Hopfen (Optimum hop conditioning)	22 hop growers
Münsterer, J. IPZ 5a	01.02.2011 Wolnzach	Hinweise zur Optimierung der Konditionierung (Notes on optimised conditioning)	18 hop growers
Münsterer, J. IPZ 5a	08.02.11 Wolnzach	Workshop Bandtrockner (Workshop on belt driers)	10 hop growers
Münsterer, J. IPZ 5a	10.02.11 Wolnzach	Workshop Bewässerungskontrolle (Workshop on irrigation control)	12 hop growers
Portner, J. IPZ 5a	15.03.11 Hüll	"Grünes Heft" discussion	Colleagues from hop research institutions in G
Schätzl, J. IPZ 5a	12.05.11; 25.05.11; 08.06.11; 15.06.11; 29.06.11; 13.07.11; 27.07.11; 10.08.11; Hüll, Wolnzach, Rohrbach, Geisenfeld	Experience sharing and training sessions	Ring consultants and experts
Seigner, E., IPZ 5c	19.-23.06.2011, Lublin, Poland	Meeting of the Scientific Commission of the International Hop Growers' Convention (IHGC)	Hop scientists (52 from 13 nations)
Doleschel, P., IPZ-L	19.07.2011 Langlau	HVG e.G. Supervisory Board Meeting	Members, specialist consultants, guests; 40 participants
Doleschel, P., IPZ-L	25.08.2011 Niederlauterbach	Niederlauterbach Hop Day	Hop growers, experts, company representatives, 100 participants

Organized by	Date/Venue	Topic	(No. of) participants
Doleschel, P., IPZ-L	01.09.2011 Raum Hallertau	Guided hop tour and plant protection conference	Politicians, gov. agencies, assoc. rep's, hop growers; approx. 100 participants
Portner, J. IPZ 5a	13.09.11 Moosburg	Hop judging at the Moosburg hop show	20 members of the hop-quality assessment commission
Lutz, A., IPZ 5c, Kammhuber, K., IPZ 5d	05.10.2011 Hüll	Hop judging for VLB Exhibition in Berlin	Hop experts from the brewing industry, science, trade, growers' association; hop consulting; F. Rothmeier, Acting Distr. Admin. for Pfaffenhofen (21 participants)
Kammhuber, K., IPZ 5d	08. -09.12.2011 Hüll	Discussion: Working group for hop analysis (AHA)	Heads of hop processing-plant laboratories, VLB, Munich Technical University, Weihenstephan, 12 participants

8.3.2 Talks

WG	Name	Topic/Title	Organizer/ Participants	Date /Venue
IPZ 5a	Münsterer, J.	Optimised hop drying through the correct ratio between drying parameters	Tettnang Hop Growers' Association / 80 participants	25.01.2011 Tettnang
IPZ 5a	Münsterer, J.	Hop drying: dimensioning, optimisation, automatation	Hop growing conference / Abensberg Office for Food, Agric. and Forestry (AELF)	26.01.2011 Elsendorf
IPZ 5a	Münsterer, J.	Optimising hop drying through the correct ratio between the drying parameters	Hop Producers' Ring (HPR) / 420 hop growers	11.01.-07.02.2011 9 venues
IPZ 5a	Münsterer, J.	Evaluation meeting hop-card index	Hops working group/ 18 hop growers	22.02.2011 Haunsbach
IPZ 5a	Münsterer, J.	Evaluation meeting hop-card index	Hop syndicate/ 40 hop growers concerned	23.02.2011 Niederlauterbach
IPZ 5a	Münsterer, J.	Evaluation meeting hop-card index	Card index working group / 8 hop growers concerned	24.02.2011 Wolnzach
IPZ 5a	Niedermeier, E.	Hops: fertilisation with primary and trace nutrients	Barth company/ 13 employees	22.02.2011 Mainburg
IPZ 5a	Niedermeier, E.	Hops: plant protection update	Hop growers' group / 11 participants	11.04.2011 Wolnzach
IPZ 5a	Niedermeier, E.	Plant protection update	Hop syndicate	01.06.2011 Niederlauterbach
IPZ 5a	Niedermeier, E.	Post-hail measures	Hallertau Hop Growers' Assoc. (HVH) / approx. 70 participants	20.06.2011 Koppenwall

WG	Name	Topic/Title	Organizer/ Participants	Date /Venue
IPZ 5a	Niedermeier, E.	Wilt: research status and control measures	Elbe-Saale Hop Growers' Assoc. / hop growers, official authorities, organisations, 56 participants	30.11.2011 Grimma /Höfgen
IPZ 5a	Niedermeier, E.	Wilt: research status and control measures;	HPR/ ISO-certified experts / 75 participants	8.12.2011 Aiglsbach
IPZ 5a	Niedermeier, E.	Old and new trial results on fertilisation and its effects on wilt infection	Hop farm management working group / 9 participants	15.12.2011 Haunsbach
IPZ 5a	Portner, J.	Costs of hop drying as a function of drying performance and extent of mechanisation	Landshut and Abensberg Offices for Food, Agriculture and Forestry (ÄELF) / 100 hop growers and guests	26.01.2011 Elsendorf
IPZ 5a	Portner, J.	Update on production techniques	BayWa / 20 employees	08.02.2011 Mainburg
IPZ 5a	Portner, J.	Update on production techniques	Beiselen GmbH / 25 participants from rural trading companies	21.02.2011 Mainburg
IPZ 5a	Portner, J.	Update on production techniques	LfL and ÄELF/ 555 hop growers and guests	23.02.-04.03.2011 9 venues
IPZ 5a	Portner, J.	Current situation with respect to licensing of plant protectives for hops	DHWV and HVH/ rural trading companies, BayWa and plant protectives industry /25 participants	27.05.2011 Mainburg
IPZ 5a	Portner, J.	Update on plant protection	AELF Roth 40 hop growers	15.07.2011 Spalt
IPZ 5a	Portner, J.	Suitable catch cropping for erosion protection in hop growing	LfL 40 participants	03.08.2011 Niederlauterbach
IPZ 5a	Portner, J.	Suitable catch cropping for erosion protection in hop growing	LfL 75 participants	04.08.2011 Aiglsbach und Niederlauterbach
IPZ 5a	Portner, J.	Current plant protection problems and possible solutions in hop growing	HVH 60 participants	01.09.2011 Bad Gögging
IPZ 5a	Portner, J.	Expert hop review 2011	Moosburg 150 guests	15.09.2011 Moosburg
IPZ 5a	Schätzl, J.	Strategies for combating primary downy mildew infection	BayWa / 20 employees	08.02.2011 Mainburg
IPZ 5a	Schätzl, J.	Strategies for combating primary downy mildew infection	Beiselen GmbH / 25 participants from rural trading companies	1.02.2011 Mainburg
IPZ 5a	Schätzl, J.	Strategies for combating primary downy mildew infection	LfL and ÄELF/ 555 hop growers and guests	23.02.-04.03.2011 9 venues

WG	Name	Topic/Title	Organizer/ Participants	Date /Venue
IPZ 5a	Schätzl, J.	Strategies for combating primary downy mildew infection	Tech. Scientific Committee (TWA), Gesellschaft für Hopfenforschung e.V. (Society of Hop Research) 30 participants	29.03.2011 Wolnzach
IPZ 5a	Schätzl, J.	Forecast training: latest plant protection update	LfL and AELF Roth, 69 hop growers	01.06.2011 Spalt
IPZ 5a	Schätzl, J.	2011 review, consulting season	Hop Producers' Ring and LfL/ Ring experts and consultants	05.12.2011 Wolnzach
IPZ 5b	Engelhard, B.	Change is the only constant - a review of 16 years of hop research and 11 requests to hop growers	LfL and ÄELF/ 555 hop growers and guests	23.02. – 04.03. 9 venues
IPZ 5b	Engelhard, B.	Investigation into possible harmful effects on bees resulting from soil treatment with Actara in hop growing	Lower Bavarian Beekeepers' Association 55 participants	22.03.11 Elsendorf
IPZ 5b	Engelhard, B.	Behaviour of bees in the hop yard and effects on use of insecticides	TWA, Gesellschaft für Hopfenforschung e.V. (Society of Hop Research), 30 participants	29.03.11 Wolnzach
IPZ 5b	Schwarz, J.	Initial results of the Federal Agency for Agriculture and Food (BLE) project "Reducing or replacing copper-containing plant protectives in organic hop farming"	Hop Production Day, Bioland Hops Working Group / 22 participants	02.02.11 Berching-Plankstetten
IPZ 5b	Schwarz, J.	Latest results of trials with whey powder spray as a means of controlling the common spider mite, Tetranychus urticae, in organic hop farming	Hop Production Day, Bioland Hops Working Group / 22 participants	02.02.11 Berching-Plankstetten
IPZ 5b	Schwarz, J.	Hop leaf and cone surface growth over the vegetation period	DLR Neustadt a. d. Weinstraße / 10 participants	17.02.11 Neustadt a.d. Weinstraße
IPZ 5b	Schwarz, J.	Registration of hop plant protectives in 2011	LfL and ÄELF/ 555 hop growers and guests	23.02.-04.03. 9 venues
IPZ 5b	Schwarz, J.	Development of integrated plant protection methods against the alfalfa snout beetle in hops 5th coordination meeting	JKI 20 participants	16.11.11 Braunschweig
IPZ 5b	Weihrauch, F.	Organic hop farming in Germany and the world: introduction and importance	Young Hop Growers' Association, winter meeting/ 65 participants	25.01.11 Niederlauterbach
IPZ 5b	Weihrauch, F.	Organic hop farming in Germany and the world: introduction and importance	Hop Production Day, Bioland Hops Working Group / 22 participants	02.02.11 Berching-Plankstetten
IPZ 5b	Weihrauch, F.	The significance of Brown and Green Lacewings as aphid predators in the special crop hops (Neuroptera: Hemerobiidae, Chrysopidae)	Entomology Congress of the German Society for General and Applied Entomology / 20 participants	24.03.11 Berlin

WG	Name	Topic/Title	Organizer/ Participants	Date /Venue
IPZ 5b	Weihrauch, F.	Overview of worldwide production of organic hops	TWA, Gesellschaft für Hopfenforschung e.V. (GfH)/ 30 participants	29.03.11 Wolnzach
IPZ 5b	Weihrauch, F.	Market analysis, organic hops – Germany, Europe, world	LfL working group 'Markets for Organic Foods' / 11 participants	13.04.11 Munich
IPZ 5b	Weihrauch, F.	Downy mildew control in organic hops: How much copper is actually needed?	International Hop Growers' Convention, Scientific Commission / 53 participants	21.06.11 Lublin (Poland)
IPZ 5b	Weihrauch, F.	Overview of key areas of activity of Hüll Hop Research Centre – Plant Protection	Visit by Tsingtao Brewery, China, with Barth & Sohn, 8 participants	11.11.11, Hüll
IPZ 5b	Weihrauch, F.	The arthropod fauna of hop cones with special regard to the neuroptera	30th anniversary of the "Useful Arthropods" working group of the German Phytomedical Society (DPG) and the German Soc. for General and Applied Entomology (DgaaE) / 55 participants	30.11.11 Geisenheim
IPZ 5b	Weihrauch, F.	Reducing copper in hops - results of a BLE (Federal Agency for Agriculture and Food) project + seasonal review and copper-strategy status in hop farming	Technical discussion: "Copper in Plant Protection", JKI and BÖLW (Organic Food Industry Federation) / 90 participants	01.12.11 Berlin-Dahlem
IPZ 5c	Drofenigg, K.	Development of methods for the molecular detection of Verticillium pathotypes in hops and strategies for containment and prevention of wilt	Postgraduate-student seminar, Prof. Hückelhoven, TUM / 25 participants	11.04.11, Freising
IPZ 5c	Drofenigg, K.	Development of a rapid molecular in-planta test for the detection of Verticillium pathotypes in hop and strategies to prevent wilt	Meeting of IHGC working group / 52 participants	22.06.11, Lublin, Poland
IPZ 5c	Lutz, A.	New trends in hop breeding	Advisory Board of the Society of Hop Research, 11 participants	14.10.11, Hüll
IPZ 5c	Lutz, A.	New trends in hop breeding	Information events for hop trade and associations / 85 participants	17.10.11, 19.10.11, 20.10.11, 24.10.11, Hüll
IPZ 5c	Lutz, A.	Hop cultivars and assessment of quality features	"Alt-Weihenstephaner Brauerbund" / 35 participants	07.11.11, Freising
IPZ 5c	Lutz, A.	Flavour hops – new hop varieties for the beer market	17th working group for ISO-certified growers / 30 participants	08.12.11, Aiglsbach

WG	Name	Topic/Title	Organizer/ Participants	Date /Venue
IPZ 5c	Oberhollenzer, K.	Resistance mechanisms of different hop genotypes to hop powdery mildew	Conference of Scientific Commission (SC) of the Internat. Hop Growers' Convention (IHGC) / 52 participants	21.06.11, Lublin, Poland
IPZ 5c	Oberhollenzer, K.	Development of a transient transformation assay and functional analysis of a hop MLO-gene in powdery mildew resistance	Postgraduate-student seminar, Prof. Hückelhoven, TUM / 23 participants	25.07.11, Freising
IPZ 5c	Seefelder, S.	Investigations about the occurrence of Verticillium in some regions of the Hallertau	48th Hop Seminar in Slovenia with international participation / 120 participants	04.02.11, Portoroz
IPZ 5c	Seefelder, S.	Investigations about occurrence and characterization of different strains of hop wilt (Verticillium ssp.) to develop a control strategy against this pathogen	33rd Congress of the European Brewery Convention	24.05.11, Glasgow
IPZ 5c	Seigner, E.	Administrative meeting of the Scientific Commission of the IHGC	Meeting of the working group of the IHGC / 52 participants	22.06.11, Lublin, Poland
IPZ 5c	Seigner, E.	Hop breeding goals	Advisory Board of the Society of Hop Research, 11 participants	14.10.11, Hüll
IPZ 5c	Seigner, E.	Current hop-breeding goals	Information events for hop trade and associations / 85 participants / 85 participants	19.10.11, 20.10.11, 24.10.11, Hüll
IPZ 5c	Seigner, E.	Overview of key areas of activity of Hüll Hop Research Centre – Breeding, chem. analysis and hop growing	Visit by Tsingtao Brewery, China, with Barth & Sohn / 8 participants	11.11.11, Hüll
IPZ 5d	Kammhuber, K.	Differentiation of the world hop range by means of the low-molecular polyphenols	GfH-TWA / 30 participants	29.03.2011 Wolnzach
IPZ 5d	Kammhuber, K.	Differentiation of the world hop collection by means of the low molecular polyphenols	Meeting of the working group of the IHGC / 52 participants	21.06.11, Lublin, Poland
IPZ 5d	Kammhuber, K.	Differentiation of the world hop collection by means of the low molecular polyphenols	Advisory Board of the SHR, 11 participants	14.10.11, Hüll
IPZ 5d	Kammhuber, K.	Differentiation of the world hop collection by means of the low molecular polyphenols	Information events for hop trade and associations / 85 participants	17.10.11, 19.10.11, 20.10.11, 24.10.11, Hüll

8.3.3 Guided tours

(WG = work group; NP = no. of participants)

WG	Name	Date	Topic/Title	Guest organisation	NP
IPZ-L, IPZ 5	Doleschel, P., Kammhuber, K., Seigner, E., Weihrauch, F.	31.08.11	Hop research at the Bavarian State Research Centre for Agriculture	Management team, Kirin, Mitsubishi; Dr. Pichlmaier, HVG	8
IPZ-L, IPZ 5c	Doleschel, P, Seefelder, S. Seigner, E.	03.03.11	Hop research – genome analysis and biotechnology	AB-InBev management team	2
IPZ 5	Kammhuber, K., Lutz, A.	25.01.11	Hop breeding and analytics	Landshut State College of Further Education	45
IPZ 5	Engelhard, B., Kammhuber, K., Lutz, A., Seigner, E.	01.03.11	Hop research	AB-InBev Management Team	7
IPZ 5	Seigner, E.. Kammhuber, K.	27.05.11	Hop research	Austrian Pig Breeders' Association	30
IPZ 5	Seigner, E., Kammhuber, K.	20.07.11	Hop research	Brewing and beverage technology students from the Centre for Life and Food Sciences (WZW)	33
IPZ 5	Lutz, A., Kammhuber, K., Seigner, E.	11.08.11	Hop research in Hüll – new trends for craft brewers	Stan Hieronymus, brewing journalist, USA	1
IPZ 5	Seigner, E., Kammhuber, K.	23.09.11	Hüll Hop Research Centre	Kirin, Mitsubishi, Dr. Pichlmaier, HVG	8
IPZ 5	Lutz, A., Kammhuber, K.	27.09.11	Hop breeding; hop analytics and quality	Brewing students, Polar, Venezuela	5
IPZ 5	Seigner, E., Lutz, A., Kammhuber, K., Weihrauch,	20.10.11	Hüll Hop Research Centre	Sapporo Brewery, Japan; HVG	6
IPZ 5	Seigner, E., Kammhuber, K.	11.11.11	Hüll Hop Research Centre	Tsingtao Brewery, China; Barth	8
IPZ 5a	Fuß, S.	27.06.11	Current disease and pest situation, hop stripping trial	IGN hop growers	25
IPZ 5a	Fuß, S.	29.08.11	Farmland walkthrough: current plant growing and protection measures and recommendations in hail-hit area	Hop growers, Mainburg hail-hit area	35
IPZ 5a	Münsterer, J.	27.07.11	Hop irrigation trials	Ring experts	12
IPZ 5a	Münsterer, J.	10.08.11	Hop irrigation trials	Workshop on irrigation, Barth & Sohn	20
IPZ 5a	Münsterer, J.	12.08.11	Hop irrigation trials	Hop growers with LfL irrigation trials	13
IPZ 5a	Münsterer, J. Fuß, S. Portner, J.	03.08.11	Irrigation trials, sensor technology in plant protection, erosion protection	Young Hop Growers' Association	40

WG	Name	Date	Topic/Title	Guest organisation	NP
IPZ 5a	Münsterer, J. Fuß, S. Portner, J.	04.08.11	Irrigation trials, sensor technology in plant protection, erosion protection	Assoc. of graduates from Landshut and Kehlheim agricultural colleges	75
IPZ 5a	Münsterer, J. Fuß, S.	03.08.11	Irrigation trials, sensor technology in plant protection	Assoc. of graduates from Freising agricultural college	18
IPZ 5a	Niedermeier, E.	24.06.10	Hop farmland walk-through; current plant protection situation and strategies	Hop growers from the Bavarian Farmers' Assoc. (BBV), representatives from the municipality of Geisenfeld in Unterpindhart. Venue: Engelbrechtsmünster	38
IPZ 5a	Niedermeier, E.	10.08.11	Farmland walkthrough: current plant protection situation and strategies	Wolnzach hop growers	16
IPZ 5a	Niedermeier, E.	11.08.11	Status assessment and wilt control measures	Fa. Barth, with contract growers from the Boston Brewery	57
IPZ 5a	Portner, J.	19.05.11	Guided tour of trials re 'Hop stripping - alternatives to Lotus'	Representatives from BayWa and rural trade, hop growers	60
IPZ 5a	Portner, J.	01.09.11	Guided (bus) tour	Guests of Assoc. of German Hop Growers	50
IPZ 5a	Schätzl, J.	12.05.11	Current plant protection and hop stripping situation, farmland walk-through	Hop growers, Au "seal district"	16
IPZ 5a	Schätzl, J.	27.07.11	Farmland walkthrough: current plant growing and protection measures in hail-hit area	Hop growers from Abens, Au, Osseltshausen	17
IPZ 5b	Schwarz, J.; Weihrauch, F.	25.08.11	Plant protection trials; organic hop farming; low-trellis system	Hop Growers' Cooperative, Mühlviertel, AT	2
IPZ 5b	Weihrauch, F.	03.02.11	Organic hop farming	University of Wisconsin, USA	3
IPZ 5b	Weihrauch, F.	13.09.11	Organic hop farming; plant protection	German Hop Trade Association	2
IPZ 5b	Weihrauch, F.	26.09.11	Organic hop farming	Hop growers, Canada	1
IPZ 5c	Lutz, A.	06.06.11	Breeding lines for brewing trials	Veltins	2
IPZ 5c	Lutz, A.	09.06.11	Hüll hop research	Agricultural Training College, Pfaffenhofen Amberger	13
IPZ 5c	Lutz, A.	21.07.11	Hop breeding – new goals	Barth, Nuremberg	2
IPZ 5c	Lutz, A.	29.07.11	Hop research in Hüll	PAF School of Agriculture, summer semester	15
IPZ 5c	Lutz, A.	08.08.11	New aroma notes in hop breeding	H.P. Drexler, Scheider-Weisse, O. Weingarten, Hop Growers' Assoc.	2

WG	Name	Date	Topic/Title	Guest organisation	NP
IPZ 5c	Lutz, A.	18.08.11	Hop research	Beer Brewing Training College, Munich	2
IPZ 5c	Lutz, A.	18.08.11	Hop breeding status, hop maturity, harvesting recommendations in 2011	Information event held by Hop Producers' Ring for ISO-certified growers	25
IPZ 5c	Lutz, A.	25.08.11	New hop breeding lines	Veltins und hop growers	2
IPZ 5c	Lutz, A.	26.08.11	Cultivars and breeding lines	Riegele Brauerei, Augsburg	5
IPZ 5c	Lutz, A.	02.09.11	Hop breeding programme	Barth, St. Johann Research Laboratory	5
IPZ 5c	Lutz, A.	06.09.11	Hüll aroma hops	Ron Barchet, Eric Toft	2
IPZ 5c	Lutz, A.	07.09.11	Hüll hop varieties and new breeding lines	BayWa, Dr. Kaltner	1
IPZ 5c	Lutz, A.	20.09.11	Hüll breeding program	Val Peacock, Dan Carey, hop/brewing experts, USA	2
IPZ 5c	Lutz, A.	20.09.11	Hüll Hop Research Centre	Sumitomo Japan, Dr. Pichlmaier, HVG	4
IPZ 5c	Lutz, A.	06.10.11	New Hüll aroma hops	St. Weingart, Barth	1
IPZ 5c	Lutz, A.	13.10.11	Hüll Hop Research Centre	Brock Wagner, Saint Arnold Brewing Company, USA, HVG	2
IPZ 5c	Lutz, A.	13.10.11	Hüll Hop Research Centre, new breeding lines	David Grinnell, Boston Brewery, Dr. Schönberger, Barth	2
IPZ 5c	Lutz, A.	26.10.11	Hüll Hop Research Centre, new breeding lines	Chris Dows, Botanix, UK	1
IPZ 5c	Lutz, A.	09.11.11	Hop breeding	D. Gamache, USA	1
IPZ 5c	Lutz, A., Seigner, E.	28.07.11	Low trellis system – breeding efforts	US Dwarf Hop Assoc., L. Roy, G. Morford	2
IPZ 5c	Lutz, A., Seigner, E.	10.08.11	Tettnang cross-breeding programme, biogenesis experiments in 2011	Tettnang Hop Growers' Association	4
IPZ 5c	Lutz, A., Seigner, E.	29.09.11	New Hüll aroma hops	Eric Toft, Schönram	1
IPZ 5c	Lutz, A., Seigner, E.	05.10.11	Hüll hop breeding, historic wild hops, new Hüll aroma hops	Mr. Lossignol, Dr. Buholzer, AB-InBev	2
IPZ 5c	Lutz, A., Seigner, E.	14.10.11	New breeding lines of the Hüll Hop Research Centre	Advisory Board der GfH, Vorstand der GfH	11
IPZ 5c	Lutz, A., Seigner, E.	17.10.11	New breeding lines of the Hüll Hop Research Centre	Hopsteiner	6
IPZ 5c	Lutz, A., Seigner, E.	19.10.11	New breeding lines of the Hüll Hop Research Centre	Hallertauer Hop Growers' Association	13
IPZ 5c	Lutz, A., Seigner, E.	19.10.11	New breeding lines of the Hüll Hop Research Centre	HVG Hop Processing Cooperative, Lupex	10
IPZ 5c	Lutz, A., Seigner, E.	20.10.11	New breeding lines of the Hüll Hop Research Centre	Hop Growers of the GfH	40

WG	Name	Date	Topic/Title	Guest organisation	NP
IPZ 5c	Lutz, A., Seigner, E.	21.10.11	New breeding lines of the Hüll Hop Research Centre	IPZ 5, GfH	11
IPZ 5c	Lutz, A., Seigner, E.	24.10.11	New breeding lines of the Hüll Hop Research Centre	Barth	9
IPZ 5c	Seigner, E.	09.03.11	Hop research at the Bavarian State Research Centre for Agriculture	Western Cape delegation, South Africa, and StMELF	6
IPZ 5c	Seigner, E.	01.07.11	Hop research	Agricultural administration representatives, Korea	25
IPZ 5c	Seigner, E.	19.08.11	Hüll Hop Research Centre	Visitors to Hallertau Hop Weeks	15
IPZ 5c	Seigner, E.	19.09.11	Hüll Hop Research Centre	AB-InBev – 4 groups (USA, Scandinavia, Greece, Asia Pacific) Dr. Buholzer	98
IPZ 5c	Seigner, E.	25.09.11	Hüll Hop Research Centre	AB-InBev – (USA,Turkey) Dr. Buholzer	21
IPZ 5c	Seigner, E.	27.09.11	Biotechnology and genome analysis in hops	Brewing students, Polar, Venezuela	5
IPZ 5c	Seigner, E.	07.11.11	Hüll Hop Research Centre, breeding and plant protection	Ann George and US grower O. Weingarten	8
IPZ 5c	Seigner, E., Kammhuber, K.	24.08.11	Hop research	Hop Products Australia, Barth	2

8.3.4 Exhibitions and posters

(WG = work group)

Name der exhibition	Exhibition items/projects and topics/posters	Organised by	Duration	WG
IHGC Scientific Commission, Lublin, Poland	Sensor controlled single plant treatment in pesticide application (poster) Pesticide reduction through sensor implementation (poster) Device for automated attachment of the supporting wires in hop growing (poster) Studies of Verticillium wilt in hops Trends in hop breeding – new aroma and bitter qualities at the Hüll Hop Research Centre	International Hop Growers' Convention, Scientific Commission	19.06.-23.06.2011	IPZ 5a IPZ 5c
HopFA at the Mainburg Gallimarkt	Device for fully automated hop-training-wire stringing (poster)	Soller booth	08.10.-10.10.2011	IPZ 5a and ILT
HopFA at the Mainburg Gallimarkt	Hop drying (poster) Required measuring points for optimised drying (poster) Integrated energy-saving strategy (poster)	ATEF booth	08.10.-10.10.2011	IPZ 5a
13th European Meeting of the IOBC/WPRS Working Group	Monitoring of click beetles with the use of pheromone traps in Hallertau hop yards	Innsbruck University, AT	19.-23.06. 2011	IPZ 5b
14th Symposium on Insect-Plant Interactions	The use of metabolomics in insect resistance studies	University of Wageningen, NL	13.-18.08. 2011	IPZ 5b

8.4 Basic and advanced training

(organised / conducted)

Name, work group	Topic	Participants
Portner, J., IPZ 5a	Downy mildew	17 1st and 3rd sem. students from Pfaffenhofen School of Agric.
Portner, J., IPZ 5a	Powdery mildew and Verticillium wilt	17 1st and 3rd sem. students from Pfaffenhofen School ofAgric.
Portner, J., IPZ 5a	Minor pests and the hop aphid	17 1st and 3rd sem. students from Pfaffenhofen School ofAgric.
Portner, J., IPZ 5a	Common spider mite	17 1st and 3rd sem. students from Pfaffenhofen School of Agric.
Portner, J., IPZ 5a	Irrigation	17 1st and 3rd sem. students from Pfaffenhofen Agric. School
Portner, J., IPZ 5a	Hop drying	17 1st and 3rd sem. students from Pfaffenhofen School of Agric.

Name, work group	Topic	Participants
Portner, J., IPZ 5a	Support and evaluation of hop-growing work projects within the scope of the Masters' Exam	2 master students
Portner, J., IPZ 5a	BiLa hop-growing course (4 evenings)	33 sideline hop farmers
Schätzl, J., IPZ 5a	Exam preparation, competence training	40 hop farm women from the Freising, Kehlheim and Pfaffenhofen districts
Schätzl, J., IPZ 5a	Competence test: use of plant protectives	32 hop farm women from the Freising, Kehlheim and Pfaffenhofen districts
Schätzl, J., IPZ 5a	Information event for vocational-school pupils	12 Pfaffenhofen vocational-school pupils
Schätzl, J., IPZ 5a	Diseases and pests, current plant protection measures, warning service in Hüll	15 2nd -semester students from the Pfaffenhofen School of Agric.
Schätzl, J., Münsterer, J., IPZ 5a	Final professional-farming examination (hop production) in Jauchshofen	Exam. candidates from the Kehlheim, Landshut and Pfaffenhofen districts
Schätzl, J., IPZ 5a	Final professional-farming examination (hop production) in Thalhausen	Exam. candidates from the Freising and Pfaffenhofen districts
Schätzl, J., IPZ 5a	Repeat examination (hop production) in Anning	Exam. candidates from the Freising district
Lutz, A., IPZ 5c	Support for seminar paper entitled "A hop cultivar's journey, from selection to brewing"	A. Senftl, Schyren Secondary School, Pfaffenhofen
Lutz, A., Weihrauch, F., Portner, J., IPZ 5	Hop production, harvesting, seedling care	A.Th. Lutz, Hagl,
Seigner, E., IPZ 5c	Support for seminar paper entitled "Transgenic hops – opportunities and risks for the future"	K. Jakobi, Schyren Secondary School, Pfaffenhofen
Seefelder, S. IPZ 5c	Chemical laboratory assistant training	Tim Nerbas
Seefelder, S. IPZ 5c	Chemical laboratory assistant training	Barbara Eichinger
Seefelder, S. IPZ 5c	Internship	Maximilian Stang

8.5 Participation in work groups, memberships

Name	Memberships
Fuß, S.	Member of the professional-farmer examination committee at the Landshut training centre
Kammhuber, K.	Member of the Analysis Committee of the European Brewery Convention (Hops Sub-Committee) Member of the Workung Group Hop Analysis (AHA)
Münsterer, J.	Member of the professional-farmer examination committee at the Landshut training centre Member of the assessment committee for hop-production investments within the investment subsidy scheme for individual farms (EIF) at the Landshut Office for Food, Agriculture and Forestry (AELF)
Portner, J.	Member of the Expert Committee on the Approval Procedure for Plant Protection Equipment, responsible for advising the JKI's Application Techniques Division on the assessment of inspected plant protection equipment Member (deputy) of the Master-Farmer Examination Committee of Lower and eastern Upper Bavaria and western Upper Bavaria
Schätzl, J.	Member of the Professional-Farmer Examination Committee at the Landshut training centre Member of the professional-farmer examination committee at the Erding/Freising training centre
Seefelder, S.	Member of the LfL-KG public relations team
Seigner, E.	Chairman (since June 2009) and secretary of the Scientific Commission of the International Hop Growers' Convention Editorial board member of "Hop Bulletin", Institute of Hop Research and Brewing, Žalec, Slovenia
Weihrauch, F.	Secretary of the executive board of the Society of German-Speaking Odonatologists Editor of the magazine "Libellula" Neuoptera work group of the German Society of General and Applied Entomology (DgaaE) – responsible for bibliography Member of the Bavarian Environmental Protection Agency's working groups on red-listed grasshoppers and dragonflies in Bavaria

8.6 Awards and commendations

Bernhard Engelhard, IPZ 5b, level-2 'Officer of the Order of the Hop', awarded by the International Hop Growers' Convention (IHGC)

Erich Niedermeier, IPZ 5a, 'Order of the Hop' awarded at the summer session of the German Hop Growers Association in Spalt

9 Current research projects financed by third parties

WG Project manager	Project	Duration	Sponsor	Cooperation
IPZ 5a J. Portner, S. Fuß	Response of important aroma and bitter varieties to reduced trellis height (6 m) and testing of new plant-protective application techniques	2008-2011	Erzeugergemeinschaft Hopfen HVG (HVG Hop Producer Group)	Mitterer, Terlan (I) Syngenta, Basel (CH)
IPZ 5a J. Portner	Studies to investigate the structural design of hop trellis systems	2009-2012	Erzeugergemeinschaft Hopfen HVG (HVG Hop Producer Group)	Bauplanungs- and Ing.-Büro S. Maier, Wolnzach
IPZ 5a J. Portner	Development and optimisation of an automatic hop-picking machine	2011-2013	Bundesanstalt für Landwirtschaft und Ernährung (BLE) (Federal Agency for Agriculture and Food)	ILT, Freising; Fuß Fahrzeug- und Maschinenbau GmbH & Co. KG, Lutzmannsdorf
HSWT-FA Gartenbau Dr. Beck	Optimisation of irrigation management in hop growing	2011-2014	Deutsche Bundesstiftung Umwelt (DBU)	HSWT-FA für Gartenbau, Freising; Fa. ATEF, Vohburg; HVG, Wolnzach
IPZ 5b Dr. Weihrauch	Reducing or replacing copper-containing plant protectives in organic hop farming	2010-2013	Bundesanstalt für Landwirtschaft und Ernährung (BLE) (Federal Agency for Agriculture and Food) within the scope of the Federal Organic Farming Programme (BÖLN)	Organic hop farm
IPZ 5b Dr. Weihrauch	Testing of an innovative forecasting model for the control of powdery mildew (*Podosphaera macularis*) in hops	2010-2012	Erzeugergemeinschaft Hopfen HVG (HVG Hop Producer Group)	4 hop yards
IPZ 5b Dr. Weihrauch Schwarz	Development of integrated methods of plant protection against the alfalfa snout beetle *(Otiorhynchus ligustici)* in hops	2008-2012	Bundesanstalt für Landwirtschaft und Ernährung;(BLE) (Fed. Agency for Food and Agriculture)	Curculio-Institut e.V., Hannover; hop growers; part of integrated JKI project
IPZ 5b/IPZ 5c Dr. Weihrauch	Long-term optimisation of aphid *(Phorodon humuli)* control in hops *(Humulus lupulus)* by means of control thresholds and breeding of aphid-tolerant hop cultivars	2008-2011	Deutsche Bundesstiftung Umwelt (DBU) (project ended on 31.03.2011; remainder of 2011: monitoring of model out of personal interest by IPZ 5b)	Hop growers
IPZ 5b/IPZ 5c/ IPZ 5d Dr. Weihrauch	Identification of compounds involved in the attraction and resistance of hop to the damson-hop aphid	2010–2012	Erzeugergemeinschaft Hopfen HVG (HVG Hop Producer Group)	Plant Research International B.V., Wageningen, NL
IPZ 5c Dr. Seigner Lutz Dr. Seefelder	PM isolates and their use in breeding PM-resistant hops	2011-2012	Erzeugergemeinschaft Hopfen HVG (HVG Hop Producer Group)	EpiLogic

WG Project manager	**Project**	**Dura-tion**	**Sponsor**	**Cooperation**
IPZ 5c Dr. Seefelder Dr. Seigner	Genotyping of *Verticillium* pathotypes in the Hallertau – basic findings concerning *Verticillium* -infection risk assessment	2008-2013	Erzeugergemeinschaft Hopfen HVG (HVG Hop Producer Group), Wissenschaftsförderung der Deutschen Brauwirtschaft e.V. (Wifö) (scientific promotion of the German Brewing Industry e.V.)	E. Niedermeier IPZ 5a; Dr. Radisek, Slovenian Institute of Hop Research and Brewing; SL; Prof.B. Javornik, Uni. Ljubljana, SL; Prof. G. Berg, University Graz, Austria
IPZ 5c Dr. Seigner	Characterisation of hop/hop powdery mildew interaction and functional analysis of defence-related genes	2008-2011	Erzeugergemeinschaft Hopfen HVG (HVG Hop Producer Group)	Prof. Hückelhoven, Munich Technical University, Centre of Life and Food Sciences (TUM-WZW); IPZ 3b; EpiLogic,
IPZ 5c Dr. Seigner Lutz	Breeding of resistant hops particularly suited for growth on low-trellis systems	2007-2011	Bundesanstalt für Landwirtschaft und Ernährung (BLE) (Federal Agency for Agriculture and Food)	J. Schrag and M. Mauermeier hop farms, Society of Hop Research (GfH)
IPZ 5c Dr. Seigner Lutz IPS 2c Dr. L. Seigner	Monitoring of dangerous viroid and viral hop infections in Germany	2011-2012	Wissenschaftliche Station für Brauerei in München e.V. (Scientific Station for Brewing in Munich)	Dr. K. Eastwell, Washington State University, Prosser, USA
IPZ 5c Dr. Seigner Lutz	Cross-breeding with the landrace Tettnanger	2011-2014	Ministerium für Ländlichen Raum, Ernährung und Verbraucherschutz (MLR) (Ministry of Land and Resources), Society of Hop Research (GfH) Hop Growers' Association Tettnang e.V.	Versuchsgut Straß, F. Wöllhaf.
IPZ 5d Dr. Kammhuber	Differentiating and classifying the world hop range with the help of low-molecular plyphenols	2010-2011	Bayerisches Staatsministerium für Ernährung Landwirtschaft und Forsten (StMELF) (Bavarian State Ministry for Food, Agric. and Forestry)	Munich Technical University, Weihenstephan, Dr. Coelhan

10 Main research areas

WG	Project	Duration	Cooperation
5a	Specialist advice on hop production techniques and business management	Ongoing	
5a	Production-related and economic evaluation of hop card indices	Ongoing	
5a	Compilation and updating of advisory-service documentation	Ongoing	
5a	Evaluation of downy mildew forecasting models and preparation of information for the warning service	Ongoing	
5a	Optimisation of plant-protective application methods and equipment; 2011: Trials to test for potential savings in plant-protective consumption through use of sensors during row treat ment, Spray-coating measurements with an innovative sprayer	Ongoing	
5a	Trials to investigate irrigation control in hop growing within the scope of the research project "Agro-climate Bavaria"	2005-2011	DWD; IAB; ILT
5a	Optimising nitrogen fertilisation by means of banded application	2007-2012	
5a	Testing of an Adcon weather model for the downy mildew warning service	2008-2013	Hop Producers' Ring
5a	Positioning of drip hose in hop irrigation	2009-2011	
5a	Hallertauer model for resource-saving hop cultivation	2010-2014	LWF; LfU Fa. Ecozept
5a	Prüfung verschiedener Nährstofflösungen und Additive zum Hopfenputzen	2011	K & S, AlzChem
5b	Testing of plant-protectives for their efficacy against various harmful organisms and their compatibility in hops as a prerequisite for registration and authorisation of these products for hop growing – offical pesticide testing according to EPPO and GEP guidelines; 2011: 93 trial variants with 38 products at 18 locations	Ongoing	Plant protection companies, hop growers
5b	Elaboration of maximum residue levels	Ongoing	Hop growers
5b	Insecticide-resistance monitoring	Ongoing	
5b	Soil pest control	Ongoing	Hop growers
5b	Investigations into the occurrence and ecology of pests and beneficial organisms in hop yards	Ongoing	TU Munich, Chair of Animal Ecology
5b	EU-wide harmonisation of trial procedures for plant-protective products in hops	2005 -	JKI; Institutes in CZ, F, PL, SI, UK
5b	Trials aimed at reducing the amount of copper used to control downy mildew	2006 -	Spiess-Urania; organic hop farmers
5b	Data pool on extent of worldwide organic hop farming	2010 -	Barth reportt
5b	Click-beetle and wire-worm monitoring in selected hop yards	2010 - 2012	JKI; DPG; Syngenta Agro GmbH, Uni Göttingen
5c	Breeding of high-quality, disease-resistant aroma and bitter varieties	Ongoing	EpiLogic, Dr. F. Felsenstein, Freising
5c	Testing of wild hops as a new genetic resource for breeding powdery-mildew-resistant cultivars	Since 1999	EpiLogic, Dr. F. Felsenstein, Freising
5c	Breeding of high-quality aroma and bitter varieties containing optimised hop components - flavour hops	Ongoing	IPZ 5d

WG	Project	Duration	Cooperation
5c	Breeding of high-quality cultivars with increased levels of health-promoting, antioxidative and microbial substances, also for areas of application other than the brewing industry	Ongoing	IPZ 5d
5c	Promoting quality through the use of molecular techniques to differentiate between hop varieties	Ongoing	IPZ 5d; propogation farms, hop tradel
5c	Use of molecular markers for testing breeding material for PM resistance and for distinguishing between male and female seedlings	Ongoing	
5c	Meristem cultures to eliminate viruses – a basic requisite for virus-free planting stock	Since 2009	IPZ 5b, Frau O. Ehrenstraßer ; IPS 2b
5c	Optimisation of in-vitro propagation – especially for foreign varieties and wild hops	Since 2010	
5d	Performance of all analytical studies in support of the work groups, especially Hop Breeding Research, in the Hop Department	Ongoing	IPZ 5a, IPZ 5b, IPZ 5c
5d	Development of analytical methods for hop polyphenols (total polyphenols, flavonoids and individual substances such as quercetin and kaempferol) based on HPLC	2007-open ended	AHA Work Group
5d	Production of pure alpha acids and their ortho-phenylenediamine complexes for monitoring and calibrating the ICE 2 and ICE 3 calibration extracts	Ongoing	AHA Work Group
5d	Ring tests for checking and standardising important analytical parameters within the AHA laboratory (e.g. linalool, nitrate, HSI)	Ongoing	AHA Work Group
5d	Development of an NIRS calibration model for alpha-acid content based on HPLC data	2000-open ended	
5d	Organisation and evaluation of ring analyses for -acid determination of hop supply contracts	2000-open	AHA Work Group
5d	Varietal authenticity checks for the food control authorities	Ongoing	Landratsämter (Lebensmittelüberwachung) (District food control authotities)
5d	Introduction and establishment of UHPLC in hop analytics	2008-open	

11 Personnel at IPZ 5 – Hops Department

The following staff members were employed at the Bavarian State Research Centre for Agriculture, Institute for Crop Science and Plant Breeding, at Hüll, Wolnzach and Freising in 2011 (WG = Work Group)

IPZ 5

Coordinator: **LLD Engelhard Bernhard (until 31.03.2011)**
Director at the LfL Dr. Peter Doleschel
(provisionally as of 01.04.2011)

Dandl Maximilian
Felsl Maria
Fischer Elke (bis 30.09.2011)
Hertwig Alexandra (as of 01.10.2011)
Hock Elfriede
Krenauer Birgit
Maier Margret
Mauermeier Michael
Pflügl Ursula
Presl Irmgard
Suchostawski Christa
Waldinger Josef (until 31.01.2011)
Weiher Johann

IPZ 5a

WG Hop Cultivation/Production Techniques
LD Portner Johann

Fischer Elke
LOI Fuß Stefan
Dipl.-Biol. (Univ.) Graf Tobias (as of 01.12.2011)
LA Münsterer Jakob
LA Niedermeier Erich
LAR Schätzl Johann

IPZ 5b

WG Plant Protection in Hop Growing
LLD Engelhard Bernhard (until 31.03.2011)
LD Portner Johann (provisionally as of 01.04.2011)

LTA Ehrenstraßer Olga
LI Meyr Georg
Dipl.-Ing. (FH) Schwarz Johannes
Dr. rer. nat. Weihrauch Florian

IPZ 5c

WG Hop Breeding Research
RD Dr. Seigner Elisabeth

Agr.-Techn. Bogenrieder Anton
CTA Forster Brigitte
Frank Daniel (until 31.03.2011)
MS Biotech. (Univ.) Drofenigg Katja
CTA Hager Petra
LTA Haugg Brigitte
Agr.-Techn. Ismann Daniel (as of 01.05.2011)
LTA Kneidl Jutta
LAR Lutz Anton
Hofmann Kerstin
Dipl.-Biol. (Univ.) Oberhollenzer Kathrin
CL Petosic Sabrina (until 31.08.2011)
BL Püschel Carolyn
ORR Dr. Seefelder Stefan

IPZ 5d

WG Hop Quality and Analytics
ORR Dr. Kammhuber Klaus

MTLA Magdalena Hainzlmaier (as of 16.08.2011)
CL Neuhof-Buckl Evi
Dipl.-Ing. agr. (Univ.) Petzina Cornelia
CL Sperr Birgit (until 28.02.2011)
CTA Weihrauch Silvia
CTA Wyschkon Birgit