

Breeding of Resistant Hops Especially Suitable for the Growth on Low Trellis Systems

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Summary

71 specific crosses were conducted from 2007 till 2011 with the aim to develop hop cultivars which due to their shorter stature, broad disease resistance and excellent brewing qualities, are particularly suitable for profitable and ecologically sustainable cultivation on low trellis systems. 29 crosses were performed with focus to produce aroma quality and 42 crosses with the goal to increase the alpha acid contents.

In each year at the beginning of March pre-selection started with these seedlings deriving from the crosses conducted the year before. Over the years in total approx. 110,000 seedlings in seed dishes were inoculated with four PM (*Podosphaera macularis* ssp. *humuli*) strains typical of the Hallertau region and thus tested for their resistance. Seedlings without visible PM infections 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. Subsequently, the PM resistant seedlings and in some cases also seedlings which had not been pre-selected for PM resistance were tested for tolerance towards downy mildew (*Pseudoperonospora humuli*). In mid May, seedlings showing increased disease resistance or tolerance were planted out in the vegetation hall, where their growth, vigor and once again their resistance towards fungal attacks under natural conditions were monitored until fall. At the same time, based on flowers male and female plants could be distinguished. For those seedlings without any flowers molecular markers were used for sex selection. Plants showing considerable deficiencies, such as severe aphid infestation, powdery mildew or root rot, or those with unsuitable growth types were discarded by fall.

Out of 3,570 seedlings in total which were grown and monitored in the growth hall, at the end of the season 2,800 female and 268 male seedlings were transplanted to the Hüll or Freising breeding yard with high trellis. During their two- to three-year-evaluation as seedlings they were tested for their vigor and growth behavior under high trellis conditions. Moreover, their resistance or tolerance towards downy and powdery mildew was assessed under natural infection conditions, especially since pesticide applications were reduced to a minimum. Here, the seedlings could also be tested for their tolerance towards Verticillium wilt, since testing is only possible with a fully developed roots system. Only agronomically promising and healthy seedlings were evaluated. At this step, in addition resistance towards non-

indigenous powdery mildew strains was tested using the detached leaf assay in the laboratory in order to achieve a broader resistance to PM of the seedlings. Finally, the most promising 141 seedlings were harvested (only approx. 5 % of a year's generation). Furthermore, the cones of these seedlings were evaluated and their cone compounds chemically analyzed. All samples harvested were analyzed for the bitter acid contents. The aroma quality was evaluated sensorically, since so far no key compounds describing aroma quality were available.

Taking to account, yield, cone assessment, chemical data and the organoleptically determined aroma values highly promising experimental lines from the respective generations were vegetatively propagated the next spring and planted out in the low trellis yard in Starzhausen.

While in 2009 and 2010 in particular seedlings with improved aroma quality were selected for the growth on low trellis system, at harvest 2011 some experimental lines showed very high alpha acid contents when grown under high trellis conditions. This means that also in the bitter sector significant progress in breeding could be achieved. In addition, last season two seedlings attracted our attention showing strong citrusy aroma. Since a new trend has been started worldwide focusing on hops with pronounced citrusy, fruity and floral aroma notes, it is of significant importance of being able to provide low trellis adapted germplasm and lines with these new aroma impressions.

Growth on the low trellis system at the farm of Schrag and Mauermeier

Seedlings 2008

In June 2010 for the first time twelve pre-selected seedlings which derived from the first specific crosses performed within this dwarf hop project (generation of seedlings 2008) were planted out to the 3-meter-trellis system in Starzhausen. These young plants showed good growth until fall. However, they were not harvested in this first year of cultivation so that the plant and its root stock did not have to bear the loss of nutrients through harvest, but could gain strength by storing nutrients in the root system. Furthermore, young hops without fully developed root system do not allow evaluating their resistance towards diseases. In addition, the contents of cone compounds are at a drastically reduced level in comparison to older hops. Thus, for these seedlings selected for the growth on low trellis systems no results were available for one full year and harvest data and results concerning their growth behavior could not be provided before the second year.

After their first harvest on low trellis, seven experimental lines attracted attention in revealing pleasantly and very fine aroma notes. With 26 or 27 aroma points of a maximum of 30, they

reached the level of the well-known Hüll aroma cultivars. Also the chemical data on bitter acids of the experimental line 2008/073/056, 2008/073/064 and 2008/073/103 were quite promising in showing alpha acid contents of approximately 10 % and yields of 1,900 – 2,300 kg /ha.

Seedlings 2008 – 2010 on low trellis systems

In June 2011, once more eight seedlings from the 2008 seedlings` generation and five from the 2009 generation, which had proven good potential under high trellis conditions, were planted out to the low trellis yard in Starzhausen. In 2012 for these seedlings the first “reliable” harvest data will be available.

Experiences gained during the growth on the low trellis yards in Pfaffenhofen and Starzhausen

From 1993 till 2002 during the BLE funded R&D projects English dwarfs, Hüll cultivars adapted to high trellis and breeding lines with shorter stature have been grown on both low trellis systems at Starzhausen and Pfaffenhofen. These trials were continued after 2002 in order to gain more information about the production of hops on three-meter-trellis systems.

In general, the rows were cultivated conventionally with 75 cm distance between the plants and on galvanized training wire.

In addition, two experimental lines with shorter stature which derived from other crossing programs were grown in two rows of each in order to compare the conventional and non-cultivation growing system and to test wire or netting as training material.

Thereby, basic problems with soil-borne diseases such as downy mildew primary infection became obvious. At the location with heavy-clay soil in Pfaffenhofen each year this disease caused problems which could only be stopped by the application of systemic fungicides. On the other side, in Starzhausen on sandy soil spider mite became a threat, especially in older stands. While in newly established plots the wire was free and vines could climb up without problems, thus no increased infestation problems with spider mite in comparison to high trellis stands could be observed. However, these problems with spider mites became worse in „older“ trial plots, where dried vines and shoots which were left on the field after harvest offered optimal overwintering conditions for spider mites. The removal of the old vines using a specific cutting machine would be the only solution. This additional operation means more costs, but significantly reduces the application of acaricides. Moreover, the removal of old vines facilitates the twining and climbing up of young vines in the next season.

In this context also the use of long-living synthetic strings as alternative material to the inflexible galvanized wires as training material showed its benefits. This material became more

flexible under warm weather condition, and then there was much more support for the twining bines. In this way, the skidding down of the heavy bines before harvest could be prevented effectively. This was also the solution for the long-lasting problem with slipped-down bines providing shelter for spider mites.

Significant progress could be achieved in the fight against red spider mites by the release of predators. In recent years, several sprayings against spider mite were inevitable, in 2011 after an early acaricid application predators were released at the location Starzhausen. A mixture of two predatory mites *Phytoseiulus persimilis* and *Amblyoseiulus californicus* was used. These predatory mites controlled very effectively the red spider mite throughout the season, so that the stand was kept mite-free until harvest. Both species are thermophilic and do not overwinter. Therefore, trials in 2012 will be continued with the indigenous overwintering species *Thyphlodromus pyrii*. In this way, an environmental beneficial and at the same time cost-effective measure to control red spider mite could be found, full in compliance with integrated pest management. .

A crucial improvement of the picking performance of the picking machine could be reached in 2010, where in particular losses of crop around the piles during the harvest could be reduced significantly. Even tightly entangled bines with the netting could be picked properly.

Furthermore, knowledge could be gained concerning the different tolerance towards the dry-hot phases of the early summer of 2011. Since at both trial locations the option for irrigation is missing, especially the extreme short (classical dwarf) types showed dramatic signs of drought damage. These dwarfs have very shortened above-ground growth and moreover, a relatively small root stock. Thus, they could not reach deeper water supplies which meant only unsatisfying yields of these dwarfs when compared with the results of last year. The semi-dwarfs, on the other hand, with more luxuriant growth showed similar yields as obtained last year.

In particular, significant economical benefits in the cultivation of hops on low-wirework systems were expected. The so-called non-cultivation system without pruning and reduced tilling might save labor capacity and reduce the employment of machines and thus would lower capital costs. During this project one objective was to investigate to what extent the significantly labor-intensive traditional cultivation form with pruning and tilling could be replaced by the so-called non-cultivation form. After three years of testing there is no conclusive trend. While in 2010 the traditional cultivation form seemed to have advantages, in 2011 the „non-cultivation“ system was as good as the other system at the trial yard in Starzhausen and in Pfaffenhofen it was superior.

Résumé

The first promising breeding lines which show the crucial characteristics of a marketable hop variety such as fine aroma quality, yields of 2 tons and satisfying disease resistance have been created in the course of this project. In the bitter sector based on last year`s harvest data some seedlings which were still grown under high trellis conditions also showed convincing alpha acids and good yield. However, at the moment relatively high susceptibility towards downy mildew and red spider mite has been observed. The sprayings with acaricides add to costs which impede the economically and ecologically effective and beneficial production on low trellis systems. But in combination with the already successful control of red spider mites by predators the costs for chemical plant protection could be reduced. High hopes are set on the numerous seedlings which were created within this project, although they are still not ready to be grown and selected on low trellis yards. So far only seedlings from 14 out of a total of 71 crosses could be evaluated in their suitability for low trellis systems based on their results obtained after being harvested on 3 meter production systems. An enormous, but still not selected potential can be expected in these progenies. These selections steps will be continued, even after the funding of this project has been stopped.

We are quite optimistic that in this breeding program low-stature hops in the aroma as well as in the bitter sector could be developed which pave the way to the profitable cultivation of hops on low trellis systems. These plants are the crucial prerequisite in order to start with the adjustments towards the low trellis system in due time. Then also the German hop growers will be able to exploit the diverse economical and ecological benefits of this innovative cultivation system. By then certainly the various still unanswered questions surrounding work technique (training material, tilling) and disease problems (spider mite infestation, downy mildew infection) have to be clarified.