# The effect of time of cutting on yield and the quality of the hop hybrid varieties Harmonie, Rubín and Agnus

**K. Krofta, J. Ježek**

*Hop Research Institute Co. Ltd., Žatec, Czech Republic*

**ABSTRACT**

The influence of mechanized cutting time on the yield and quality of hops was studied for three years (2007, 2008 and 2009) in three Czech hybrid varieties Harmonie, Rubín and Agnus. The cutting term classified as 'early' was carried out at the turn of March and April. Further cutting dates were made at intervals of 7–10 days and they were classified as 'middle' and 'late' ones. Yield and contents of alpha acids were evaluated during the machine harvest. The measured data revealed no statistical relationship between term of cutting, alpha acid content and yield in any of the tested cultivars. However, during the experimental period considerable inter-annual differences were observed, especially in the yield. Average yield in the range of 2.0–2.5 t/ha in the period 2007–2008 decreased to 1.2–1.9 t/ha in 2009 due to downy mildew attack. On the basis of the obtained data it can be recommended to cut the hybrid varieties Harmonie, Rubín and Agnus in the first ten days of April, taking into account other factors such as age and the location of hop garden and current weather conditions.

**Keywords**: hops; hop cutting; term of cutting; yield of hops; quality of hops; alpha acid

Cutting hops is one of the key agro-technical operations within hop growing. This operation means removal of new wood from the root system of hop crowns. Properly executed cuts should be smooth and straight. Correctly done cutting effects yield of hops not only in the current season but in the subsequent seasons as well. Hop cutting greatly influences the lifetime of the hop plants. It also serves to regulate shape of hop crowns, thus maintaining them in needed depth below the ground. Without any cutting it is difficult to keep the hop in a flat culture. Trials to miss this operation were not successful. As hop plants to be cut are under the ground, cutting is performed at a depth up to 5 cm below the ground level. Theoretically, it is possible to make cutting either in the fall and or in the spring, however, most growers prefer to do it in the spring. Cutting of the Saaz aroma variety (Saazer) is recommended during the first and second decade of April, and in some localities even later (Kopecky and Sachl 1985). Until the 1960's, hop crowns were cut by hand using special knives. Today this operation is carried out using a pair of mechanized rotating cutting discs.

Introduction of mechanized cutting meant the beginning of a new and revolutionary hop cutting technique. Labour peak was reduced in the spring because the cut could be done in a shorter time period, which was favourable for hop plants (Snobl 1981). Several years of trials (Sachl 1967) revealed that there was not a significant difference in both quality and quantity of harvested cones between mechanized and manual cutting; according to the author mechanized cutting had a positive effect on balanced germination of hop shoots. When mechanical re-cutting is carried out there are some changes in morphology of the underground organs in hop plants. The hills increase size of hop crowns in the direction of rows. Mechanical damage leads to mortality of approximately 0.3% of plants depending on soil and hydrological conditions of the site (Sachl 1968). Effect of cutting time on yield and alpha acid content of Saazer in two locations in the years 1971–1973 was published by Stranc (2007). He found that hop plants had

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more vigorous growth habit after the autumn cutting. On the other hand, at the time of cone maturation they were more affected by drought with a negative impact on yield and alpha acid content. The best experience was achieved with early and mid-spring cutting. Timing of cutting can be very effective in regulation onset of vegetation in springtime. Cutting of hybrid varieties is more difficult as these have a different vegetation period, longer than Saazer. For this reason, their cutting requires different approaches (Koren 2007). Cutting hybrid hops is recommended as early as the second decade of March. It is recommended to keep the rule – the older hop plants are, the earlier cutting should be. In warmer localities with lighter soil, hop plants ought to be cut later, and on the contrary, in colder heavy soils hop plants should be cut earlier, in order to speed up the time of sprouting and training of hops shoots (Kopecky 2008). Effect of cutting in Agnus variety on yield and alpha acid content was examined by Krivanek (2008) in the years 2003–2005. He found that later cutting caused a reduction in the number of shoots suitable for training and time lag for the development and maturation of hop cones until the first decade of September. Commonly, the highest yield and alpha acid content in all years of the investigated period were shown at hop plants cut shallower as well as later, at the end of the second decade of April.

This paper presents the results obtained from three years of field trials aimed at the determination of optimal term of cutting in three Czech hop hybrid varieties. The evaluation parameters were the yield and alpha acid content. During vegetation, the growth dynamics of the hop plants and their habit were compared as well.

## MATERIAL AND METHODS

The influence of mechanized cutting time on yield and quality (alpha acid content) of hops was studied in the years 2007, 2008 and 2009 with three Czech hybrid cultivars: Harmonie, Rubín and Agnus. Harmonie is an aroma variety, characterized by a balanced content of alpha and beta acids in the range of 5–8% in weight. It is a 'semi-late' hop with vegetation period of 135–138 days. Rubín belongs to the bitter hops. It is characterized by red-purple bine and high growing vitality. The length of the vegetation period is 136–140 days. Agnus is a variety, which contains up to 15% of alpha acids and is thus suitable for production of hop extracts. The length of the vegetation period is 132–138 days. Agrotechnical experiments were carried out at the 'Ctvercova' hop garden in the farm of Hop Research Institute in Stekník. The hop garden was founded in a uniform spacing: 300 × 114 cm in the autumn 2003. In terms shown in Table 1, mechanical cutting in the length of 3 rows was carried out. The area of each experimental variant was 0.2 ha, and the whole field trial occupied the area of 1.8 ha. The cutting term classified as 'early' was carried out at the turn of March and April. Further cutting dates were set in intervals of 7–10 days and they were classified as 'middle' and 'late' ones. Late cutting was carried out between the 15$^{th}$ and the17$^{th}$ of April. The depth of cutting was uniform up to 5 cm below the ground level. Training of hop plants was done on several dates as listed in Table 2.

Weather conditions during the initial phase of the hop growth from March to June are shown in Table 3. Longitudinal growth of hop plants after training was regularly evaluated until they reached the top of the trellis. Harvest was done mechanically on the stationary picking machine Wolf 300 in the stage of technological maturity. Hops picking was carried out in the following way: each experimental plot was picked in a columnar arrangement and each variant had four replications. Weight of picked hops was converted to a theoretical yield of dried hops in t/ha. Within each experimental variant a sample of hop cones was taken and dried in an oven chamber to a final moisture content 8–10% of weight. Immediately after drying the cones were analyzed for alpha and

Table 1. Terms of cutting of hybrid varieties in the period 2007–2009

| Year | Early | Middle | Late |
|---|---|---|---|
| 2007 | March 31 | April 11 | April 17 |
| 2008 | March 26 | April 9 | April 17 |
| 2009 | April 1 | April 7 | April 15 |

Table 2. Terms of training of hybrid varieties depending on the cutting date in the period 2007–2009

| Year | Early | Middle | Late |
|---|---|---|---|
| 2007 | April 23 | April 28 | May 2 |
| 2008 | May 1 | May 8 | May 17 |
| 2009 | April 26 | May 4 | May 8 |

Table 3. Weather conditions (daily mean temperature, precipitation) in the period March–June in the years 2007–2009

| Month/year | 2007 | | 2008 | | 2009 | |
|---|---|---|---|---|---|---|
| | temperature (°C) | precipitation (mm) | temperature (°C) | precipitation (mm) | temperature (°C) | precipitation (mm) |
| March | 6.4 | 16.8 | 4.8 | 16.8 | 5.6 | 21.8 |
| April | 11.7 | 2.8 | 8.8 | 50.4 | 13.0 | 22.8 |
| May | 15.8 | 58.4 | 14.6 | 50.6 | 14.7 | 135.0 |
| June | 19.4 | 60.2 | 18.8 | 92.0 | 16.1 | 73.4 |

beta acids by liquid chromatography method EBC 7.7 (Analytica 1998). Analyses were performed on a liquid chromatograph SHIMADZU LC 20A (Shimadzu Corporation, Kyoto, Japan). The statistical evaluation of yield and alpha acid contents data were performed with a single parameter analysis of variance (ANOVA) using statistical software QC-Expert, Version 2.5 (TriloByte Pardubice).

## RESULTS AND DISCUSSION

Basic weather conditions listed in Table 3 show considerable variation in the weather conditions in the individual years. April 2009 was exceptionally warm. Temperatures reached the values of 4.5°C above the long-term average. Warm weather was accompanied by the lack of rainfall. Low precipitations in April were also typical for the year 2007. Monitoring of growth dynamics of the hop plant showed that the early cutting increased quantity of biomass. Besides, flowering stage began earlier. In the middle of May hybrids, which were cut early reached the height of 2.5–3 m. Hop plants cut in later terms were shorter by 1–2 m at that time. The delay in their development was evident at the beginning of June when the plants cut early were at two thirds of trellis height, whereas the late cut plants were in the middle of the trellis. Visual change occurred in early July, when all the plants reached the top of trellis gradually within a week time. In the later vegetation stages the plants that were cut early were more vigorous than plants cut later. It reflected higher crop shading. On the contrary, the later cut plants had more noticeable light transmission. In spring the ability of young shoots to self-train around the guide wires was recorded. The visual observations showed that hops shoots, depending on weather conditions, reached the length, at which they were able to train, on average 14–15 days after the cutting date. The best self-training ability was observed in Agnus. At the time of the training, more than 30 % of shoots were self-trained. Variability of determined values of alpha acid contents and yields of four replications in all the tested varieties throughout the

Table 4. Yield of dry hops (t/ha) of Harmonie, Rubín and Agnus varieties in the period 2007–2009, depending on the term of cutting

| | 2007 | | | 2008 | | | 2009 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 31. 3. | 11. 4. | 17. 4. | 26. 3. | 9. 4. | 17. 4. | 1. 4. | 7. 4. | 15. 4. |
| Harmonie | | | | | | | | | |
| Arithmetic mean | 2.98 | 2.64 | 2.76 | 2.43 | 1.80 | 2.22 | 1.78 | 1.84 | 1.67 |
| Median | 2.97 | 2.56 | 2.82 | 2.49 | 1.76 | 2.29 | 1.81 | 1.87 | 1.61 |
| Rubín | | | | | | | | | |
| Arithmetic mean | 2.26 | 2.22 | 2.53 | 2.35 | 2.19 | 2.17 | 1.06 | 1.21 | 1.23 |
| Median | 2.25 | 2.26 | 2.58 | 2.33 | 2.19 | 2.20 | 1.12 | 1.18 | 1.24 |
| Agnus | | | | | | | | | |
| Arithmetic mean | 2.36 | 2.84 | 2.29 | 2.46 | 2.39 | 2.60 | 1.79 | 1.54 | 1.52 |
| Median | 2.35 | 2.72 | 2.38 | 2.54 | 2.30 | 2.64 | 1.75 | 1.55 | 1.52 |

Table 5. Content of alpha acid in varieties Harmonie, Rubín and Agnus depending on the term of cutting in the period of 2007–2009

| | 2007 | | | 2008 | | | 2009 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 31. 3. | 11. 4. | 17. 4. | 26. 3. | 9. 4. | 17. 4. | 1. 4. | 7. 4. | 15. 4. |
| Harmonie | | | | | | | | | |
| Arithmetic mean | 8.87 | 8.49 | 9.47 | 9.48 | 10.63 | 9.94 | 10.08 | 10.24 | 10.78 |
| Median | 8.78 | 8.49 | 9.38 | 9.33 | 10.64 | 9.91 | 9.91 | 10.25 | 10.73 |
| Rubín | | | | | | | | | |
| Arithmetic mean | 12.04 | 12.06 | 11.49 | 13.39 | 14.26 | 13.54 | 13.60 | 14.72 | 13.53 |
| Median | 12.07 | 12.12 | 11.71 | 13.61 | 14.14 | 13.62 | 13.57 | 14.75 | 13.52 |
| Agnus | | | | | | | | | |
| Arithmetic mean | 10.44 | 10.21 | 10.21 | 14.45 | 14.36 | 14.32 | 13.55 | 12.66 | 13.55 |
| Median | 10.56 | 10.06 | 10.22 | 14.37 | 14.48 | 14.34 | 13.57 | 12.61 | 13.53 |

experimental period are expressed as arithmetic means and medians. Data are shown in Tables 4, 5, and Figures 1–2 (Harmonie). Statistical evaluation of primary data by analysis of variance is summarized in Table 7. Statistical significance was tested by the *F*-test. Statistical evaluation of data showed that the differences in yields and in alpha acid contents depending on the time of the cutting are statistically significant only for a few experimental variants (Table 6).

Statistically significant relationships in Harmonie are complementary because higher/lower yield can be to some extent offset by lower/higher alpha acid content. Before harvest hop plant quickly reacts to changing weather conditions. In certain years alpha acid content still change in the course of

Table 6. Experimental variants

| Year | Variety | Parameter | Statistical significance |
|---|---|---|---|
| 2008 | Harmonie | yield | Early cutting date provided higher yield than middle one |
| 2008 | Harmonie | alpha | Contents of alpha acids in the middle term of cutting were higher than in early cutting |
| 2009 | Agnus | yield | Early cutting date provided higher yield than middle and late ones |
| 2009 | Rubín | alpha | Content of alpha acids in the middle cutting term was significantly higher than in the early and late cuttings |

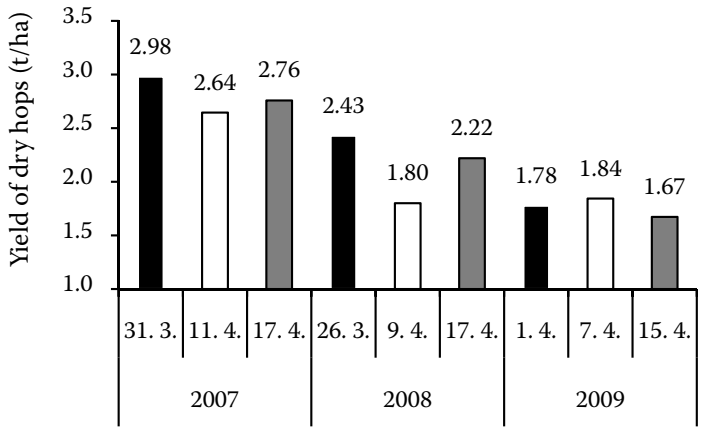


Figure 1. Yield of dry hops in Harmonie (t/ha) depending on the term of cutting in the period 2007–2009

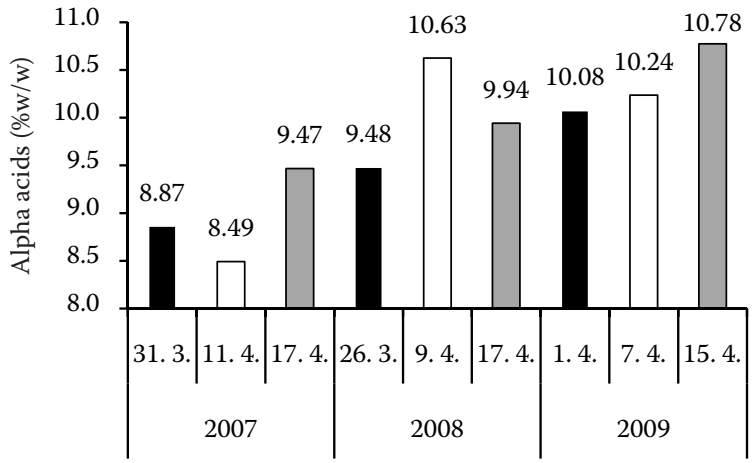


Figure 2. Content of alpha acids in Harmonie depending on the term cutting in the period 2007–2009

the second half of August and the first decade of September. Therefore, a big difference in alpha acid contents at the beginning and the end of harvest is commonly observed (Krofta and Kucera 2009).

Interdependence of yield and alpha acid content was confirmed within the statistical assessment of the derived parameter – yield of alpha acids per 1 ha. In the statistical evaluation of the production of alpha acids from 1 ha and term of cutting with the help of the analysis of variance number of statistically significant differences substantially decreased (Table 7). Agnus was the only one of the original four which confirmed significance in 2009.

Differences in yield and alpha acid content of the remaining experimental treatments with different times of cutting are statistically insignificant, although at they may seem relatively large (e.g. high alpha acid content in Harmony with the late cutting term in 2009 and the highest yield of Agnus in the middle term of cutting in 2007). During the experimental period, significant annual variations were recorded especially for yield, independently on the term of cutting. For example in 2009, the yield was severely affected due to severe attack of downy mildew (*Pseudoperonospora humuli* Miy. et Tak.), in all varieties; it was caused by frequent precipitations as well as by morning fogs in

Table 7. Statistical evaluation of the significance of differences in yield among, acid content and alpha acids production (kg/ha) varieties Harmonie, Rubín and Agnus depending on the term of cutting in the period 2007–2009

| | 2007 | | | 2008 | | | 2009 | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | A | B | C | A | B | C |
| Differences in yield | | | | | | | | | |
| Harmonie | | inconclusive | | | A-B* | | | inconclusive | |
| Rubín | | inconclusive | | | inconclusive | | | inconclusive | |
| Agnus | | inconclusive | | | inconclusive | | | A-B A-C* | |
| Differences in alpha acid content | | | | | | | | | |
| Harmonie | | inconclusive | | | A-B* | | | inconclusive | |
| Rubín | | inconclusive | | | inconclusive | | | A-B* B-C* | |
| Agnus | | inconclusive | | | inconclusive | | | inconclusive | |
| Differences of alpha acids production | | | | | | | | | |
| Harmonie | | inconclusive | | | inconclusive | | | inconclusive | |
| Rubín | | inconclusive | | | inconclusive | | | inconclusive | |
| Agnus | | inconclusive | | | inconclusive | | | A-B* A-C* | |

A – early cutting; B – middle cutting; C – late cutting; *capital letters indicate statistical significance

the locality close to the Ohre river. Important fungicide treatments in June and at the beginning of July were hindered by muddy ground. Contents of alpha acids, which are dependent on weather conditions during the flowering and ripening of hop cones along the period from June to August, were the lowest in 2007. The measured data found no systematic, statistically conclusive link between time of cutting, alpha acid content and yield of any of the tested varieties. Cutting time, which in relation to yield and alpha acid content seems to be the optimal one, in the coming years is evaluated as less favorable. These results do not correspond completely with the conclusions reached by Krivanek (2008). The time period in which hop crowns are cut undoubtedly influences yield and alpha acids. However, at the time of cutting at the beginning of the vegetation season, the course of weather conditions cannot be reliably predicted. Therefore, the findings did not formulate a clear conclusion regarding the deadline for growers to cut the tested hybrid varieties. From the perspective of the trial results it may be advisable to cut the cultivars Harmonie, Rubín, Agnus during the first decade of April, taking into account other factors such as age and the location of a hop garden, actual weather conditions, etc. Experience with cultivation of the most common Czech hybrid varieties Premiant and Sladek show that the cutting can be carried out even earlier, during the second half of March.

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*Corresponding author:*

Ing. Karel Krofta, PhD., Chmelařský institut s.r.o, Kadaňská 2525, 438 46 Žatec, Česká republika
e-mail: k.krofta@telecom.cz