Dynamics of Hop Growth and Accumulation of α–acids in Normal and Extreme Climatic Conditions

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SUMMARY

The influence of normal and extreme weather conditions on the dynamics of hop growth, of cones development and accumulation of α-acids during three years of cultivation of hop cv. Aurora has been studied. The results of the comparative study show the dependence of the start of blooming and time period from second shooting (F3) on flowering (F7), yield of the hop cones and share of α–acids in the dry matter of cones.

It has been concluded that the increasing sum of effective temperature has a negative influence on the yield of hop cones and accumulation of α–acids. The increase of temperature and drought during year 2003 caused decrease of the yield of hop cones from 1800 to 900 kg/ha and the share of α–acids from 11.5 to 6.2 % when compared to "good hop year" (2001).

KEY WORDS

hop, Aurora, dynamics of hop growth, accumulation of α–acids

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Received: May 4, 2004

INTRODUCTION

The dynamics of hop growth, generative development and the accumulation of α–acids have a very strong impact on yield and quality of hop cones (Howard and Tatchell, 1956, Kralj, 1962, Hacin, 1987, Zmrzlak, 1991, Zmrzlak and Kajfež-Bogataj, 1996). These phenomena in hop plant physiology depend on the interaction between cultivar and environmental conditions (Knapič and Oset, 1995, Majer, 1995). Climatic conditions as well as the level of provided tillage and fertilizing have strong impact on hop growth and development and accumulation of α–acids in hop cones. The aim of this research is to determine the dynamics of hop growth and development as well as α–acid accumulation in vegetation years with normal and extreme weather conditions, in order to plan, organize and apply all agricultural measures and begin hop harvest at the right time to minimize the total loss of α–acids.

MATERIALS AND METHODS

Research was carried out on hop cv. Aurora planted in hop garden near the village of Gregurovec (close to Križevci), during the three vegetation years (2001, 2002 and 2003). The height of hop plants was measured by tape measure. The content α–acids was determined by the method of lead conductance value of hops, powder and pellets (Analytica-EBC, 7.4, 1998) and dry matter content by the method of moisture content of hops and hop products (Analytica-EBC, 7.2, 1998). All the values of hop height during different phenological stages were transformed by logarithmic transformation, after preliminary testing of the least significant differences of the plant height in pair plots. Correlation between effective temperatures $[\Sigma(\frac{min.temp.+max.temp.}{2} - 5°C)]$ and α–acids as well as dry matter accumulation was determined by Spearman's coefficient of rank correlation (Little and Hills, 1978). Meteorological data were collected at the Field Station of Agro meteorology in Križevci, which is five kilometers from hop garden location by air.

RESULTS AND DISCUSSION

Dynamics of hop growth and development during 2001 and 2002 were regular (Fig. 1 and 2). It can be seen that vegetative hop growth in the year 2001 was finished before the end of June, which is very favorable for the generative development of hop cones. The most intensive hop growth was during the first half of May. Weather conditions during 2001 had the positive impact on the dynamics of hop growth and development of cones. Therefore that year was considered as a typical ¼hop year½Total rainfall from hop pruning to the end of hop harvest was among 500 mm. Furthermore, it was distributed very well

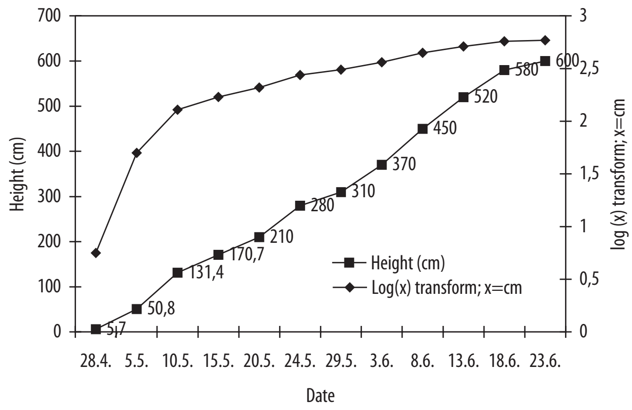

Figure 1. Dynamics of hop growth in 2001 cv. Aurora

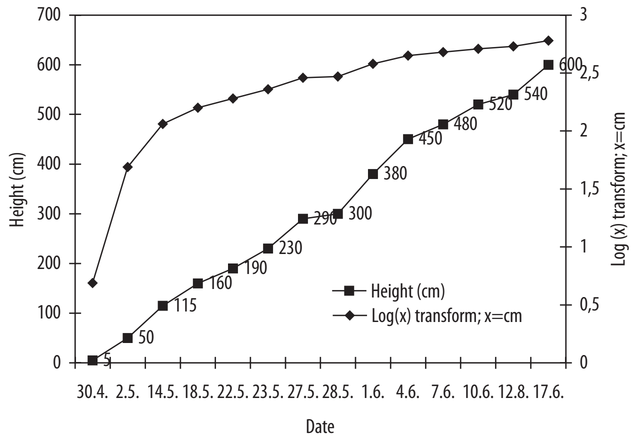

Figure 2. Dynamics of hop growth in 2002 cv. Aurora

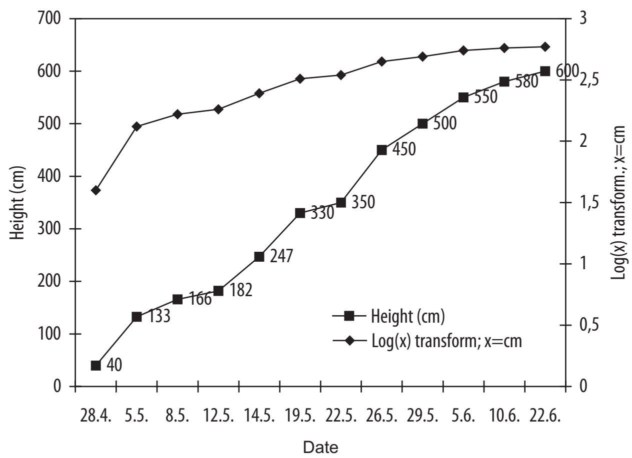

Figure 3. Dynamics of hop growth in 2003 cv. Aurora

during vegetation, particularly in the most critical stages of growth and development, in May (47.2 mm of total rainfall, average month air temperature of 17.4°C) and June (89.9 mm of rainfalls, average month air temperature 17.9°C).

Although it was sufficient in the year 2002, total rainfall (514 mm) was not well distributed during the hop vegetation, particularly in June (only 53 mm). Nevertheless, it did not have a negative impact on the dynamics of hop growth and development, thanks to tillage in May and June and preserved soil moisture reserves (total rainfall in April was 118 mm).

Next year (2003) was extremely dry (only 264 mm of total rainfall) as a consequence of an unusually stable area of high air pressure, the so-called 'Omega layers' (Engelhard, 2003). The result was a completely irregular hop growth and cone development, which is quite visible from the logarithmic curve of growth intensity (Fig. 3).

High temperatures and insufficient rainfall at the beginning of April (average temperature 10.3°C and only 22.4 mm of rainfalls) caused an early start of the generative development stages. At the beginning of June (5 June) the highest plants started flowering in spite of the fact that they had not finished their vegetative growth (average plant height was 550 cm). Irregularity was connected with the extremely high temperature and the sum of the effective temperatures (623°C). The result was an early flowering after pruning, which corresponds to a data from the literature (Kralj, 1962, Zmrzlak, 1991, Zmrzlak and Kajfež-Bogataj, 1996.). The basic feature of such irregular hop growth and hop cones development during 2003 was faster generative development in comparison with vegetative growth. The consequences are significantly low yield and decrease of the quality of hop cones in comparison with years 2001 and 2002 (Tab. 1).

The reductions in cone and α–acid yields caused by drought were recorded all over Central Europe in year 2003, particularly in Slovenia, Czech Republic and South Germany (Bavaria, Hüll region). For example, in Hüll region as well as all over Germany, there was less than 50% of normal rainfall; in some parts it was only 29% (Engelhard, 2003).

According to Howard and Tatchell, the curves of accumulation of α–acids show non-linear trend (Howard and Tatchell, 1956). By using the Spearman's coefficients of rank correlation, the strong correlation was found between α–acids and dry matter accumulation in hop cones $r_s=0.76$ [$\Sigma d^2=168$, $F_{exp}=18.7^{**}$ ($F_{(1\%)}=8.86$)] (Srečec, 2003). However, it is possible to conclude that increasing sum of effective temperatures has a negative impact on the accumulation of α–acids in hop cones (Fig. 4) during

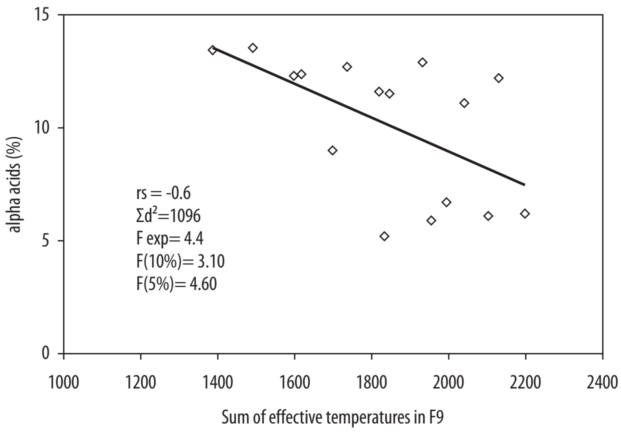

Figure 4. Impact of the increase of effective temperatures on α–acids accumulation in hop cones of cv. Aurora

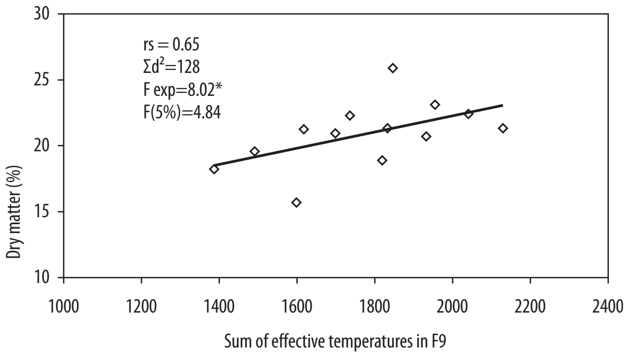

Figure 5. Impact of the increase of effective temperatures on dry matter accumulation in hop cones of cv. Aurora

the stage of technological maturity (F9), $r_s=-0.6$ [$\Sigma d^2=1096$, $F_{exp}=4.4$ ($F_{(10\%)}=3.10$)]. On the other hand, the increase of effective temperatures has a positive influence on the accumulation of dry matter in hop cones (Fig. 5) at the same stage (F9), $r_s=0.65$ [$\Sigma d^2=128$, $F_{exp}=8.02^{*}$ ($F_{(5\%)}=4.84$)].

These results are in line with Hacin's results (1987) based on microscopic studies of the formation of lupulin glands. He described the stage of blooming (F7), formation of hop cones (F8) and the stage of technological maturity of hop cones (F9) as the most important stages for final yield of hop cones and α–acid accumulation. He also found a total correlation between total rainfall and yield (r=0.92)

Figure 6. Accumulation of α–acids in hop cones of cv. Aurora during the technological maturity (F9) in extreme drought conditions in 2001, 2002 and 2003

Year	Blooming (Start)	Number of days from second shooting (F3) to flowering (F7)	Hop cone yield (kg/ha)	Share of α-acids (% in dry matter)
2001	23.6.	57	1800	11.5
2002	28.6.	71	2000	10.2
2003	5.6.	50	900	6.2
LSD=5%			101	1.07
LSD=1%			234	2.48

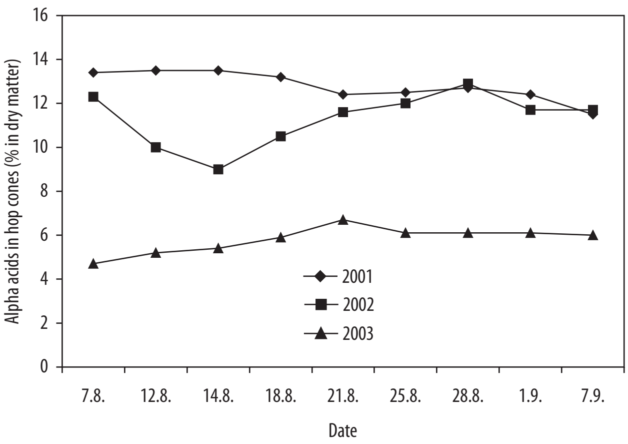

Figure 6. Accumulation of α–acids in hop cones of cv. Aurora during the technological maturity (F9) in extreme drought conditions in 2001, 2002 and 2003

and very strong correlation between total rainfall and α–acids content (r = 0.89) for hop cultivar Aurora. According to Hacin high temperatures (above 20°C) from the end of April to the end of May, cause faster vegetative growth and earlier blooming and hop cones formation on lower insertions of hop plants. In relation to this, number of hop cones on the upper insertions decreased as well as the total yield, because the hop cones on the lower insertions cannot compensate the number and size of cones on upper plant insertions.

This is confirmed by our observations during the extreme drought in 2003. In April, May and June 2003 vegetation year, average temperatures varied between 10.3°C in April to 23.5°C in June. Moreover, maximum temperatures in May were even higher than 32°C and definitely caused earlier blooming. So, very poor yield of hop cones of cv. Aurora in 2003 is the consequence of the extreme heath (Tab. 1).

In conditions of extreme drought during the stage of technological maturity of hop cones (F9), it is completely impossible to plan and organize hop harvest at the right time in order to "catch" the top of the α–acid accumulation curve (Fig. 6). However, in vegetation years with normal vegetation conditions hop harvest of cv. Aurora in north west Croatia (particularly in Sub-Kalnik region) should be done from 15 August to 5 September at the latest, in order to minimize total loss of α–acids during hop processing into hop pellets and/or storage time of the hop cones in bales (Srečec, 2003).

CONCLUSIONS

Sum of effective temperatures and total rainfall have a very strong influence on yield of hop cones and content of α–acids.

Extreme drought during the vegetative growth (F3, F4 and F5) and high temperatures (with maximum values above of 30°C) cause earlier blooming and hop cones formation on the lower insertion of hop plants and on the other hand weak cones formation on the upper plant insertion.

Sum of effective temperatures have a negative impact on the accumulation of α–acids in hop cones during the stage of technological maturity (F9), rs=-0.6, but increase of effective temperatures has a positive influence on the accumulation of dry matter in hop cones at the same stage (F9), rs=0.65.

In the conditions of extreme drought during the stage of technological maturity of hop cones (F9), it is completely impossible to plan and organize hop harvest at the right time in order to "catch" the top of the α–acid accumulation curve.

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acs69_09