Response of the Czech hybrid hop cultivar Agnus to the term of pruning, depth of pruning and number of trained bines

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ABSTRACT

Agnus is a Czech hybrid hop cultivar and a statistically significant influence of depth and term of pruning on harvested hop cones yield and on alpha-bitter acids content in hop cones were found in this study. Evaluated agrotechnical measures, i.e. depth of pruning, term of pruning and number of trained bines, considerably influenced performance and quality of newly grown hop genotype. Every year, we found a positive influence of shallow pruning on yield (increase of dry hop cones yield in 2003 by 0.37 t/ha, in 2004 by 0.28 t/ha and in 2005 by 0.02 t/ha). The hop yield of plants treated with shallow pruning increased on average by 11.6% in three years. We proved a statistically significant influence of three-bines training system on one hop pole, i.e. 3 + 3 bines from each plant. We found that alpha-bitter acids content corresponds with cones yield and indicates a convenience of shallow pruning. Pruning term influenced alpha-bitter acids yield and dynamics of their formation (in the first pruning term yield it was 155 kg/ha, in the second pruning term it was 169 kg/ha, and in the third pruning term it was 175 kg/ha).

Keywords: *Humulus lupulus*; hybrid cultivars; hop pruning; depth of pruning; term of pruning; number of trained bines

A very important agrotechnical measure, by which future quality of hop cones is influenced, is mechanized hop pruning (Perry 2006, Jurčák et al. 2007). According to Sachl (1961), by pruning we regulate term of shoots sprouting, length of vegetation period of aboveground parts and also organogenesis. Late spring pruning (at the end of the third decade of April and at the beginning of May) retards and weakens growth of hop plants (cultivar Saaz hop) and thus significantly disturbs balance between vegetative growth and fertility (Osvald 1946). Kopecký (1997) recommends paying more attention to weather conditions and soil structure in pruning term selection.

According to Kořen (2007) hybrid cultivars require different agrotechnics than Saaz hop. Different cultivar characteristics are confirmed also by works of Luo (2006). Kopecký (1997) reports that hybrid cultivars require shallow pruning; he thus proposes shallow pruning in hop gardens with hybrid cultivars, maximum in the depth of 5 cm.

Cones yield is influenced by number of bines trained to the top of construction (Kořen 2007). Bine training is time-limited and total effect is determined by number of trained bines, term and quality of work. We agree with some authors, e.g. Sachl (1961), who recommend three-bines training, which can increase yields in comparison with two-bines bushes. According to Rybáček (1980) and Darby (2006) habitus of above-ground parts of hop plants influences number of trained bines per one hop pole and their regular winding and in three-bines training we reach higher weight of above-ground plant part. Results presented by Kořen (2007) confirm that in growing of the Czech hybrid cultivars, there are differences in agrotechnics in comparison with traditional Saaz hop cultivar. He showed that a determining yield

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component in hybrid cultivars is a number of trained bines per 1 ha.

Osvald (1946), Sachl (1961), Rybáček (1980) report that pruning retardation in Saaz hop shifts butonization period, hop maturation and plants thus get into less favourable period for alpha-bitter acids formation. According to De Keukeleire et al. (2003), each hop cultivar has its individual accumulation period of alpha-bitter acids. Alpha-bitter acids are the most important components of hop; they ensure typical bitter taste of beer and belong among basic criteria of hop quality for beer production. Their amount in hop cones is a basic cultivar characteristic, and their formation is influenced by many factors during cones maturation period (Krofta 2001), which is also confirmed by work of Green (1997).

MATERIAL AND METHODS

The experimental locality has the long-term average air temperature of 8.4°C and yearly precipitations of 438 mm. Agrometeorological year 2002/03 was generally more humid and warmer, but the vegetation period was very warm (+2.1°C) in comparison with the long-term average. Agrometeorological year 2003/04 was very

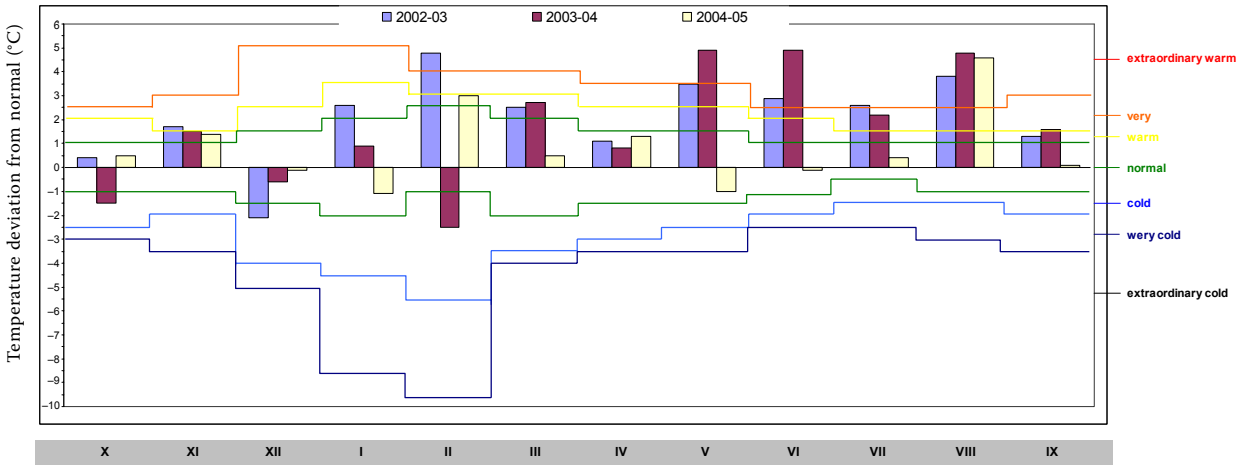

Figure 1. Žatec air temperature – monthly classification according to average air temperature deviation from normal during years 2002/03–2004/05

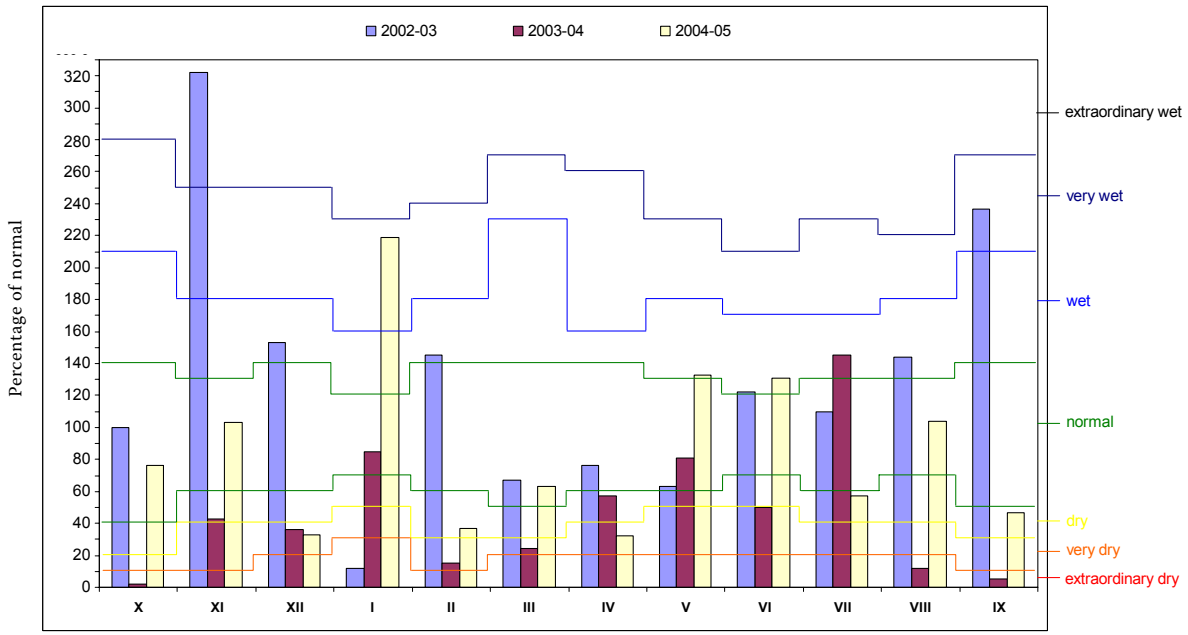

Figure 2. Žatec sum of precipitations – monthly classification according to percentage of normal during years 2002/03–2004/05

Table 1. Influence of pruning depth on quality and yield of fresh hop (α = 0.05)

Pruning	Hop yield per plot (kg)	Conclu-siveness	Yield from one plant (kg)	Conclu-siveness	Yield from one vine (kg)	Conclu-siveness	Alpha-bitter acids content (%)	Conclu-siveness
Shallow	20.99	A	2.62	A	0.65	A	11.71	A
Deep	18.86	B	2.35	B	0.57	B	9.41	B
LSD	0.1066		0.013		0.0066		0.048	

Averages marked with the same letters are statistically significantly different

warm, with unusually warm months of April, May and August. This year was also very dry; sum of precipitations was by 208 mm lower in comparison with the long-term yearly sum of precipitations. Agrometeorological year 2004/05 was warm with the highest variation in August, which was very warm and dry. Weather characteristics in individual years are shown in Figures 1 and 2.

Hybrid cultivar Agnus was planted at experimental hop garden of Hop Research Institute in Žatec, on the field of hop poles with 3 rows with the length of 200 m and spacing of 300 × 100 cm. Hop plants were 7 years old and fully productive at the beginning of experiment. Experimental hop garden is situated near the Ohře River, in the centre of the lowland part of valley. Soil is of alluvial type composed of mixture of humus sand clay sediments of the Ohře River and clay loam sediments from the Blšanka River. Soil profile is deep, arable land is clayey with small amount of sand. Arable land layer is slightly humus, soil pH 6.2–7.0. The soil has favourable physical conditions with good inner drainage. Natural nutrients reserve is very good.

In spring the soil at the hop garden was loosened to the depth of 10–15 cm. Hop pruning was done by pruning machine CH 9–016. The pruning was done in three terms: (1) early spring term (end of March), (2) medium term (the first decade of April) and (3) late term (the second decade of April). Each of the 3 rows of cultivar was divided into two parts according to the height of pruning. Deep pruning was done above surface of underground part of hop plant and in shallow pruning 5–8 cm of new wood was left. Pruning quality was controlled randomly; underground parts of hop plant were not damaged by pruning.

Each plant had two hop poles. According to the above-mentioned variants (term and depth of pruning), the plants were divided into subvariants with 8 plants + reserve, 4× repeated. From each plant bines were trained to hop pole as follows: (a) 2 + 2 vines (4 bines) + 1 reserve left, (b) 2 + 3 vines (5 bines) + 1 reserve left and (c) 3 + 3 vines (6 bines) + 1 reserve left.

Harvest was done at the end of the first decade of September; yield of dry hop was determined by

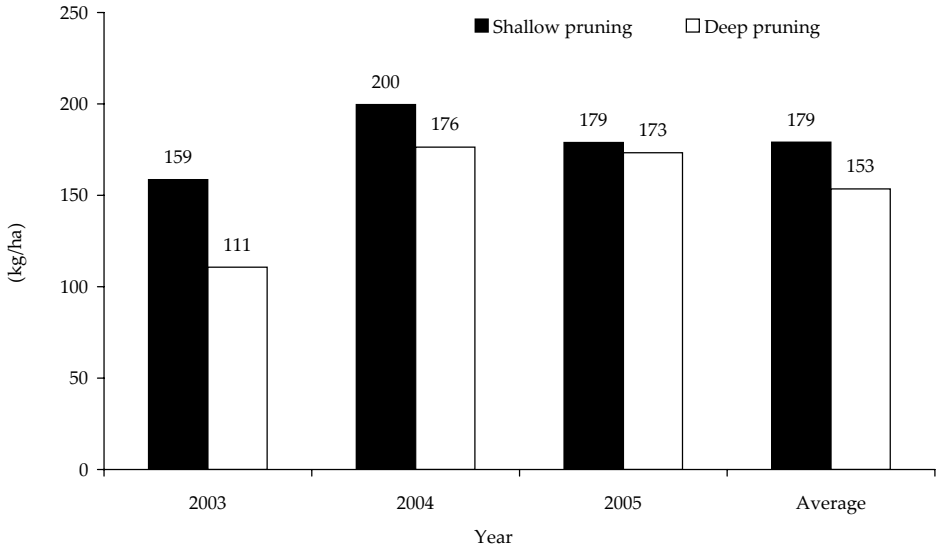

Figure 3. Influence of pruning depth on yield of alpha-bitter acids (average of 6 varieties)

Table 2. Influence of pruning term on quality and yield of fresh hop (α = 0.05)

Pruning term	Hop yield per plot (kg)	Conclu-siveness	Yield from one plant (kg)	Conclu-siveness	Yield from one vine (kg)	Conclu-siveness	Alpha-bitter acids content (%)	Conclu-siveness
1	16.85	C	2.16	C	0.53	B	9.32	C
2	18.36	B	2.29	B	0.56	B	10.63	B
3	21.24	A	2.65	A	0.66	A	11.71	A
LSD	0.15		0.019		0.0096		0.078	

Averages marked with the same letters are statistically significantly different

calculation from fresh hop (coefficient 4.1) and calculated per hectare (3 000 plants/ha). Samples for alpha-bitter acids determination during maturation were collected from middle part of hop vine branching, which is in the 2/3 of height, from fertile shoots, with intervals of 3–4 days up to harvest. Analyses of alpha-bitter acids content were done in the laboratory of Hop Research Institute in Žatec, according to ČSN (Czech State Norm) 462520-15.

Multifactorial analysis of variance was used for evaluation of cogency of difference of recorded values (SAS, Version 9.1. – F5 ANOVA, SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

The average of monitored years and variants showed that shallow pruning was more convenient both in hop yield and in alpha-bitter acids content (Table 1). Hop yield in variant with shallow pruning (1.92 t/ha) increased in average of three years by 11% in comparison with deep pruning. Stand with shallow pruning had higher number of quality shoots for training, better regeneration after pruning and better and faster initial growth. Cones had higher alpha-bitter acids content; due to faster start, the plants had a more favourable period for their formation (Figure 3).

The results shown in Table 2 prove that the highest effect from green hop yield and from alpha-bitter acids content was reached in late (second decade of April) pruning term. Yield of dry hop in variant with late pruning term was by 1.60 t/ha higher, which is by 8.6% more in comparison with the first term (1.48 t/ha) and by 3.8% more in comparison with the second term (1.55 t/ha). It was observed that after the third term of pruning the plants were more budded; moreover, after prun-

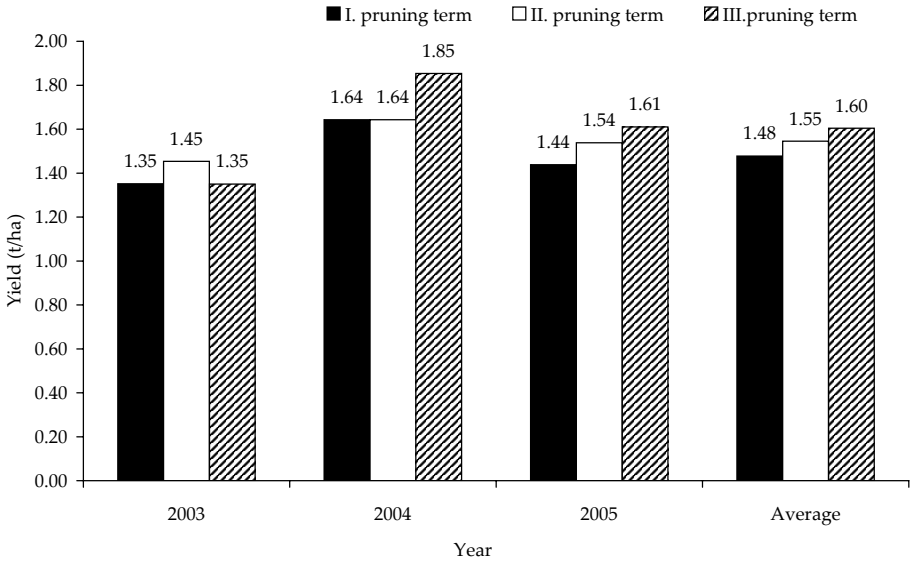

Figure 4. Influence of pruning term on dry hop yield (average of 6 varieties)

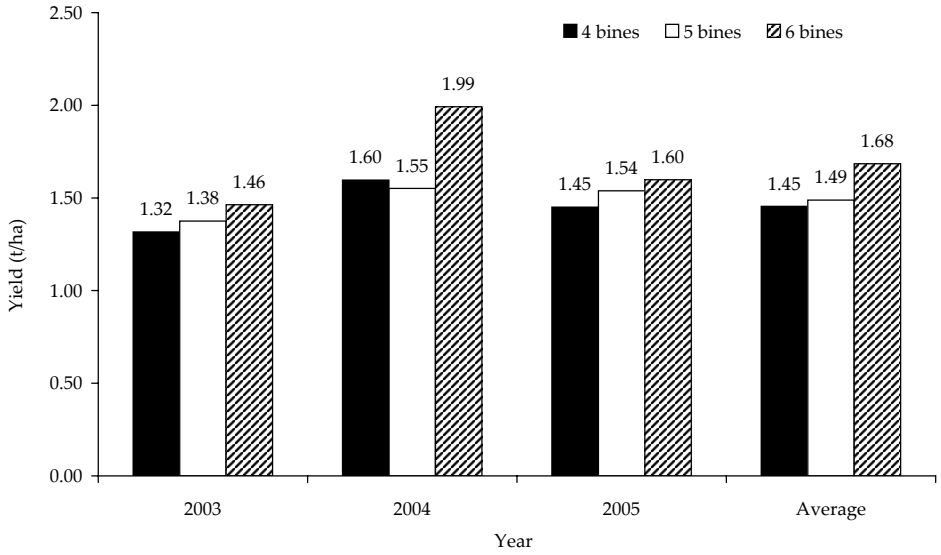

Figure 5. Influence of number of trained vines on yield of dry hop (average of 6 varieties)

ing the amount of shoots suitable for training is limited. Medium up to late pruning can be used in hybrid cultivar Agnus to postpone the intensive growth onset. During early pruning, plants are not ready enough for growth, and thus pruning would not postpone vegetation, whereas pruning at the beginning of April retards plants in growth. Our results are in agreement with Kopecký (1997) who suggests that pruning term is a factor, which is the most dependent on year conditions and hop garden location. It can be evidenced by yield variability of dry hop cones in individual variants and monitored years (Figure 4). Evaluated data were strongly influenced by results in 2004. However, practical recommendations for suitable pruning term are difficult to define on the basis of only one experiment and locality.

In number of trained vines per one hop pole (Figures 5 and 6) a positive influence of the three trained shoots on hop cones yield (1.94 t/ha) was observed, while alpha-acids content did not change very much (11.55%). Differences among obtained values are statistically significant (Table 3). Nevertheless, some difficulties were expected in training of the three vines per hop pole, namely in deflecting of growth tops, but it did not happen in any of the experimental years. By training of 6 vines from 1 plant to two hop poles, average yield of hop cones increased by 10% (to 1.94 t/ha) in compared to 5 vines (2 + 3) and by 26% (1.53 t/ha)

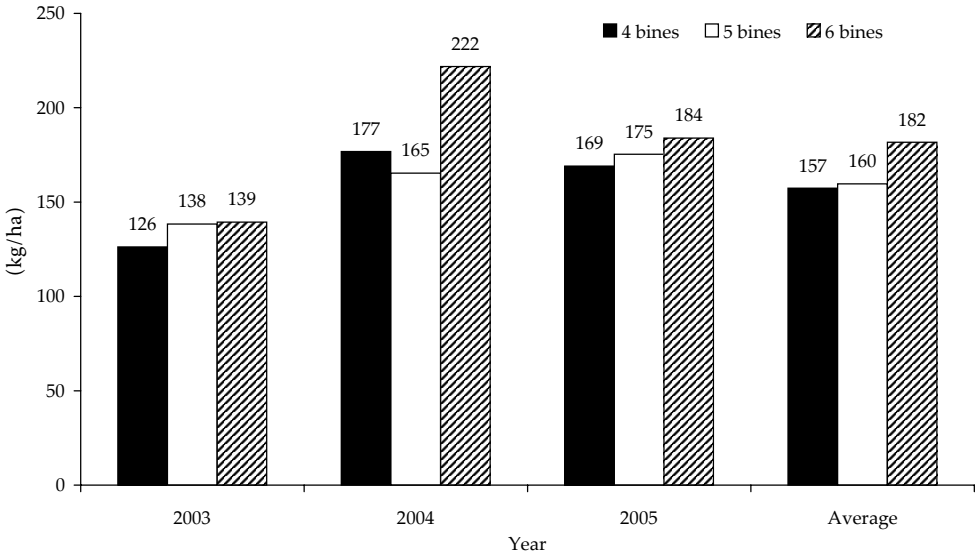

Figure 6. Influence of number of trained vines on yield of alpha-bitter acids (average of 6 varieties)

Table 3. Influence of number of trained vines on quality and yield of fresh hop (α = 0.05)

Number of trained vines from plant	Hop yield per plot (kg)	Conclu-siveness	Yield from one plant (kg)	Conclu-siveness	Yield from one vine (kg)	Conclu-siveness	Alpha-bitter acids content (%)	Conclu-siveness
4	16.72	B	2.09	B	0.52	A	11.58	A
5	18.38	C	2.29	C	0.45	B	11.52	A
6	21.18	A	2.65	A	0.44	B	11.55	A
LSD	0.156		0.019		0.0096		0.078	

Averages marked with the same letters are statistically significantly different

compared to 4 vines (2 + 2); alpha-bitter acids content remained the same. This finding did not prove a hypothesis about convenience of training of the smaller number of vines for higher plants habitus and higher competitiveness in stand.

Figures 7–9 show dynamics of alpha-bitter acids increase during hop cones maturation. A decrease of alpha-bitter acids content can be observed in early spring pruning, contrary to medium and late pruning term where an increasing tendency was reported. Late pruning terms shift vegetation development of plants. Tendency for alpha-bitter acids content increase is very interesting. Only early pruning term shows maturity of harvested hop cones; harvest on September 9 was probably too early for medium and late term.

We can conclude that cultivar Agnus has different dynamics of alpha-bitter acids formation in hop cones during its maturation. It was found that yield and alpha-bitter acids content correspond with cones yield and indicate thus suitability of more shallow pruning at the end of March and beginning of April; it is in accordance with Štranc et al. (2007) who reported that pruning in the first half of April shifts technological maturity to later period and statistically significantly increases yield and alpha-bitter acids content in harvested cones, but only to a certain time. During harvest of the first pruning term stand, alpha-bitter acids content in cones increased in the second and third harvest term. Changed pruning term influenced time of cones maturation, i.e. by growth under different moisture conditions.

Phenology phases, habitus formation, flower formation including plants height confirmed the results of Kořen (2007), that hybrid cultivars are different from Saaz hop. Our study has shown that late and shallow pruning in cultivar Agnus

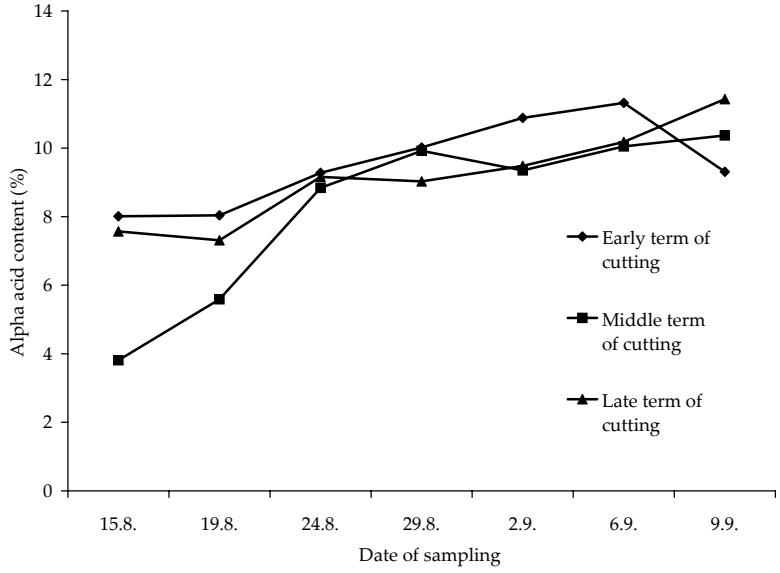

Figure 7. Influence of pruning term on dynamics of alpha-bitter acids formation in 2003

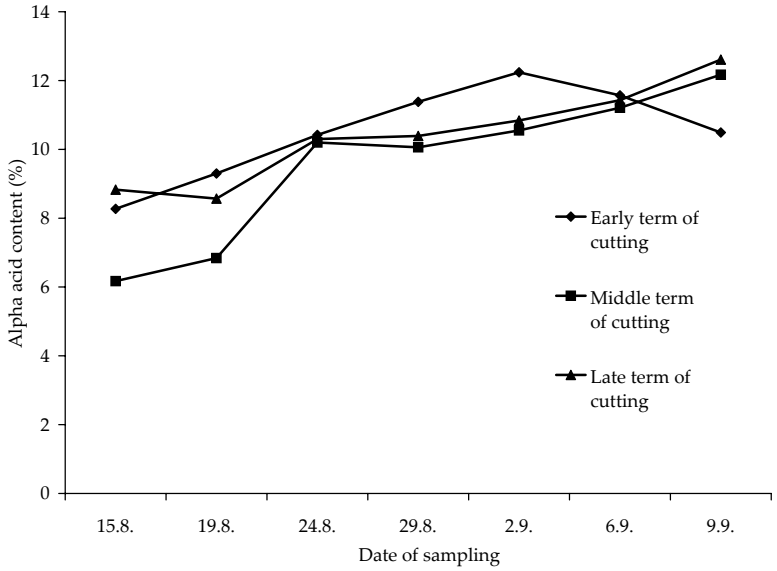

Figure 8. Influence of pruning term on dynamics of alpha-bitter acids formation in 2004

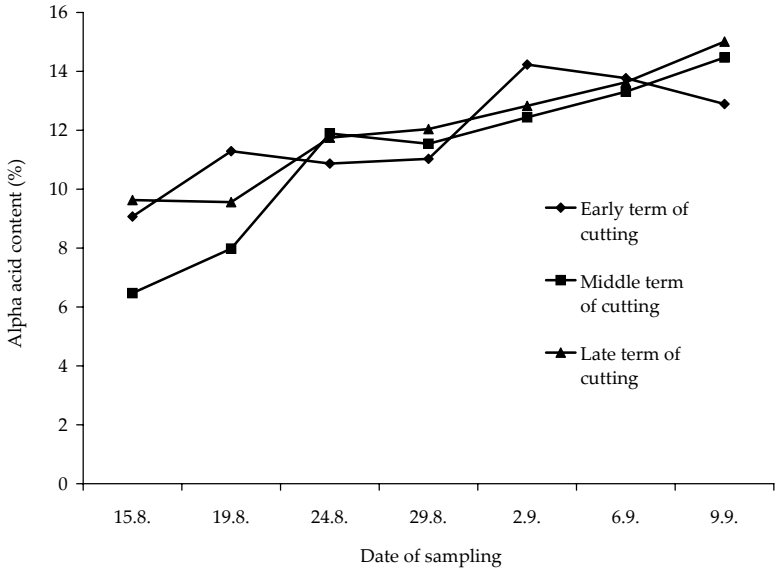

Figure 9. Influence of pruning term on dynamics of alpha-bitter acids formation in 2005

caused growth retardation, lower number of shoots suitable for training and later formed flowers. Compared to early-pruned plants, this treatment also caused a smaller number of cones; on the other hand, these cones were of a bigger size. Maturation was postponed due to growth retardation, which showed itself in dynamics of alpha-bitter acids formation.

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