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Flowering, Forcing, Storage and Vase Life of *Hamamelis*

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Summary

Hamamelis comprises many selected cultivars flowering during winter and early spring. Early flowering and the exotic flowers may therefore be of interest for forcing and sale as cut flowers. Three cultivars of *Hamamelis* x *intermedia,* 'Arnold Promise', 'Diane' and 'Jelena', and the cultivar 'Pallida' of *Hamamelis mollis,* and one seedling selection of *H. mollis* were grown on the South-Western coast of Norway for six growing seasons (1997 to 2002). The amount of flowers on the branches differed between cultivars but was stable within cultivar from year to year. The time of full bloom differed from year to year for the same cultivar by 20 to 30 days (d), and the latest cultivar ('Diane') bloomed on average 34 d later than the earliest ('Jelena'). Branches of all cultivars harvested for forcing before mid December flowered poorly and only after 15 to 20 d in forcing conditions. When harvested in January, flowering was abundant and occurred after only 2 to 5 d in forcing conditions. The longest spell of flowering was observed in *H. intermedia* 'Arnold Promise' and the shortest in *H. mollis* 'Pallida'. However, keeping quality differed from year to year, with the longest keeping quality occurring in flowers which bloomed when temperatures in the field were stable. Storage conditions could be made to compensate for low temperatures under outdoor conditions and stored branches would then flower after the same forcing time as branches harvested directly from the field. Different temperatures during storage (3, 6 and 9 °C) did not influence the number of days until flowering, but vase life decreased with increasing time and temperature in storage.

Key words. cultivars – cut flowers – keeping quality – phenology – Witch Hazel

Introduction

Hamamelis flowers from late autumn, at mid winter and during the spring, depending on species and cultivar (Mione and Bogle 1990; Jianhua et al. 2000). These particular flowering times, together with the exotic flower anatomy of these species attracts the attention of both customers of cut flowers and florists. However, production of these species may only be of interest if the protocols of harvest time, storage conditions, forcing conditions and keeping quality are available to the producers.

For flowering to occur in the winter and early spring, the flower buds are initiated and developed to a certain stage before the plants enter dormancy in the autumn. Spring flowering woody species usually initiate flower bud development in mid to late summer. The flowers may continue to develop until early spring before the flowers finally open (Miére et al. 1996; Battey 2000). The time between the initiation, development and actual flowering is interrupted by a winter season in temperate regions, when plants must be prepared to endure harsh conditions. Common signal substances have been found for initiating the timing of flowering and growth cessation in trees (Rohde and Bhalerao 2007). Very few trees in temperate regions experience growth or flowering during the winter as temperatures may frequently drop below freezing. However, the witch hazels are one of only a few genera that flower annually during the harsh winters of Northern Europe. However, the flowering period can be short due to unfavourable weather conditions during the flowering period. Therefore the best time for harvesting branches for forcing into flower would be before the onset of the most serious frosts, *i.e.* before January. To do this successfully requires an understanding of the time when the flower buds are ready to respond to forcing after the shoots are released from physiological dormancy. To achieve suitable results from branches harvested before they actually flower, acceptable storage and forcing conditions must be ascertained. Storage conditions should ideally contribute to the release of any eventual remaining dormancy in flower buds at the time of harvest. Comprehensive reviews of seasonality of flowering and the role of dormancy have been given by Battey (2000) and Rohde and Bhalerao (2007).

For flowering to occur, the flowers need first to be initiated and developed. Second, the chilling demands of the flower buds need to be fulfilled. And third, the environmental conditions must be favourable for flowering. Those factors which control the dormancy of the flower buds may also be the factors that decide flowering time (Battey 2000). The hypothesis of this work was that flower buds of cultivars of *Hamamelis* would only be ready to flower after a certain length of exposure to the influence of low temperatures during autumn and winter, either out door or during the cold storage of branches with flower buds. This paper reports the experiments with cultivars and species of *Hamamelis* and examines the possibilities of storing and forcing branches into flowering and the good keeping quality of the flowers under indoor conditions.

Materials and Methods

The cultivars and the experimental field

The cultivars tested were chosen to reflect the variation in flower size and colour (Table 1). In the early spring of 1997 plants of the same age that were 50 to 60 cm tall and with 3 to 4 branches were planted in the open field at Særheim on the South Western coast of Norway (58° 47' N, 5° 41' E). The plants were put into a 1.5 m wide soil covering mulch of woven black plastic (Mypex). The distance between the plants within the rows was 2.5 m and there was 3.5 m between the rows. Positions of species and cultivars were randomised with three plants per plot and three plots in each of three blocks. Thus the total number of plants per cultivar was 27 and the area of the field was 1100 m^2. However due to a miss identification of cultivars at the propagating nursery 12 plants had to be excluded from the experiment. The soil was a mineral soil with humus content of about 5 %.

Flowering under out door conditions

The amount of flowering was recorded in 1998 and 2002 as a score on a subjective scale from 1–9, where 1 = no or very few flowers and 5 = flowers on 50 % of the twigs and 9 = flowers on all branches from the base of the twig to the tip. The phenology of flowering was recorded for four years (1998–2001), as the date of the onset of flowering, date of full bloom (75 % open flowers) and date of the first visible wilting of the flowers.

Forcing conditions

In order to study when the flowers were free to respond to forcing and how the flowering proceeded, branches of 'Arnold Promise', 'Diane' and 'Pallida' were collected at different dates, taken into forcing conditions at 22 ± 0.2 °C, 50 % relative humidity and with 1000 lux of light from fluorescent lamps (Phillips, TL 33) for 12 h per day. Three branches of each cultivar were put into each of three vases with 0.5 L of deionised water. The branches were harvested on October 2, November 13, November 27, December 11 and December 28.

Storage capability of branches before forcing

In 1999 an experiment was set up with the cultivars 'Diane' and 'Pallida' in order to examine the storage capability and keeping quality of these cultivars. 20 to 30 cm long branches with visible flower buds were harvested on November 30, either for immediate forcing or after 4, 8 or 12 weeks of storage at 0, 3 and 6 °C. The branches harvested comprised the two last years wood, and were considered to be of the same physiological stage and of similar quality. The saturation deficits of the storage chambers were approximately 1 g m^{-3}. The dates for the start of forcing were thus December 1, December 28, January 26 and February 23. The branches were stored in perforated plastic bags (made for carrot storage), and the cut ends of the branches were packed in moist peat moss in order to prevent desiccation during storage time. Within cultivar variation in time until flowering in *Hamamelis* is very small, and each bag contained nine branches, enough for three replicates each with three branches. After storage, branches of each cultivar were forced using the method described above. Registration of results included the percentage of flowers that opened, number of days until the first flowers opened, days until 75 % of the flowers were open (full bloom) and days from full bloom until wilting started (the persistence time).

Statistical analysis

Data in the field were collected for each individual plant and averaged within blocks and statistically analysed (SAS Institute, version 9.1) with a General Linear Model. Mean values were separated by the Ryan-Einot-Gabriel-Welch multiple range test. A regression analysis was made for the time when 75 % of the flowers were open (outdoors), versus the mean monthly temperatures and the monthly sum of the temperatures. In the forcing experiments nine branches were collected from each of the studied cultivars and the statistical analysis was made on the mean values observed for three branches in each of three vases (replicates). In the storage experiment comparisons were made using storage time and temperature as the fixed variables. In order to examine the dormancy status of the flower buds during this experiment, a regression analysis was made for time from the start of forcing until flowering occurred, versus the varying inset dates.

Table 1. Properties of cultivars of *Hamamelis* spp. included in the experiment, according to Krüssmann (1977).

Species and cultivars	Flower size	Flower colour	Size of the plant
H. x intermedia 'Arnold Promise'	medium	golden yellow	medium (3 m)
H. x intermedia 'Diane'	medium to large	carmine red	large (4 m)
H. x intermedia 'Jelena'	large	copper-orange	large
H. mollis	small	golden yellow	large (5 m)
H. mollis 'Pallida'*	medium	sulphur yellow	medium

*The nomenclature of this variety is confusing, since it is described by some authors as a *Hamamelis* x *intermedia* hybrid.

Results

Phenology of flowering under natural conditions

The time of full flowering differed from year to year (Fig. 1), with the latest flowering in year one, when full bloom was reached in mid to late February. However, most years the plants were in full bloom in mid to late January. In every year 'Diane' was the latest to flower and 'Jelena' was the earliest, with an average difference over four years of 40 d (P-value <0.0001). The other cultivars reached full bloom at practically the same time, *i.e.* at a time between those of 'Diane' and 'Jelena'. In 2001 the keeping quality, from full bloom until wilting of the flowers, lasted almost twice as long as in the other three years (P<0.0001). 'Jelena' maintained flowers of good quality for the longest time, with an average keeping period of 33 d of flowering, *i.e.* the number of days from full bloom until senescence of flowers. 'Diane' and the *H. mollis* seedlings maintained the flowers for 17 and 18 d respectively, and the other varieties were intermediate with respect to persistence time under outdoor conditions. The worst conditions, shortening the keeping quality of the flowers dramatically, occurred when temperature alternated between frosty and mild weather, often with rain (data not shown).

Amount of flowers in the field

Differences in the amount of flowers could not be found between the two years (2001 and 2002), when this was scored for the shrubs. *H. mollis* had fewer flowers than all the other cultivars (P<0.0001). 'Arnold Promise' and 'Jelena' had the largest score for amount of flowers, with a score that was 59 % higher than for *H. mollis* (data not shown). Amongst the other cultivars differences in the amounts of flowers were small and insignificant. No interaction between cultivars and year of registration was found.

Forcing branches harvested from the field

When branches with flower buds were harvested on October 2 and transferred directly to forcing conditions the harvested branches never came into bloom. Flowering started after 14 to 20 d when the branches were harvested on November 13 (Fig. 2A). When using branches harvested in mid December, the forcing time needed until flowering decreased for all cultivars, by 2.7 to 4.9 d. 'Diane' started flowering about 2 d later than 'Arnold Promise' and 'Pallida' (P<0.016). As the number of days needed for forcing until flowering decreased the proportion of flower buds that opened increased from 10 to 20 % for 'Arnold Promise' and 'Diane', and 60 % for 'Pallida' for the first harvest, and to 86 to 90 % when forcing started after about mid December (Fig. 2B). There was a significant difference between the cultivars in the proportion of open flowers when forcing was started by November 13 when 'Pallida' had most open flowers (P<0.0001). However, when forcing started later no differences were found between the tested cultivars. The relationship between time of commencement of forcing conditions and time until the start of flowering ($T_{flowering}$) could be described by the regression function;

$T_{flowering} = 27.7 - 13.2\ t + 1.8\ t^2$ ($R^2 = 0.87$),

where t = the time of harvesting of branches and the start of forcing. For time of wilting of the flowers a similar function was found;

$T_{wilting} = 41.9 - 16.2t + 2.1t^2$ ($R^2 = 0.92$)

and the proportion of open flowers could be described by;

$T_{\%open} = -7.0 + 47.5\ t - 5.9\ t^2$ ($R^2 = 0.68$).

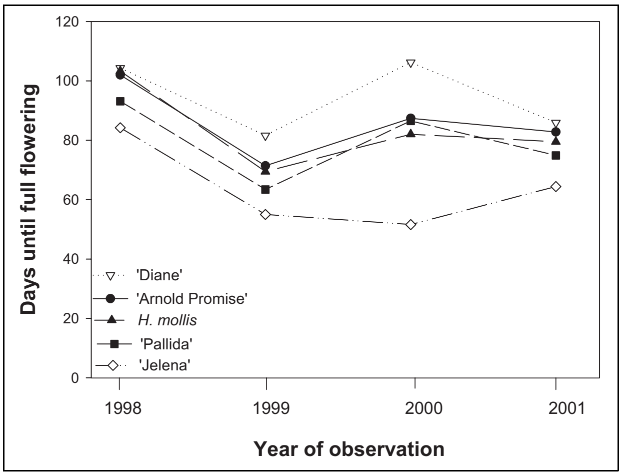

Fig. 1. The number of days until 75 % of the flowers of tested *Hamamelis* cultivars were open. Day no. 1 was the starting date for observations, November 13.

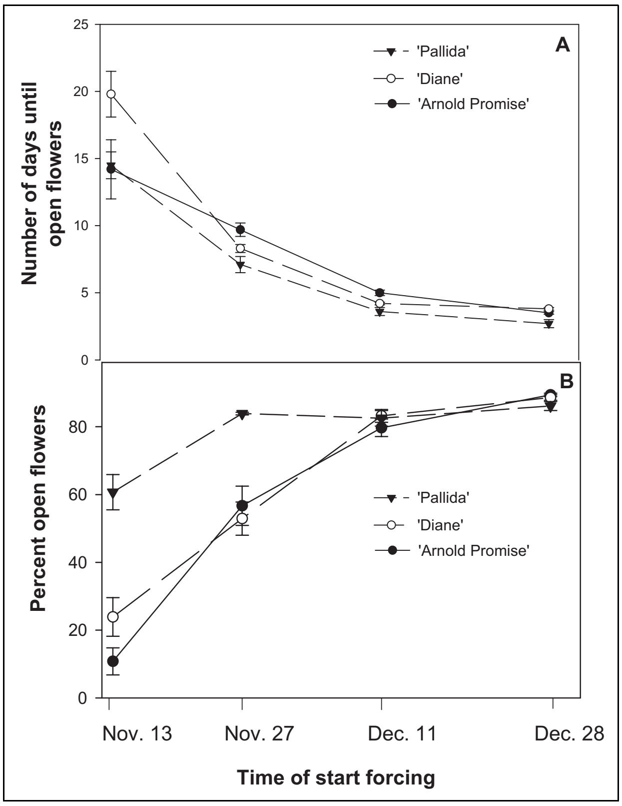

Fig. 2. The number of days until the first open flowers of *Hamamelis* (A) and percentage of the total numbers of open flowers (B) determined after start of forcing of branches with flower buds at November 13, November 27, December 11 and December 28. Error bars are standard error.

Forcing after storage of the branches

The two cultivars used in this part of the study ('Diane' and 'Pallida') did not differ in their responses to storage conditions and the results are therefore presented for pooled data. Storage of branches with flower buds was successful until the end of February. Time until full bloom was 9.8 d if the buds were forced with no time in storage (forcing start November 30, see Fig. 3.). After four weeks of storage, full bloom was reached after 5.3 d and if the branches were stored for 8 and 12 weeks, flowering started within 2 to 4 d.

The number of days from the start of forcing until flowering changed by 5 to 6 d whereas the time between the stage of full bloom until wilting changed little, with an average time of open flowers of 5 to 6 d. Increasing the storage temperature reduced the keeping quality. The amount of flower buds reaching the flowering stage also decreased at the highest temperature (data not shown).

Discussion

Phenology of flowering under natural conditions

The time of commencing of flowering depended on the year (Fig. 1), with the latest flowering in 1998 (the first year). In many species the photoperiod or the effect of chilling is important for the initiation and development of flowers. Both flower induction and the initiation of dormancy may be affected by temperature, photoperiod and an interaction of environmental factors, as was found in raspberry (Sønsteby and Heide 2008). In *Hamamelis* the flower buds are visible at a relatively early stage during late summer, indicating that the flowers are either initiated by long days or by internal signals, as shown for *Rosacea* fruit trees (Battey 2000). High temperatures in September were found to delay flowering in *Pyrus communis* (Atkinson and Lucas 1996) and also the spring bud burst in *Betula* and *Alnus* (Heide 2003). The consistent differences between the *Hamamelis* cultivars in time of flowering shows that harvesting time can be spread over some time, even for the limited number of cultivars used in this experiment. The persistence of flowers under outdoor conditions differed between cultivars and years (data not shown), but the time at the open flowers stage seemed to be long when compared to that observed in *H. virginiana* in Michigan, where persistence of single flowers was about 14 d (Steven 1983). The long persistence time in most of the years of the present field experiment are probably also caused by favourable weather conditions. However, the selection of cultivars for the experiments may also have been an important factor.

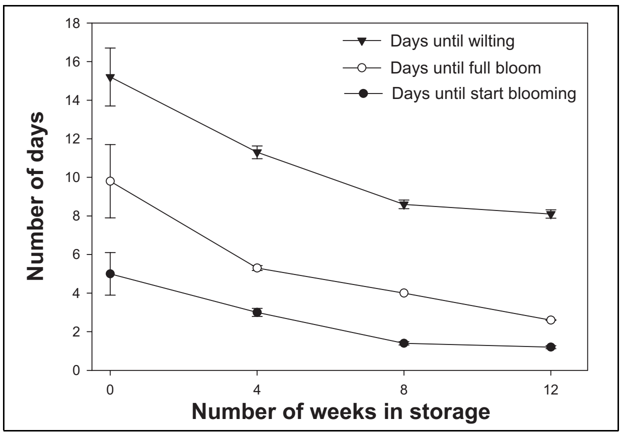

Fig. 3. The number of days from start of forcing until start of flowering, until full bloom and wilting in *Hamamelis* after 0, 4, 8 and 12 weeks in storage before forcing. Error bars are standard error.

Amounts of flowers in the field

The flower production was good in all years, in contrast to what was found in *H. virginiana* (Steven 1983). As the climate at the testing site of the present experiment is relatively cool during the summer, one might expect that flower initiation and development would be a limiting factor for the flowering performance of *Hamamelis*. However, significant differences were not observed in the amount of flowers between the two years of recording this character (2001 and 2002), but both years were characterised by high mean temperatures in July and August. *H. mollis* had the lowest score for flowers. This selection also had the least autumn colours and had green leaves until the leaves fell (data not shown). This may indicate that climatic adaptation to the site may not be optimal for this particular selection of *H. mollis*. However, in the rest of the cultivars the number of flowers on the shrubs was evaluated as large every year. *H. virginiana* had the highest number of flowers when growing in the canopy gaps as compared to under an intact canopy (Brigham and Brigham 1989). The number of leaves necessary for the floral induction in mango was only $^1/_4$ of a cross-cut leaf per stem (Davenport et al. 2006). This shows that the induction of flowers may be less dependent on resource acquisition than the conditions for flower development. Steven (1983) observed a larger fruit crop when plants were grown in open sun than under a closed canopy. The environmental conditions (light and leaf temperatures) are important for the induction and development of flowers also in *Hamamelis*. However, plants that are typically variable in flowering are often characterised by heavy cropping that may deplete the plants of resources for flower initiation and development in the same year. This is probably not the case for *Hamamelis* grown in the climate of the test site and flowering may not be hindered from year to year. The results of this research show that the shrubs have a very good ability to initiate and develop flowers in North European coastal climates. However, the cultivars tested here were selected for their prolific flowering qualities. The site of the experimental field is well sheltered from cold winds, a factor that has probably contributed to the good results in flower formation. In Northern Europe *Hamamaelis* should be planted in full sun, with optimal environmental conditions for the initiation and development of flowers.

Forcing branches harvested from the field

Branches harvested and directly transferred to forcing conditions before mid December required a long time until flowering occurred and the proportion of flowers that opened was low. However, after mid December, forcing was quick and there was a high percentage of open flowers. This is consistent with what was found with the forcing of *Lavandula angustifolia* Mill. (Whitman et al. 1996). However, chilling in *Lavandula* promotes a vernalisation process rather than having an effect on the breaking down of dormancy (Monaghan et al. 2004). In the present experiments it was observed that even after the *Hamamelis* flower buds were formed and were visible on the shrub, dormancy in these buds inhibited flowering, despite environmental conditions being favourable to their doing so. The *Hamamelis* cultivars are propagated from adult propagules, and thus flowering can occur, even a short time after the propagation took place. Although the flowers of *Hamamelis* seem to be well developed early in the season and the flower buds are already visible early in the autumn, low temperatures may be necessary to finish their development. The function of low temperatures may therefore be limited only to the breakdown of dormancy in the flower buds. A sufficiently high temperature is then required to develop the flower buds into flowers. In several woody species, for example *Pieris* (Sytsema and Ruesink 1996), and *Hebe* (Noack et al. 1996), flowering has been shown to occur faster when forcing took place after an increased amount of cold treatment had been administered. Higher summer temperatures probably speed up the process of flower initiation and development, making the flowers ready to bloom at an earlier date if temperatures are high. So, when there have been high summer and autumn temperatures the buds may react earlier to low temperatures and so bring forward the flowering time. However, the most effective chilling temperatures for breaking dormancy are 3 to 6 °C and a high autumn temperature may delay rather than cause earlier flowering if effective chilling temperatures starts later in the autumn.

Forcing after storage of the branches

The experiments show that dormancy in the flowers will prevent them from developing rapidly if the branches are harvested early and then forced. However, storage of the branches will compensate for the chilling experienced under natural outdoor conditions and after 4 to 8 weeks of storage at 3 to 9 °C, flowering will readily occur after 2 to 4 d under forcing conditions. There may be different physiological processes regulating the bud break and the break of flower buds. However, a larger amount of day degrees may be needed for the breakdown of dormancy in vegetative than in generative buds, or there may simply be different threshold temperatures required for the processes to start. Excessive cold treatment of peach and nectarine flower buds decreased the number of open flowers (Gariglio et al. 2006), possibly caused by physiological damage to the buds. Gariglio et al. (2006) conclude that flower buds of peach and nectarine require less cold treatment than do the leaf buds. The branches of *Hamamelis* can safely be harvested before the cold and variable winter weather sets in and jeopardise the flower buds. However, stored branches wilted 3–4 d earlier than those forced directly from the field (data not shown). This was also observed in the woody species of *Weigela*, *Buddleja*, and *Cercis* (Redman et al. 2002), with a decrease in vase life after storage and often the largest decrease at the highest storage temperatures. This probably demonstrates the plants' use of resources through respiration under storage conditions. Storing the plant materials at lower temperatures can effectively decrease respiration, but care should be taken in order to avoid damage to plant tissues by low temperatures (Redman et al. 2002). In the present experiment the lowest storage temperature was 0 °C, which may still cause some respiration from the branches and consequent loss of carbohydrates that could otherwise have been used to extend vase life. *Hamamelis* is stored without leaves or open flowers and the danger of damage to plant tissues by even lower temperatures is probably small. At lower temperatures damage by storage related fungi should also be less, although this was not a problem in the present experiments.

Conclusion

The flower buds need cooling in order to break their dormancy and cooling in the storage gives the same effect as by natural cooling in the field. The shortest forcing time to flowering is found under natural conditions from mid January. Nevertheless, the practical treatment of branches as well as their storage conditions may be further improved in order to increase the persistence time of flowers after forcing.

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