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Morphologic differentiation of flower buds and development of dead flowers in autumn and winter 1998/99; flowering and fruitset 1999 in the sour cherry cv. 'Stevnsbaer' on four rootstocks.

Morphologische Differenzierung von Blütenknospen und Entwicklung von toten Blüten im Herbst und im Winter 1998/99; Blüte und Fruchtansatz in 1999 in der Sauerkirschensorte Stevnsbaer auf vier Unterlagen.

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Summary

In sour cherry cv. 'Stevnsbaer' 4 rootstocks were monitored for differentiation of flower buds and development of dead flowers in autumn and winter 1998/99. Rootstocks included were Colt, Weiroot 10, F12/1 and Gisela 5. No differences in morphological differentiation of flower buds during autumn and winter were demonstrated among the rootstocks. On March 15th, 68,9–82,1% of the flowers were found to be damaged or dead and no significant differences between rootstocks were found. However, a significant difference in flower stage between Colt and Weiroot 10 was established on March 15th. It is indicated that the most developed flowers in Colt die during winter probably because of frost. It is suggested that flower quality expressed as percent damaged/dead flowers and dead flower buds and fruitset are linked to flower bud quality in March. Flowers on Weiroot 10 were more differentiated than flowers on Colt on March 15th. A clear difference in flower quality is demonstrated in the flowering period. Colt had a poor flower bud and flower quality seen as a high percentage of dead flowers and flower buds and a detrimental fruit set of 4,9 %. Gisela 5 had a poor flower bud and flower quality and the fruitset was 10,3 %. F12/1 and Weiroot 10 showed to have the best quality of flower buds and flower and the fruitset was respectively 23,2 % and 15,7 %.

Zusammenfassung

Im Herbst und Winter 1998/99 wurden die Differenzierung von Blütenknospen und die Entwicklung von toten Blüten der Sauerkirschensorte Stevnsbaer auf vier Unterlagen bonitiert. Die Unterlagen waren Colt, Weiroot 10, F12/1 und Gisela 5. Zwischen den Unterlagen wurden keine Unterschiede bezüglich der morphologischen Differenzierung der Blütenknospen während des Herbstes und des Winters festgestellt. Am 15. März wurden 68,9–82,1% der Blüten beschädigt oder tot aufgefunden und es wurden keine signifkanten Unterschiede zwischen den Unterlagen gefunden. Jedoch wurde ein bedeutender Unterschied bezüglich des Entwicklungsstadiums der Blüten zwischen Colt und Weiroot am 15. März beobachtet. Es hat den Anschein, dass die am meisten entwickelten Blüten in Colt während des Winters vermutlich durch Frostschäden sterben. Es wird da von ansgegangen, dass die Blütenqualität ausgedrückt als der prozentualer Anteil beschädigter oder toter Blüten und toter Blütenknospen und der Fruchtansatz, zur Blütenknospenqualität im März korreliert ist. Am 15. März waren Blüten auf Weiroot 10 weiter differentiziert als Blüten auf Colt. Ein deutlicher Unterschied bezüglich der Blütenqualität wurde zur Blüte sichtbar. Die Unterlage Colt hatte eine geringe Blütenknospen- und Blütenqualität, die als hoher Prozentsatz beschädigter oder toter Blüten und toter Blütenknospen, wie auch durch einen sehr niedrigen Fruchansatz von 4,9 % dokumentiert wurde. Gisela 5 zeigte eine schlechte Blütenknospen- und Blütenqualität und der Fruchtansatz betrug nur 10,3 %. F12/1 und Weiroot 10 zeigten die beste Qualität der Blütenknospen und Blüten und der Fruchtansatz lag bei 23,2 % beziehungsweise 15,7 %.

Introduction

In sour cherry, flower buds are formed in lateral buds on short shoots on older wood and to varying extents on extension shoots (FEUCHT 1961). RASMUSSEN et al. (1983) and MORTENSEN at al. (1987) investigated the relationship between shoot length and flower bud distribution in cv. 'Stevnsbaer' and noted that nearly all buds on extension shoots shorter than 20 cm were floral. On longer shoots the proportion of flower buds dropped markedly, leaf buds occurred particularly in the mid-zone of the shoot.

Flower initiation and development of bud nodes has been described in cv 'Stevnsbaer' (DENCKER and HANSEN 1993) and differentiation has been described for sour cherry in Germany (ZELLER 1955) and Michigan (DIAZ et al. 1981). It has been demonstrated that the differentiation progresses quickly in late summer and autumn while stagnation occurs in winter.

In sour cherry cv. 'Stevnsbaer' the occurence of dead flowers is normal and in some years a serious problem (MORTENSEN et al. 1987).

The main sour cherry rootstock used in Northern Europe was for decades *Prunus avium* as seedlings or the clone F12/1. More efficient rootstocks have been introduced. Colt introduced in 1966 (TYDEMANN and

GARNER 1966) proved to be more yield efficient than *P. avium* (CALLESEN 1991), PENNELL et al. 1983).

Weiroot 10 which is a *P. cerasus* selection (SCHIMMELPFENG and LIEBSTER 1979), (TREUTTER et al. 1993) is shown to be very high yielding compared to several other rootstocks (WERTHEIM et al. 1998).

Gisela 5 was introduced for sweet cherry as a very precocious rootstock (GRUPPE 1985a GRUPPE 1985b), (FRANKEN-BEMBENEK and GRUPPE 1985a) and(FRANKEN and GRUPPE 1985b). The value of Gisela 5 has since been demonstrated for a wide range of places in Europe by WERTHEIM et al. (1998).

According to VESTERGAARD et al. (1997b) temperatures below zero can be responsible for big differences in visible damage to flowers and the final fruit set.

The present study describes the morphological changes of flower buds during autumn and winter 1998/99 on 4 rootstocks in cv. 'Stevnsbaer'. Differences in flower quality as number of flowers per cluster, number of flowers and dead flowers and number of fruits is registered. Fruitset is calculated and fruit yield recorded in autumn 1999. The intention is to reveal if a connection between flower bud quality in autumn and winter and flower quality in bloom can be described.

Materials and Methods

'Stevnsbaer' trees were planted on 4 different rootstocks in the experimental orchard, Aarslev, in 1988. The rootstocks were: Colt, Weiroot 10, F12/1 and Gisela 5. Four trees of each rootstock uniform in size and vigour were selected for this investigation

Differentiation of flower buds was followed from September 28th 1998 to March 15th 1999. Flower buds were collected twice a month in October and November 1998, and later collection was done once a month. From the periphery at about 1.5 m's height five one-year-old shoots were collected from 4 trees of each rootstock on each collection date. On 28 September and 14 October only 3 shoots pr. tree were collected. In total 48 or 80 shoots between 20 and 40 cm length were collected from the trees every sampling date. Shoots were kept in plastic bags with humid air in a cool storage at 3,5 °C. until examination, which was performed as soon as possibly after a collection.

All buds on every shoot were dissected and examined under a stereo light microscope. After removal of the bud scales every flower was evaluated and given a score for stage of differentiation, according to Table 1, and damaged or dead flowers were noted. The first 4 numbers in flower stage are used to describe the early differentiation and have no current interest in our investigation. Damaged flowers were more or less brown while fresh flowers appeared turgid and had a uniform fresh green colour. In dead flowers pistils or eventually more parts of the flower were black. It was noted as well if the bud was a leaf bud.

Temperature data were obtained from a local weather station every day from 28 September 1998 until 15 March 1999, Figure 3, and in the flowering period from 3 May until 25 May 1999, Figure 4.

In 1999 flowering data were recorded. The following registrations were performed: Total number of flowers on 10 shoots placed all around the 4 trees of each rootstock at about 1,5-m. height. The counting was done on 28 April when flowers were in the balloon-stage. The number of damaged and dead flowers, indicated by deformed or brown or black pistils, was counted at full open stage on 10 May. Dead flower buds indicated as closed dry buds at full flowering were registered at the same time. The number of fruits on the same shoots was counted 6 July. Fruitset is calculated as percent fruits of number of fresh flowers 10 May. Trees were machine harvested 30 August and yield recorded in kg pr. tree.

Table 1. Description of flower bud stages determined between 28 September, 1998 and 15 March, 1999
Beschreibung der Stadien der Blütenknospen zwischen den 28.September, 1998 und 15 März, 1999

Flower stage *Entwicklungsstadien*	Description *Beschreibung*
5	Sepals and petals are visible *Kelch- und Kronblätter sind sichtbar*
6	Sepals, petals and stamens are visible *Kelch-, Kron- und Staubblätter sind sichtbar*
7	Sepals, petals, stamens and pistil are visible, pistil is convex *Kelch-, Kron- und Staubblätter und der Stempel sind sichtbar*
8	As 7, but stigma is flattened and concave *Wie 7, aber der Stempel ist flachgedrückt und konkav*
9	As 8 but stigma is more differentiated, broad and granulated *Wie 8, aber die Differenzierung der Stempel ist weiter vorgeschritten, breit und granuliert*

Data management was made with the SAS statistical package (SAS, Version 6.12, 1985). Flower bud data until 23 November were analysed with the procedure GLM and means were separated with LSD ($p<0.05$). From 7 December Lsmeans were calculated due to unbalanced design and pairwise separated by t-test ($p<0.05$). Statistical analysis was carried out for flower-stage-data and percentage-fresh-flowers-in-buds-data on average data for every shoot. For every sampling date a dataset consisted of 48 or 80 averages: 4 rootstocks, 4 blocks (trees) and 3 or 5 shoots.

Flowering data: Number of flowers pr cluster, percentage of damaged or dead flower buds and fruitset, were analysed with the procedure GLM and means were separated with LSD ($p<0.05$). The fruitset data was arsen-transformed due to a not normal data distribution. A flowering dataset consisted of average data for every shoot e.g. 160 numbers: 4 rootstocks, 4 blocks (trees) and 10 shoots. Data for fruit production in kg pr tree were not analysed statistical because of too few observations.

Results

The number of flowers pr bud varied in the experimental period from 3,1 to 3,9 for all rootstocks. The average number of flowers pr bud was until 7 December significant higher in Gisela 5 (3,6–3,9) than the other rootstocks (3,1–3,5). The number of flowers pr. bud varied from 3,2 till 3,6 after 7 December until 15 March.

The flower stage was investigated on every bud on every shoot on 9 dates. No significant differences in

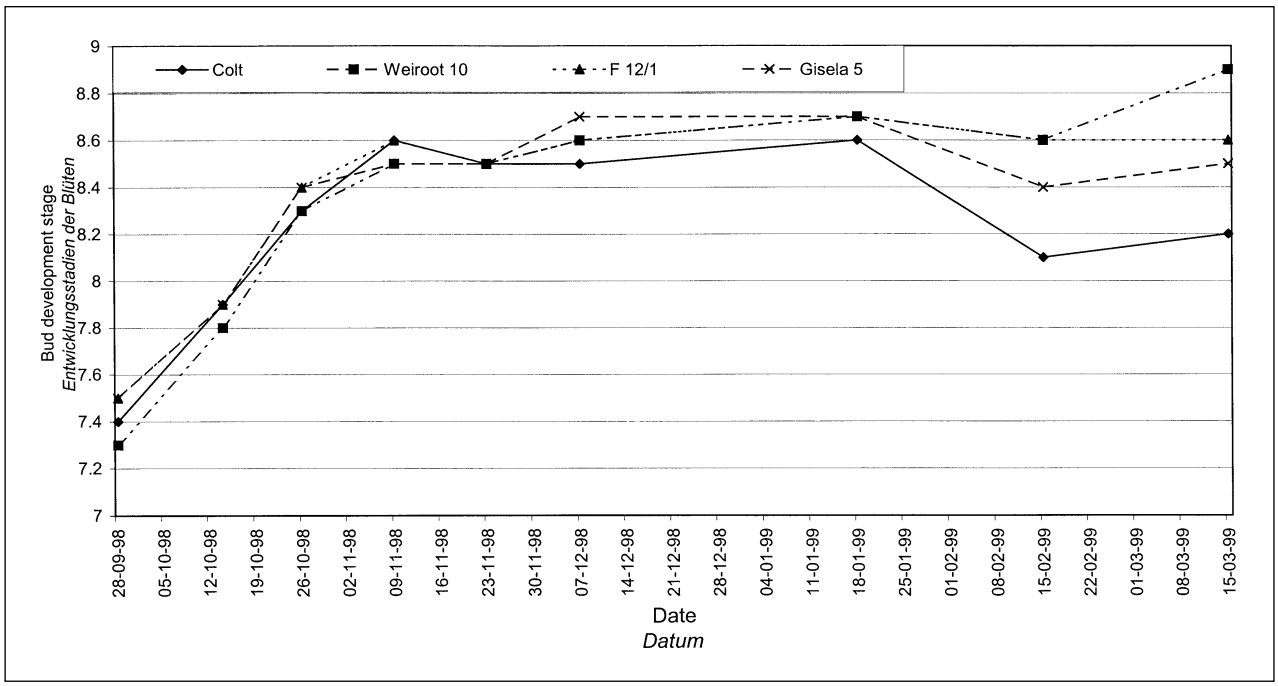


Fig. 1. Development of flower bud stages in cv. Stevnsbaer on 4 rootstocks, 1998–99
Entwicklungsverlauf von Blütenknospen in 'Stevnsbaer' auf 4 Unterlagen, 1998–99

flower bud differentiation were found between rootstocks until 15 March, Figure 1. Flowers on Weiroot 10 were on average significantly more developed than flowers on Colt on 15 March.

Differentiation of flower buds progressed on all rootstocks until 9 November without significant differences between rootstocks, Figure 1. Only small and not significant increases in flower stages occurred during winter on the different rootstocks. Weiroot 10 was the only rootstock that seemed to continue development of flower buds from 18 January to 15 March, but the observed increase in flower bud stage was not significant. The most developed flowers on Colt apparently died after 18 January, which resulted in a significantly lower score in flower stage 15 February. In some shoots a tendency of less developed flowers in buds near shoots tips were observed; but in general, no clear effect of bud position on the shoot and the flower stage was found, results are not presented.

Flower mortality began to increase after 9 November; the fastest decrease in fresh flowers occurred from 9 November until 7 December, Figure 2. No significant differences in the number of dead flowers between rootstocks were observed on any date but two. On 23 November, F12/1 had significantly more fresh flowers than Colt and on 18 January, Weiroot 10 and Colt had higher percentages fresh flowers than F12/1 and Gisela 5. At the last examination on 15 March between 68,9 and 82,1 percent of the flowers were dead.

Average and minimum air temperature revealed that the first autumn frost in 1998 was on 1 November and slight frost was on 2, 5 and 13 November as well, Figure 3. A period of 12 days with frost began on 16 November; the lowest temperature in this period was –6.2 °C. The coldest period in winter 1999 was from 11–14 February where minimum temperature dropped to –13,7 °C. There was no frost in the flowering period in 1999, Figure 4.

'Stevnsbaer' on Colt began to bloom Fifth May, on Weiroot 10 and on Gisela 5, Fourth May and on F12/1, Third May, Table 2. The duration of the flowering 1999 was 20 days, except for Gisela 5 where bloom lasted 18 days.

At flowering between 39,1 and 52,8 percent of the flower buds were found to be dead and therefore never flowered, Table 3. Counting of flowers revealed that Colt had fewer flowers pr cluster than the other 3 rootstocks. At flowering it was found that 12,7–24,1 percent of the flowers were damaged or dead and consequently unable to set fruit. Fruitset varied from 4,9 percent on Colt to 23,2 percent on F12/1. Fruit yield was for cv 'Stevnsbaer' on F12/1 13,5 kg pr. tree and no measurable yield was obtained on Colt. The yield was an average of only 4 trees therefore it is not possible to make statistical analysis of the data.

Discussion

We found in accordance to MORTENSEN et al. (1987) that sour cherry cv. 'Stevnsbaer' has differentiated all flower parts before entering dormancy, Figure 1. The existence of a relationship between the time of formation of a given flower and its subsequent ability to set fruit has been postulated (DIAZ et al. 1981). In our investigation shows that rootstock did not affect the rate of flower bud development in autumn and winter, Figure 1; subsequent to flower initiation the rate of flower bud development is equal for all rootstocks. This suggests that differences in fruitset are not related to flower differentiation in autumn and early winter.

MORTENSEN et al. (1987) excluded winter and spring frost as the principal causes of flower mortality.

Table 2. Flowering of cv. Stevnsbaer as effected by 4 rootstocks, 1999.
Blütezeit von 'Stevnsbaer' auf 4 Unterlagen, 1999

Rootstock *Unterlage*	Beginning* *Blühbeginn**	Full bloom** *Vollblüte***	Petal fall*** *Blühende****	Period, days *Periode, Tage*
Colt	5 May	14 May	25 May	20
Weiroot 10	4 May	14 May	24 May	20
F 12/1	3 May	14 May	23 May	20
Gisela 5	4 May	12 May	22 May	18

* 10 % open flowers / *10 % der Blüten sind geöffnet*
** 90 % open flowers, petal starts to fall / *90 %der Blüten sind geöffnet, Blütenblätter beginnen zu Fallen*
*** 90 % dropped petals / *90 % der Blütenblätter sind abgefallen*

Table 3. Flowers pr cluster, damaged or dead flowers, fruitset and yield in cv. Stevnsbaer on 4 rootstocks, 1999
Blüten pro Blütenstande, beschädigte oder tote Blüten, Fruchtansatz und Ertrag von 'Stevnsbaer' auf 4 Unterlagen, 1999

Rootstock	Flowers pr cluster number	Damaged or dead flowers percent	Dead flower buds percent	Fruitset percent	Fruit Yield kg/tree
Unterlage	*Blüten pro Blütenstand Anzahl*	*Beschädigte oder tote Blüten Prozent*	*Tote Blütenknospen Prozent*	*Fruchtansatz Prozent*	*Ertrag kg/Baum*
Colt	2.5 b*	24.1 a	52.8 a	4.9 d	0
Weiroot 10	2.9 a	12.7 b	42.2 bc	15.7 b	9,6
F 12/1	2.7 a	13.6 b	39.1 c	23.2 a	13,5
Gisela 5	2.7 a	18.1 ab	48.8 ab	10.3 c	2,4

* Means within column followed by the same letter do not differ at the 5 % level of significance.
Durchschnitte in Spalten mit gleichem Buchstaben sind nicht signifikant verschieden (5 %)

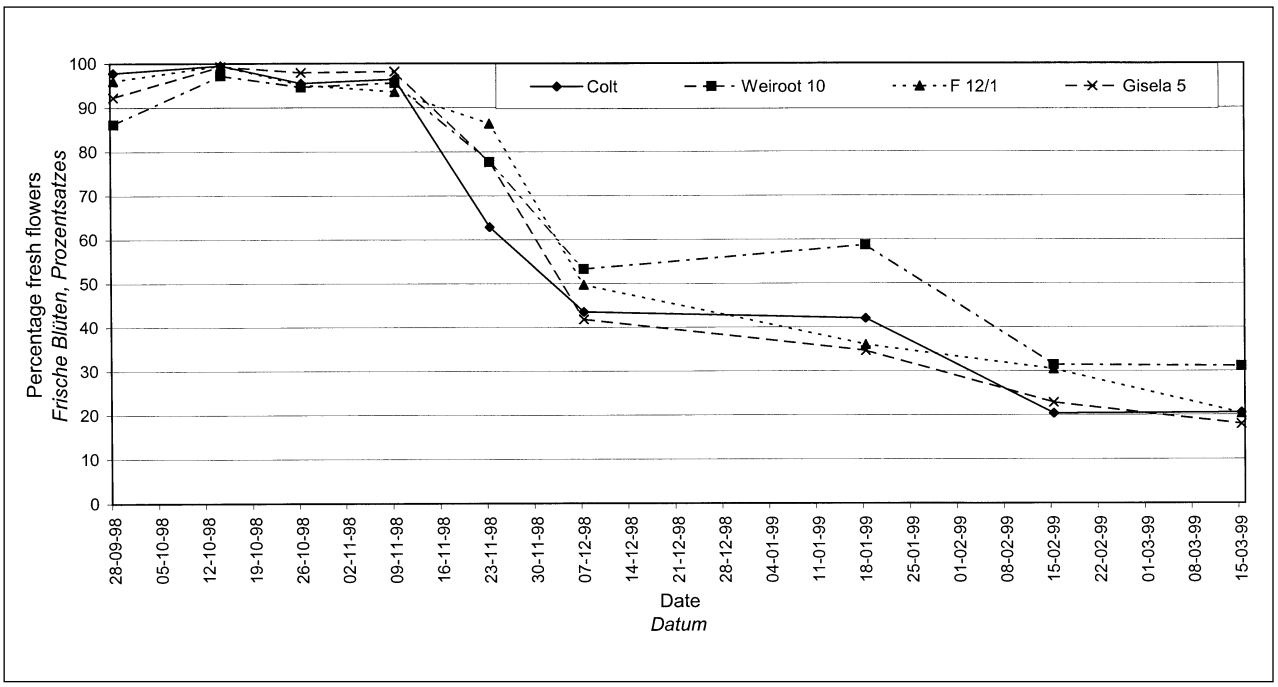


Fig. 2. Fresh flowers in buds of cv. Stevnsbaer on 4 rootstocks, 1998–99
Frische Blüten in den Knospen von 'Stevnsbaer' auf 4 Unterlagen,1998–99

In our study the development of dead flowers increased dramatically between 9 November and 7 December, Figure 2. This is obviously caused by a period with many days and nights with frost, Figure 3. In related studies (MORTENSEN et al. 1987) it has been observed that a big increase in the development of dead flowers occurred as late as in February. Comparison of our result with those of MORTENSEN et al. (1987) suggest that weather conditions the specific year may be very important for the rate of development of dead flowers.

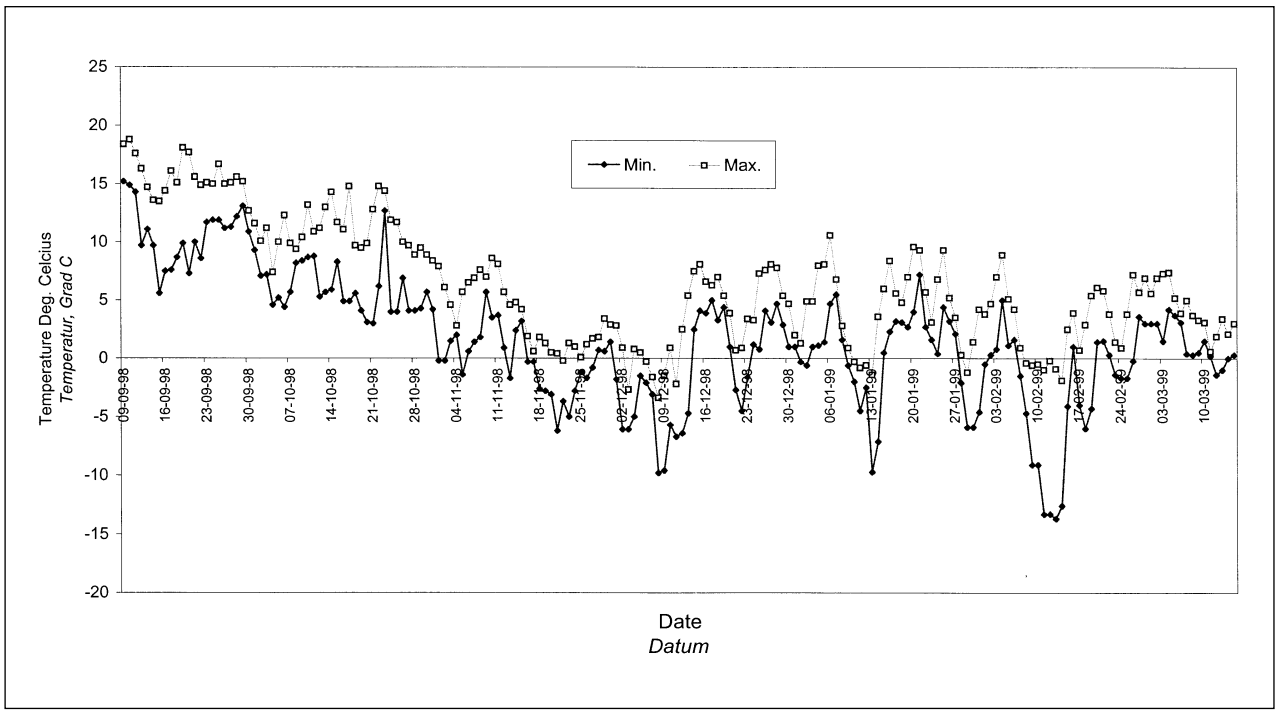


Fig. 3. Air temperature at Aarslev, 1998–99
Lufttemperatur in Aarslev, 1998–99

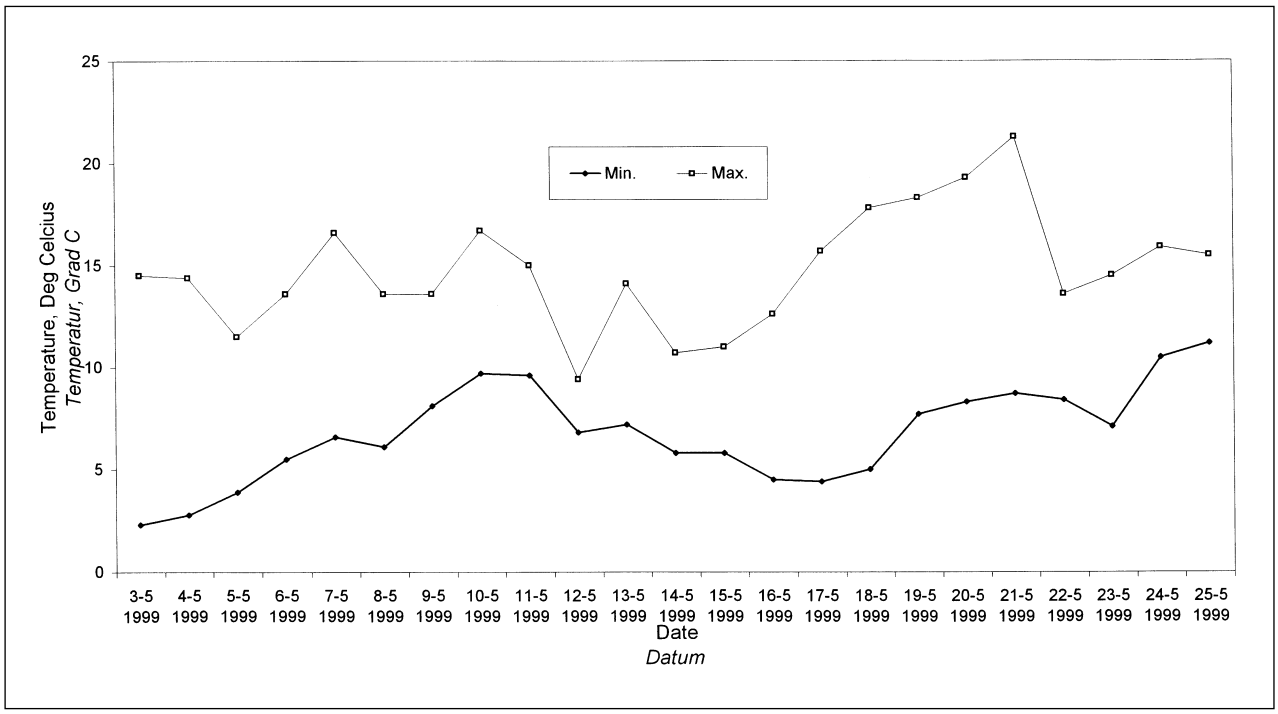


Fig. 4. Air temperature in the flowering period at Aarslev, 1999
Lufttemperatur während der Blüte in Aarslev, 1999

It has been established that rootstock influences the frost tolerance of flowers (VESTERGAARD et al. 1997b) and that Weiroot 10 is extremely frost tolerant in spring. Although frost occurs in spring a high fruitset on Weiroot 10 might be expected. GRAUSLUND and HANSEN (1980) demonstrated that frost damages in cv. 'Stevnsbaer' in general occur when temperature at bud break is –8 °C to – 9 °C. No frost occurred in the flowering period in 1999, Figure 4; consequently frost in bloom is not the reason for low fruitset and devel-

opment of damaged and dead flowers on Colt in 1999, Table 3.

The rootstock Colt has been claimed to be frost sensitive in the flowering period (CALLESEN and VITTRUP, 1996). Our investigation demonstrates that Colt is frost sensitive in winter as well. The most developed flowers died during the winter before 15 March probably caused by frost, Figure 1. The consequence was less developed flowers with an apparently poor quality indicated by a poor fruitset, a high percent of damaged or dead flowers and dead buds and no harvestable yield, Table 3. In accordance with VESTERGAARD et al. (1997a) a distinct difference in the fruitset for the different rootstocks was established. 1999 was a detrimental year for fruitset in cv. 'Stevnsbaer'. In comparison to 1992 (VESTERGAARD et al. (1997a) only F12/1 obtained a better fruitset in 1999. Our investigation showed that the percent of dead flowers and dead flower buds was lowest in cv. 'Stevnsbaer' on F12/1 and on Weiroot 10, Table 2.

In the present study differences in fruitset and fruit yield apparently reflect differences in flower quality between the different rootstocks. F12/1 and Weiroot 10 seem to be superior to Gisela 5 and Colt in respect to flower bud and flower quality in cv 'Stevnsbaer', Figure 1 and Table 2. The results can not be explained by the stages of flower bud differentiation in autumn and winter; but must in 1998/99 be a consequence of differences in frost resistance in late winter. The difference in fruitset resulted in a difference in fruit yield, Table 3. Trees on Weiroot 10 and F12/1 produced a medium yield while on Gisela 5 and especially on Colt without a yield was disappointing. The present study demonstrates that flower quality depends on the flower differentiation stage in early spring (15 March). Flowers on Weiroot 10 and F12/1 were more differentiated 15 March than on Colt. This resulted in increased flower quality on Weiroot 10 and F12/1.

A reduction in the number of flowers pr cluster occurred from autumn to flowering in all rootstocks. No differences in the number of flowers were found in autumn and winter between rootstocks. However a reduction must have occurred after 15 March; because in bloom only 2,5–2,9 flowers/cluster were found while on 15 March the number was 3,2–3,6. It appears that the onset of flowering is linked with developmental stage of flowers in late winter e.g. the tendency that flowers of Colt are less developed 15 March resulted in beginning of flowering 1–2 days later than the other rootstocks. The maximum temperature in the flowering period was most days higher than the limit for bee flying (12–14°) (NØRGAARD HOLM 1977), thus if bees do not differentiate between rootstocks, lack of pollination is not responsible for the disappointing fruitset in Colt. VITTRUP (1998) collected flowering data for cv. 'Stevnsbaer' for 1960–1997 and he found that the longest flowering period, obtained in 1987, was 20 days. It thus appear that the flowering period was long in 1999; this indicate in addition to adequate bee-flying temperatures that pollination must have been sufficient in 1999.

Conclusion

No differences in morphological differentiation of 'Stevnsbaer' flower buds during autumn and winter were demonstrated among the rootstocks Colt, Weiroot 10, F12/1 and Gisela 5. However in late winter (March 15th) flowers on Weiroot 10 were more differentiated than flowers on Colt . The most developed flowers of Colt died during the winter probably due to high frost sensitivity. The flower quality can be related to the flower bud quality in late winter. A clear difference in flower quality was demonstrated among the rootstocks. Colt had a poor flower bud and flower quality seen as a high percentage of dead flowers and flower buds and a detrimental fruit set of 4,9 %. Gisela 5 had a poor flower bud and flower quality and the fruitset was 10,3 %. F12/1 and Weiroot 10 had the best flower bud and flower quality and the fruitset was respectively 23,2 % and 15,7 %.

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