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# The influence of heterostyly on the fructification of two *Chaenomeles* species

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Summary

The fructification of *Chaenomeles japonica* Lindl. and *Ch. x superba* grown in the Botanical Garden in Lublin was investigated in 1999 and 2002-2003. The influence of heterostyly on the degree of fruit setting and considerable morphological differences between fruits were examined. The three form heterostyly influenced the fruit to flowers ratio and fruit weight. Long-styled flowers set significantly more fruit (approx. 70%) and of higher weight (approx. 26 g) in comparison to fruit from mid-styled flowers – 50% and 20 g, respectively. The higher yield was obtained from *Chaenomeles japonica* ~ 1-2 kg. The average yield of *Ch. x superba* was ~ 0.9 kg. While planting *Chaenomeles* shrubs for fruit production, attention should be paid to the participation of flower types with the view to eliminating shrubs with the domination of short-styled flowers with degenerated ovary.

Key words: *Chaenomeles japonica*, *Chaenomeles x superba*, heterostyly, fructification

## INTRODUCTION

Recent years have witnessed a growing interest in the fruit of rarely cultivated and wild species (Makosz, 2000). They supplement the offer of food-processing industry, which uses the fruit of these species in the production of jams, juices, jellies, etc. Among those of interest for the food-processing industry are the apple-like fruits of different species of *Chaenomeles*, which are a rich source of ascorbic acid, pectines, and minerals (Lesińska, 1986; Thomas et al., 2000). *Chaenomeles* bushes are easy to grow since they are not particularly demanding. Additionally, they provide a valuable pollen and nectar source in the spring (Denisow, 2002). Their flowers show heterostyly, which follows from their predisposition for being pollinated by insects (Buczkowska and Kowalska, 1999; Denisow and Szklanowska, 1999; Anderson and Ascher, 2000; Beverly et al., 2001). In Poland, the fruits

of *Chaenomeles* species are generally used on a small scale by people who grow them for their private use as there are no production plantations. The fruits of *Chaenomeles* show considerable morphological differences, while their bushes display substantial fluctuation of yield (Lesińska and Kraus, 1987). The present work has been an attempt at explaining the reason of this phenomenon as well as finding out the correlation between this fact and flower heterostyly.

## MATERIAL AND METHODS

The experiments were carried out in 1999 and in 2002-2003. The bushes of *Chaenomeles japonica* Lindl. and *Chaenomeles x superba* Rehd. were grown on loess soil, pH 6.0, in the dendrological section of the UMCS Botanical Garden in Lublin, Poland. The bushes were surrounded by frequently mowed grass.

In every year of the experiment the number of flowers per every experimental bush was established. Because the form of heterostyly was taken into account and the percentage of different flower types fluctuated, all flowers on the branches of the experimental bushes were counted. Some flowers were provided with labels containing information about a particular heterostyly form. The fruits set were counted 3 weeks after blooming. Three sprouts from every experimental bush were isolated with a gauze cover before flowering in order to exclude insect pollinators and cross-pollination and to check the degree of self-pollination. The ripe fruits were picked in September, separately depending on flower type. The weight of the fruits in each group was established, and the number of seeds per fruit was calculated. The seeds were weighted and then the average weight of 1000 seeds was calculated.

The results were worked out statistically by double factor ANOVA. The significance of the differences between the averages was estimated by Duncan's test at á=0.05. Tables and charts show the relevant averages.

## RESULTS

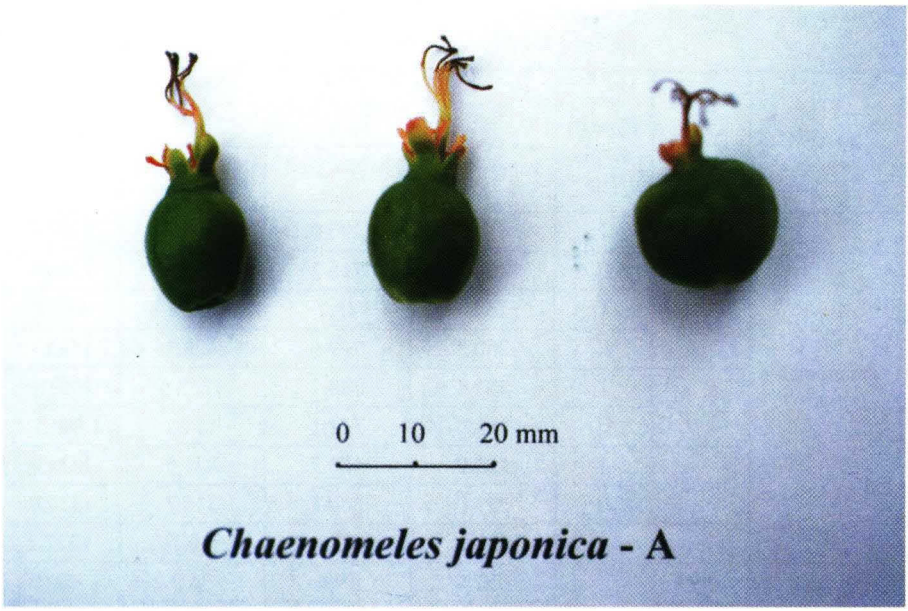
The blooming of *Chaenomeles japonica* began about 7 days earlier than the blooming of *Ch.ˣ superba* and lasted from the 3rd decade of April till mid-May. The studied species differed in the abundance of blooming and were characterised by the tendency for alternate blooming (Table 1). The average number of flowers per shrub was 1320 for *Ch. japonica* and only 417 for *Ch. x superba*. *Chaenomeles japonica* shrubs exhibited different participation of three flower forms. Two types of *Chaenomeles japonica* shrubs were differentiated. Type I was characterised by the domination of mid-styled flowers, type II – showed the domination of flowers with the style at the level of androecium. All experimental shrubs of *Ch. x superba* revealed significant domination of long-styled flowers.

Table 1
The abundance of blooming and participation of flowers of two types of *Chaenomeles japonica* and *Ch.* x *superba* in 1999 and 2002-2003

| Species | Year | Type of shrub | Form of flower | | | Total |
|---|---|---|---|---|---|---|
| | | | Long-styled (A) | Mid-styled (B) | Short-styled (C) | |
| *Chaenomeles japonica* | 1999 | I | 419.2 | 205.0 | 905.8 | 1530.0 |
| | | II | 295.3 | 716.2 | 368.5 | 1380.0 |
| | 2002 | I | 235.4 | 48.7 | 286.1 | 570.2 |
| | | II | 250.2 | 767.6 | 428.3 | 1446.1 |
| | 2003 | I | 382.4 | 238.1 | 1272.6 | 1893.1 |
| | | II | 94.2 | 512.1 | 154.2 | 760.5 |
| | Mean | I | 229.0 | 163.9 | 821.5 | 1214.4 |
| | | II | 313.0 | 800.3 | 316.7 | 1430.0 |
| | Mean | | $271.0_{A}$ | $482.1_{B}$ | $569.1_{C}$ | $1322.2_{y}$ |
| *Chaenomeles x superba* | 1999 | | 352.4 | 19.6 | 34.2 | $406.2_{a}$ |
| | 2002 | | 237.2 | 35.1 | 57.4 | $329.7_{a}$ |
| | 2003 | | 360.7 | 56.3 | 98.8 | $515.8_{b}$ |
| | Mean | | $316.8_{C}$ | $37.0_{A}$ | $63.5_{B}$ | $417.2_{x}$ |

Means followed by the same latter are not differ at a= 0.05 by Duncan test

Both species under examination showed the influence of the pollination treatment applied and the morphological styles structure on fruit setting (Fig.1, 2). Under isolators fruits were obtained only from mid-styled flowers (type B). Mid-styled flowers set 28% (*Ch. japonica*) and 19% (*Ch. x superba*) of fruits in relation to the number of flowers. However, the fruits set after autogamy were not preserved on the bushes till harvest. The isolated long-styled flowers with the stigmas much higher than the anthers did not set fruit after self-pollination. When cross-pollination was possible, with pollinating insects transferring pollen, the fruit set ratio depended on heterostyly form in the case of both species under examination (Table 2). Long-styled flowers (A) set fruit in the highest degree 76% (*Ch. japonica*) and 60% (*Ch. x superba*) and for both species only 10-20% of set fruit were ripe in September. The percentage of fruit set from mid–styled flowers (type B) was about 50%, i.e. considerably lower than in the case of long-styled flowers (type A). Similarly, the percentage of ripe fruit was significantly lower for the fruit set from flowers of type B, namely less then 10%. Short-styled flowers (C) with degenerated ovaries, did not set fruit irrespective of species and pollination treatment. The yield of *Chaenomeles* species depended on the participation of flower forms and the abundance of blooming. *Chaenomeles japonica* produced approx. 1.2-2.0 kg of fruits per bush, depending on the year of study and type of bush. *Chaenomeles x superba* gave 0.9 kg of fruits, on average.



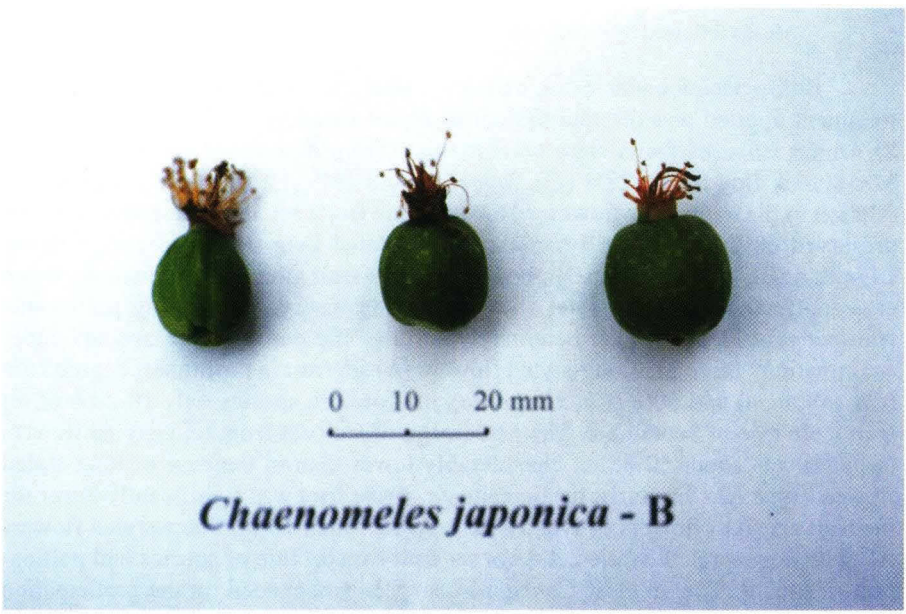




Fig. 1. The fruits set from A- long-styled and B- mid- styled flowers of *Chaenomeles japonica*

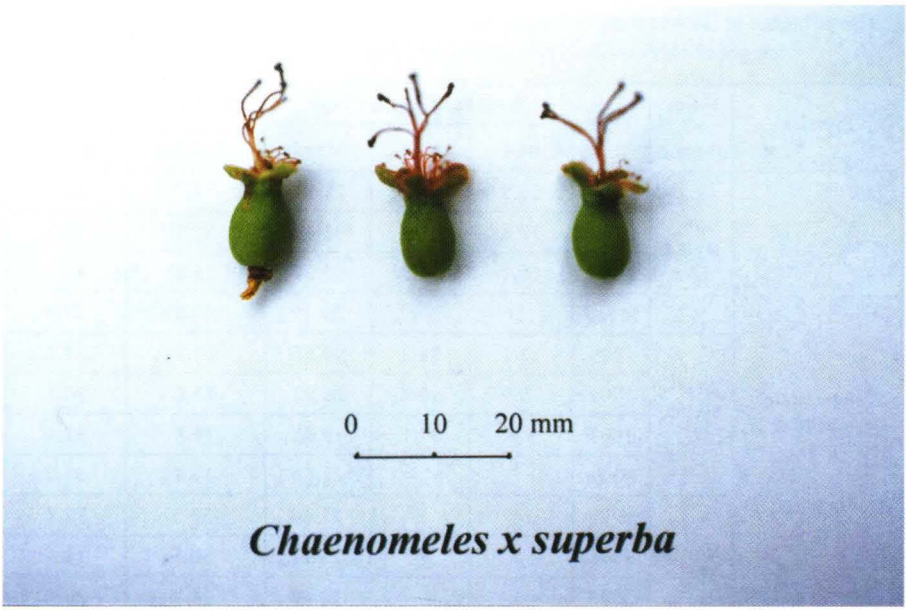



Fig. 2. The fruits set from long-styled flowers of *Chaenomeles x superba*

Table 2
The fruit set from different types of flowers of *Chaenomeles japonica* and *Ch.x superba* and shrubs yield in the years of study

| Species | Year | Form of flower | | | | Yield in kg· shrub $^{-1}$ | | |
|---|---|---|---|---|---|---|---|---|
| | | Long-styled (A) | | Mid-styled (B) | | | | |
| | | % | | % | | | | |
| | | Set fruits | Ripe fruits | Set fruits | Ripe fruits | A | B | Total |
| *Chaenomeles japonica* Type I | 1999 | 84.7 | 12.2 | 67.1 | 9.5 | 1.3 | 0.4 | 1.7 |
| | 2002 | 75.1 | 16.3 | 55.3 | 6.5 | 1.2 | 0.07 | 1.27 |
| | 2003 | 80.2 | 11.3 | 46.5 | 5.3 | 1.2 | 0.2 | 1.4 |
| | Mean | 80.0 $_{B}$ | 13.3 | 56.3 $_{A}$ | 7.1 | 1.2 | 0.2 | 1.4 $_{B}$ |
| *Chaenomeles japonica* Type II | 1999 | 73.3 | 10.7 | 54.2 | 8.3 | 0.7 | 1.2 | 1.9 |
| | 2002 | 81.2 | 12.8 | 46.5 | 5.5 | 1.0 | 1.0 | 2.0 |
| | 2003 | 72.5 | 11.0 | 55.1 | 9.5 | 0.3 | 0.9 | 1.2 |
| | Mean | 75.7 $_{B}$ | 11.5 | 51.9 $_{A}$ | 7.8 | 0.67 | 1.03 | 1.7 $_{BC}$ |
| *Chaenomeles x superba* | 1999 | 91.3 | 11.1 | 73.4 | - | 0.8 | - | 0.8 |
| | 2002 | 44.2 | 14.5 | 36.5 | - | 0.7 | - | 0.7 |
| | 2003 | 42.6 | 20.1 | 42.1 | - | 1.3 | - | 1.3 |
| | Mean | 59.4 $_{B}$ | 15.2 | 50.7 $_{A}$ | | 0.9 | | 0.9 $_{A}$ |

Means followed by the same letter are not differ at a= 0.05 by Duncan test

Table 3

The influence of flowers morphology on the weight of fruits, number of seeds per fruit and weight of 1000 seeds of two species of *Chaenomeles* in years of study

| Species | Form of flower | Year | Weight of one fruit (g) | | | Number of seeds per one fruit | Weight of 1000 seeds (g) |
|---|---|---|---|---|---|---|---|
| | | | min | max | Mean | | |
| *Chaenomeles japonica* | Long-styled (A) | 1999 | 26.8 | 58.6 | 28.81 | 37.7 | 28.4 |
| | | 2002 | 17.8 | 62.3 | 31.47 | 57.2 | 17.7 |
| | | 2003 | 16.1 | 39.6 | 27.31 | 25.6 | 24.4 |
| | | Mean | | | $29.19_{B}$ | $40.2_{B}$ | $23.5_{A}$ |
| | Mid-styled (B) | 1999 | 13.1 | 28.2 | 20.55 | 34.7 | 37.1 |
| | | 2002 | 10.9 | 26.4 | 26.97 | 43.8 | 30.1 |
| | | 2003 | 8.8 | 37.1 | 19.41 | 24.3 | 32.4 |
| | | Mean | | | $21.64_{A}$ | $34.3_{A}$ | $33.2_{B}$ |
| | Mean | 1999 | | | $22.68_{a}$ | $36.2_{b}$ | 32.8 |
| | | 2002 | | | $28.22_{b}$ | $50.5_{c}$ | 18.5 |
| | | 2003 | | | $23.36_{a}$ | $24.9_{a}$ | 20.1 |
| | | Mean | | | $24.75_{Y}$ | $37.2_{Y}$ | $23.8_{Y}$ |
| *Chaenomeles* x *superba* | Long-styled (A) | 1999 | 21.3 | 36.2 | 24.1 | 30.4 | 13.4 |
| | | 2002 | 19.1 | 39.4 | 23.1 | 32.7 | 18.5 |
| | | 2003 | 14.5 | 32.1 | 26.3 | 34.6 | 20.1 |
| | | Mean | | | $24.5_{B}$ | $32.6_{B}$ | $17.3_{A}$ |
| | Mid-styled (B) | 1999 | 7.3 | 26.7 | 19.5 | 23.6 | 23.5 |
| | | 2002 | 5.9 | 36.3 | 16.6 | 20.7 | 28.0 |
| | | 2003 | 8.5 | 25.4 | 18.9 | 24.5 | 26.7 |
| | | Mean | | | $18.3_{A}$ | $22.9_{A}$ | $26.1_{B}$ |
| | Mean for years | 1999 | | | $25.32_{c}$ | $27.0_{ab}$ | $18.5_{a}$ |
| | | 2002 | | | $19.85_{a}$ | $26.7_{a}$ | $23.3_{b}$ |
| | | 2003 | | | $22.6_{b}$ | $29.6_{b}$ | $23.4_{b}$ |
| | | Mean | | | $22.59_{X}$ | $27.8_{X}$ | $21.7_{X}$ |

Means followed by the same letter are not differ at a= 0.05 by Duncan test

Heterostyly influenced the weight of fruit (Table 3). The average weight of fruit set from long-styled flowers was 29.2 g (*Ch. japonica*) and 24.5 g (*Ch. x superba*). The weight of fruit set from mid-styled flowers was 21.6 g and 18.3 g, respectively. The participation of big fruits >25 g was higher in the yield of *Ch. japonica* (Fig. 3).

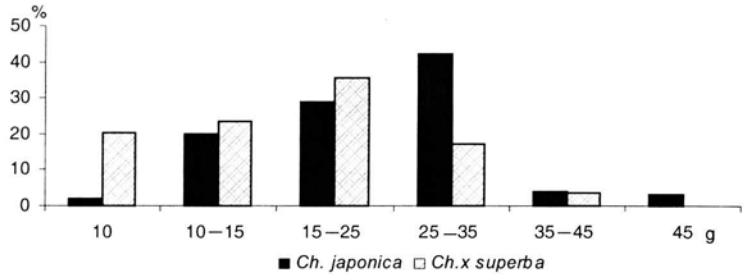



Fig. 3. The participation of ripe fruits of two *Chaenomeles species* in size classes (average from 3 years)

The fruits of *Chaenomeles* species are aromatic and show yellowish colouring at the time of ripening in September, which is more intensive for *Chaenomeles japonica*.

## DISCUSSION

The flowers of the studied species of *Chaenomeles* reveal a three form heterostyly, which determines their fruit setting and weight. Flowers with well-developed anthers in short-styled flowers are functionally male and did not set fruit for either species. Fruits were set only from long-styled flowers (A) and from mid-styled flowers (B). Long-styled flowers set 60-76% of fruit, compared to the 50% set in the case of mid-styled flowers. The significant differences in the degree of fruit set by these types of flowers seems to be caused by the existence of only cross-pollination in the case of type A flowers and both cross-pollination and less effective self-pollination in the case of type B flowers. Similar dependencies were observed by Buczkowska and Kowalska (1999) for different cultivars of *Solanum melongena*, and *Lythrum salicaria* by Beverly et al. (2001).

The form of heterostyly in the flowers of *Chaenomeles* determined the weight of fruits. Long-styled flowers produced bigger fruits. The style morphology influenced the weight of fruits in *Solanum melongena* as well (Buczkowska and Kowalska, 1999). The differences in the fruit weight exhibited by the shrubs of *Chaenomeles japonica* and *Chaenomeles x superba* confirm the observations made by Lesińska and Kraus (1987) and testify to the influence of particular species characteristics on the fruit yield. In both experiments *Chaenomeles japonica* produced much bigger fruits.

The following conclusions were drown from the study:

1. The phenomenon of heterostyly, the proportionate participation of flower type, and the abundance of blooming influence the fruit yield obtained from *Ch. japonica* and *Ch. x superba*.

2. The degree of fruit setting and their weight depends on the form of heterostyly. Long-styled flowers are best fitted for cross-pollination and set 60-76% of fruit in relation to flowers. The ratio is approx. 50% for mid-styled flowers. Short-styled flowers did not set fruit. The average weight of one fruit was 24-29 g for set from long-styled flowers and 18-21 g for set from mid-styled flowers.
3. The participation of big fruits was higher in *Chaenomeles japonica*. The average weight of one *Chaenomeles japonica* fruit was 24.5 g and 22.0 g for *Chaenomeles x superba*.
4. Planting *Chaenomeles x shrubs* for fruit production the attention should be pay to the participation of flower types with the view to eliminating shrubs with the domination of short-styled flowers.

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**Wpływ heterostylii na owocowanie dwóch gatunków z rodzaju *Chaenomeles***

## Streszczenie

W latach 1999 i 2002-2003 na terenie Ogrodu Botanicznego w Lublinie badano owocowanie krzewów pigwowca japońskiego (*Chaenomeles japonica* Lindl.) i pośredniego (*Ch. x superba* Rehd.). Sprawdzano czy stopień wiązania owoców oraz

ich duże zróżnicowanie morfologiczne zależy od występującej w kwiatach trójpostaciowej heterostylii. Zjawisko heterostylii miało wpływ na liczbę owoców powstających w stosunku do liczby kwiatów oraz na ich masę. Kwiaty z długimi szyjkami słupka wiązały istotnie więcej owoców (średnio 70%) i o większej masie (przeciętnie 26 g) w porównaniu z kwiatami ze słupkowiem na poziomie pręcikowia, odpowiednio średnio 50% i 20g. Wyższe plony uzyskiwano z krzewów pigwowca japońskiego ok. 1-2 kg. Średni plon krzewów pigwowca pośredniego wynosił ok. 0,9 kg. Uprawiając krzewy pigwowca z przeznaczeniem na zbiór owoców należy wybierać do nasadzeń krzewy z dużym udziałem kwiatów z długimi szyjkami słupka oraz ze słupkowiem na poziomie pręcikowia, eliminując z nasadzeń krzewy z przewagą kwiatów funkcjonalnie męskich – ze zdegenerowanym słupkowiem.