Inflorescence Blast and Flower Bud Abnormalities of *Spiraea* × *vanhouttei* and their Causes

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Abstract: In ornamental gardening, *Spiraea* × *vanhouttei* is a frequently planted spirea species in the Czech Republic. In 2003, there arose a suspicion of possible occurrence of fire blight caused by *Erwinia amylovora* on spirea shrubs in Prague and its environs. This suspicion was disproved for a certainty. The absence of the fire blight pathogen in symptomatic spirea plants stimulates a further effort to tackle the problem of a cause of conspicuous fire blight-like symptoms or inflorescence blast occurring on some spirea shrubs. The subject of this paper is: (i) to describe symptoms, incidence and severity of inflorescence blast, bud and flower abnormalities occurring in *Spiraea* × *vanhouttei* shrubs; (ii) to find out differences in the occurrence of blasted inflorescences between *Spiraea* species and cultivars with the intention of verifying the hypothesis that the blast inflorescence and sterility of some spirea species are associated with hybrid species. Symptoms of inflorescence blast are every growing season. No seed is produced by blasted inflorescences. Besides inflorescence blast, aborted floral buds appeared sporadically on a small scale. Spirea species were split into four categories according to the incidence of blasted inflorescences. Out of 52 species evaluated, 10% showed no or scarce incidence, 52% medium incidence, 27% high incidence and 11% very high incidence. The scarce incidence of blasted inflorescences was connected with the high seed production. And vice versa, very high incidence of blighted inflorescences was closely connected with no or low seed production or with high incidence of sterility. Fifteen out of the evaluated spirea species are the result of hybridization. These hybrids occur in each of the four categories of spirea species distinguished by the incidence of blasted inflorescence. However, it is remarkable that the highest incidence of hybrid spireas occurs in the category with the highest incidence of blasted inflorescence (83.33%). In the remaining three categories of spirea species, the proportion of hybrids ranged from 18 to 21%. It might indicate some connection of spirea hybrids with sterility.

Keywords: Vanhoutte spirea; hybrids; inflorescence blast; flower bud abnormalities, sterility

In 2003, the target of Department of Bacteriology of the Crop Research Institute in Prague-Ruzyně was to verify a suspicion that fire blight caused by *Erwinia amylovora* occurred on spirea shrubs in Prague and its environs. This suspicion could not be *a priori* refused because some *Spiraea* species were included in the list of host plants of *E. amylovora* (Zwet & Keil 1979) and the fire blight pathogen was established in the territory of Prague since 1986 (Kůdela 1988).

The misdoubt that spirea shrubs in Prague and environs were attacked by the fire blight pathogen in 2002 and 2003 was disproved for a certainty on the basis of several times repeated microbiological analyses of tissues from spirea plants with symptoms similar to fire blight and taken from some localities in Prague, Slaný, Kladno and environs (Kůdela V., Korba J., Šillerová J., Jeřábková R., unpublished results). The absence of the fire blight pathogen in symptomatic spirea plants stimulates

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our further effort to tackle the problem of a cause of conspicuous fire blight-like symptoms or inflorescence blast occurring on some spirea shrubs.

The genus *Spiraea* L., spirea, encompasses more than 100 species of deciduous shrubs of the family *Rosaceae* Juss., subfamily *Spiraeoideae* Focke, and/or the family *Spiraeaceae* Humb., Bonpl. & Kunth. Shrubs of these species are widespread in the temperate and subtropical zone of the northern hemisphere (Businský & Businská 2002). Within a species, as many as 15 to 20 cultivars may have been recognized (Zasada & Stickney 2007). Recently, approximately 12 species have frequently been planted as ornamentals (Koblížek 1992) and some of them, e.g. *S. alba*, were naturalized.

In ornamental gardening, *Spiraea* × *vanhouttei* (Briot) Zab., commonly named as Vanhoutte spirea or Van Houtte spiraea, is the most frequently planted spirea species in the Czech Republic (Businský & Businská 2002). In the Czech Lands, Vanhoutte spirea has been grown since 1927, and recently it has been one of the most valuable cultural spireas. It has not probably become naturalized in the flora of the Czech Republic (Koblížek 1992; Businský & Businská 2002). Suggested uses for plants of this species include border, hedge, screen and solitaire. Vanhoutte spirea is popular for its masses of showy white flower and graceful, arching growth habit. According to Businský and Businská (2002) Vanhoutte spirea belongs to the first-rate category of taxa which are perspective for planting in conditions of the Czech Republic. In addition, plants of this fully hardy taxon are easily maintained.

The subject of this paper is: (i) to describe symptoms, incidence and severity of inflorescence blast, bud and flower abnormalities occurring in *Spiraea* × *vanhouttei* shrubs; (ii) to find out differences in the occurrence of blasted inflorescences between *Spiraea* species and cultivars with the intention of verifying the hypothesis that the blast inflorescence and sterility of some spirea species are associated with hybrid species.

MATERIAL AND METHODS

Plants and localities

The incidence and symptom development of inflorescence blast, bud and floral abnormalities were recorded in *Spiraea* × *vanhouttei* shrubs in ornamental parks and hedges along roads in Prague and its environs. Surveying started in 2002 and continued in 2003–2007. Three basic view points were situated in Prague-Pankrác (hedges), Prague-Ruzyně (park and hedges) and Prague-Červený vrch (strip plantings). Specimens of inflorescences were taken for detail evaluation minimally twice during the growing season, namely during full flowering and then approximately tree weeks after petal shedding.

The Prague urban area is particularly suited for surveying the health state of *Spiraea* × *vanhouttei* shrubs for their high concentration in hedges and parks. They were chiefly planted along roads in the 1960s and 1970s. Out of tens of thousands of spirea shrubs grown in the Prague area approximately 95% belongs to *S.* × *vanhouttei* (V. Čermáková, personal communication).

Incidence of blasted inflorescences among *Spiraea* species and cultivars

The spirea assortments were surveyed in the Dendrological Garden of Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Průhonice (Central Bohemia) and in the Průhonice Castle Park & Arboretum, Institute of Botany, Academy of Sciences of the Czech Republic.

In April 2007, a thorough evaluation of the incidence of blasted inflorescences among *Spiraea* species and cultivars was carried out in the assortment of the Dendrological Garden in Průhonice. The list of evaluated spirea genotypes is given in Table 1.

Four categories of the degree of incidence were recognized according to the percentage of blasted inflorescences: 0–10% = no or very scarce incidence; 11–50% = medium incidence; 51–90% = high incidence; 91–100% = very high incidence.

RESULTS AND DISCUSSION

Symptoms associated with inflorescence blast of *Spiraea* × *vanhouttei*

No symptoms of damage are apparent on flowers during blossoming. The first conspicuous symptoms of blast are not observed until the period of petal shedding. Initially, a single flower may be affected and finally all flowers in the inflorescence are afflicted. Petals first appear wilted and other flower parts, anther and filament petal, stigma, style and ovary, become dark brown to black. The blast progresses into receptacle, sepals, flower

Table 1. Differences in the occurrence of blasted inflorescences between *Spiraea* species and cultivars; locality: Dendrological Garden in Průhonice

Percentage of blasted inflorescences per 1 shrub	*Spiraea* species/cultivars
0–10	*S. henryi* Hemsl. (1887) var. *notabilis, S. japonica* L. fil. (1781) var. *ovalifolia* Franch. (1886), *S. nipponica* Maxim. (1886)_{ BIII 113}, *S. nipponica* Maxim. × *S. trichocarpa* Nakai, *S. veitchii* Hemsl. (1903)
11–50	*S. alba* Du Roi (1772), *S. albifora* (Miq.) Zab. (= S. *japonica* 'Albiflora'), *S. betulifolia* Pall. (1784), *S. blumei* G.Don (1832), *S. bumalda* 'Pruhoniciana', *S. corymbosa* Raf. (1814) [= *S. betulifotia* subsp. *corymbosa* (Raf) Taylor & MacBryde], *S. douglasii* Hook. (1834), *S. faurieana* Schneid. (1905), *S. fritschiana* Schneid. (1905), *S. henryi* Hemsl. (1887), *S. humilis* Pojark. (1939), *S. latifolia* (Ait.) Borkh. (1803), *S. media* Schmidt (1792) var. *media*, *S. media* Schmidt (1792) var. *molliss* (K. Koch & Bouche) Schneid, *S. menziensis* Hook. (1834) [= *S. douglasii* Hook. Presl (1834)], *S. nipponica* Maxim. (1886) Flachenfüller, *S. nipponica* Maxim. (1886) 'Snowmould', *S. salicifolia* L. (1753), *S. salicifolia* L. (1753), *S. sargentiana* Rehd. (1913), *S. tomentosa* L. (1753), *S. uratensis Franch*. (1883), *S.* × *billardii* Herincq (1855), *S.* × *billardii* Herincq (1855) cv. 'Triumphans', *S.* × *blanda* Zab. (1884), *S.* × *macrothyrsa* Dipp. (1893), *S.* × *microthyrsa* Zab. (1893)
51–90	*S. betulifolia* Pall. × *S. chamaedryfolia* L., *S. billardii* Hérincq (1855), *S. bumalda* 'Pygmaea alba', *S. chamaedryfolia* L. (1753), *S. douglasii* Hook. (1834), *S. fritschiana* Schneid. (1905), *S. latifolia* (Ait.) Borkh. (1803) S. × *notha*, *S. media* Schmidt (1792), *S. trichocarpa* Nakai (1909), *S. trilobata* L. {GI 13 }, *S. wilsonii* Duthie(1906), *S. wilsonii* Duthie(1906), *S.* × *bumalda* 'Froebelii', *S.* × *notha* Zab (1908)
91–100	*S.* 'Arguta' [= *S.* × *arguta* Zab.], *S. alba* Du Roi (1772), *S.* × *billardi* Herincq (1855), *S.* × cinerea Zab. (1884) 'Grefsheim', *S.* × *margaritae* Zab. (= *S.* × *foxiii* 'Margaritae', *S.* × *vanhouttei* (Briot) Zab. (1884)

pedicel and inflorescence peduncle. The whole inflorescence turns umbery to black, appears dried and shrivelled. Blasted inflorescences bend at the right angle in the bottom part of ramification (Figures 1–3). They usually remain attached to the shrubs and are clinging to shoots till the next growing season. Dry blasted inflorescences can easily be crushed into powder. In some cases, the blasted inflorescences are broken off at the place of bending so that lower parts of blasted peduncles remain attached to shrubs and rise above shoots or branches for a long time (Figure 4). No seed is produced by blasted inflorescences. In compliance with the established plant health terminology (Shurtleff & Awerre III 1997), we suggest to call this disorder of spireas manifested itself by the failure to produce seeds due to a sudden pernicious death of inflorescence tissues as inflorescence blast.

Inflorescence blast of Vanhoutte spirea shows symptoms that closely resemble the blossom blight caused by *E. amylovora*. In contrast to inflorescence blast of Vanhoutte spirea, the blighted peduncles of susceptible host plants of *E. amylovora* often exude droplets of bacterial ooze during warm, humid weather. Symptoms of blossom blight are apparent during blossoming, while the symptoms of inflorescence blast are manifested up to blossoming. During our surveys at three basic view points situated in the Prague urban area lasting several years, a high incidence of inflorescence blast of Vanhoutte spirea was recorded each year.

Figure 1. Inflorescence blast in Vanhoutte spirea (on the right) in comparison with asymptomatic inflorescences (left); photo by K. Veverka

Since the propitious conditions for an epidemic of fire blight are only approximately every six years in the Czech Republic (Kůdela 1988) and blast inflorescence of Vanhoutte spirea occurs every four to five years, it can be regarded as an indirect confirmation that there is no causal connection between the blast inflorescence and the fire blight organism.

Figure 2. Severe blasted inflorescences in Vanhoutte spirea; photo by V. Krejzar

Figure 3. The blast progress in the inflorescence of Vanhoutte spirea from receptacle to inflorescence pedicel; photo by V. Krejzar

Figure 4. Blasted peduncles remaining attached to shoots of Vanhoutte spirea shrub when top parts of inflorescences are broken off; photo by K. Veverka

Bud and flower abnormalities occurring in *Spiraea × vanhouttei*

A many-flowered umbel-like raceme is characteristic of the normal inflorescence of Vanhoutte spirea. In general, the pedicels originate fairly together, but occasionally the lowermost flowers are considerably scattered (Harris 1917). We have observed inflorescence abnormalities in the form of production of an accessory pedicel below the terminal receptacle (Figure 5) and even a pedicel growing directly out from the receptacle (Figure 6).

Vanhoutte spirea showed a relatively frequent incidence of floral bud abortion. The symptoms of this disorder were differentiated depending on the timing of abortion and on the extent of afflicted buds. Individual aborted floral buds or each bud in the inflorescence failed to develop into a complete flower (Figure 7a, b). The aborted floral buds of various types were dark violet to black and their surface appeared as varnished at first but later the varnish gloss disappeared (Figure 7c–f).

In the days of Harris (1917), variation of abnormalities in the inflorescence of Vanhoutte spirea was regarded as it was dependent upon the peculiarities of the individual plants to some extent and as it was partly determined by unspecified environmental conditions. The abortion of flowers and fruits is high in Virginia spirea growing in the southern Appalachian Mountains, particularly in years of low water availability (Ogle 1991). Factors regulating the flower bud differentiation, and thus the flowering potential, vary for those species that differentiate flower buds in late summer-autumn compared to those that differentiate in the spring shortly before flowering (Batta 1977 cit. Businský & Businská 2002; Zasada & Stickney 2007).

In general, flower initiation and flower formation can be influenced essentially, positively or negatively, by a certain period of low temperature. For example, based on meteorological data it was concluded that the higher incidence of fruit doubles and other fruit abnormalities in the CR in 2004 was correlated with heat and drought stress in 2003 (Kůdela & Krejzar 2005). In *S. cantonensis,* the optimum temperature for flower initiation was about 10°C. However, no flower initiation and flower development in the early stages of flower formation were observed at 20°C or above. A certain period of low temperature followed by warm conditions was essential to further development of the flower bud and anthesis. The flower buds began to develop again and came into flower normally only when the plant was treated at 0°C for 6 to 8 weeks after flower initiation and then it was carried into the greenhouse maintained at 15°C or above (Goi *et al.* 1975). To sum up, it seems to be probable that the causes of bud and flower abnormalities of Vanhoutte spirea are effective in preanthesis period.

Figure 5. The accessory pedicel situated below the terminal receptacle; photo by V. Krejzar

Figure 6. The accessory pedicel growing directly out from the receptacle of Vanhoutte spirea inflorescence; photo by V. Krejzar

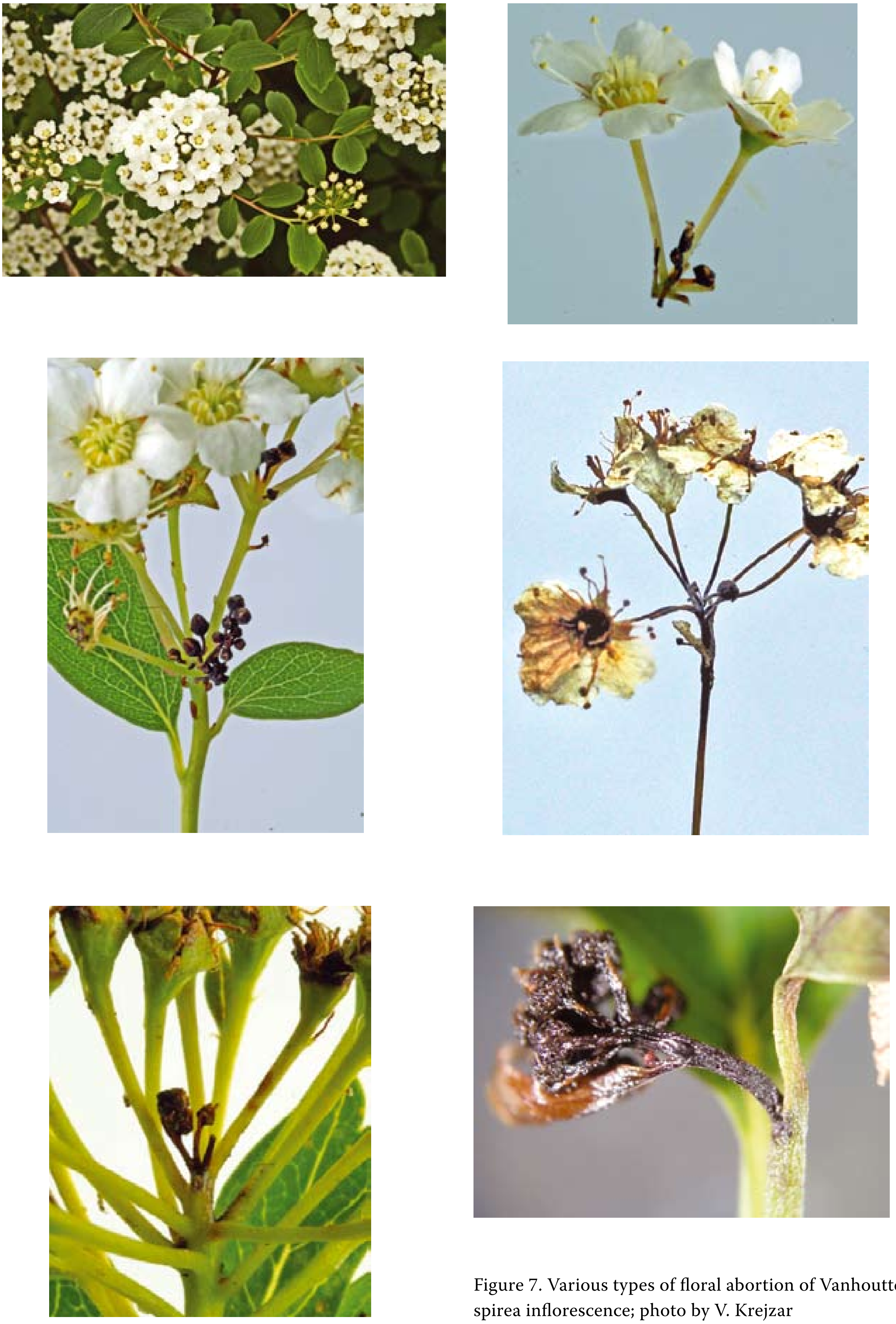

Figure 7. Various types of floral abortion of Vanhoutte spirea inflorescence; photo by V. Krejzar

Figure 8. Secondary inflorescence of Vanhoutte spirea with unblasted flower (in the middle) in comparison with blasted primary inflorescences (on the right and on the left); photo by K. Veverka

The incidence of blasted inflorescences among *Spiraea* species and cultivars

Spiraea species were split into four categories according to the incidence of blasted inflorescences. Out of 52 species evaluated, 10% showed no or scarce incidence, 52% medium incidence, 27% high incidence and 11% very high incidence (Table 1). The scarce incidence of blasted inflorescences was connected with the high seed production. And vice versa, very high incidence of blighted inflorescences was closely connected with no or low seed production or with high incidence of sterility.

Figure 9. Secondary inflorescence of Vanhoutte spirea with developed fruits (on the left) in comparison with blasted primary inflorescence (on the right); photo by K. Veverka

Fifteen out of the evaluated spirea species are the result of hybridization. These hybrids occur in each of the four categories of spirea species distinguishing itself by the incidence of blasted inflorescence. When we compare the proportion of hybrids of all species in particular groups, it is clear that the highest incidence of hybrid spireas is in the category distinguishing itself by the highest incidence of blasted inflorescence (83.33%). In the remaining three categories of spirea species, the proportion of hybrids ranged from 18 to 21% (Table 1). It might indicate some connection of spirea hybrids with sterility.

According to our multiyear survey of Vanhoutte spirea in the Prague urban area, Vanhoutte spirea can be characterized by a very high degree of sterility. It was only in 2007 when for the first time we could get view of some many-seeded capsular fruits (follicles) with seeds developed from only a few secondary inflorescences of Vanhoutte spirea shrubs (Figures 8 and 9). It is evident that the sexual reproductive capacity of Vanhoutte spirea is seriously impaired. According to scarce knowledge of the history of *S.* × *vanhouttei*, the hybrid is a result of crossing between *S. trilobata* and *S. cantoniensis* done near Paris in about 1862 (Bean 1981, cit. Businský & Businská 2002). A presumption is that the existing population of grown Vanhoutte spirea represents only one genotype (Businský, personal communication). Limited or no sexual reproduction means that the probability of cross-pollination from different clones, necessary for a good seed set, is reduced. In this connection it is worthy to mention the alleged or hypothetical spirea hybrid, *S.* × *bumalda*, which produces a plenty of seeds. This hybrid is a result of crossing between *S. japonica* and *S. albiflora*, however, the hybrid species status of this taxon is not justified (Businský & Businská 2002).

Analogously to Vanhoutte spirea, most populations of *S. virginiana* appear clonal consisting of root sprouts representing a single genetic individual. Seeds have been seen rarely, and seedlings even more rarely. Often, only one portion of the corymb (flower cluster) to corymb will produce seed. This suggests that the Virginia spirea has a mostly self-incompatible breeding system and that wild populations consist of one – or very few – clones. However, when plants from different localities are grown together, they fruit prolifically and produce viable seed (Ogle 1991).

The problem of sterility causes

The causes of sterility in Vanhoutte spirea hybrid species are poorly understood. We can only deduce from analogous cases in other spirea species (see above) and from common knowledge that interspecific hybrids are more often fertile and may reproduce though there still exist unviable or sterile hybrids. The degree of infertility varies in different species and in their hybrid progeny from absolute sterility to complete fertility. The basis of hybrid sterility may be genic, chromosomal, or cytoplasmatic (Rieger *et al.* 1976). Plant sterility may also be caused by environmental effects, e.g. water stress-induced spikelet sterility limits rice production under upland conditions (Selote & Kha-Chorpa 2004).

When we consider the causes of Vanhoutte spirea sterilization, we have taken into account also problems connected with pollination, fertilization and plant pathogens.

As to pollination, Spirea species are wind pollinated or pollinated by insects (Koblížek 1992), namely by beetles (without specification). Beetles tend to pollinate flowers that are dull white or green with an odour that is often unpleasant to humans — perhaps strongly fruity or fetid. The flowers may be solitary or in clusters of smaller flowers (Anonymous 2007). Vanhoutte spirea is not included in the list of plants pollinated by bees (D. Titěra, personal communication). All *Spiraea* species have flowers with nectaries which appear as small pads between the stamen filaments (Evans & Dickinson 1999). If the pollination of Vanhoutte spirea were dependent on beetles, it might probably be a problem.

Phytoplasmas are important plant pathogens which are associated with diseases in several hundred plant species worldwide. Diseases associated with the presence of phytoplasmas in phloem typically exhibit an array of symptoms suggestive of profound disturbances in the normal balance of plant hormones. Symptoms in plants include also sterility of flowers. Since the time when *S.* × *vanhoutei* was established, i.e. in 1860, this species has been propagated only vegetatively. Therefore, it can be anticipated than the level of contamination of grown Vanhoutte spireas with viral and phytoplasmal pathogens during so long-lasting vegetative propagation accumulated and can be very high. Unfortunately, the knowledge of these types of pathogens connected with Vanhoutte spireas is utterly inadequate.

Phytoplasma (recently named as *Spiraea stunt phytoplasma*), which belongs to X-disease group (16SrIII), was reported to infect spirea and to probably be lethal to *S. tomentosa* at one location in the Central New York State. Affected plants were observed to grow feebly beginning in the first year after symptoms appeared and finally died (Griffith *et al.* 1994a, b). Phytoplasmas, which shared a low identity with *Spireas stunt phytoplasma* and exhibited symptoms of witches'-broom, stunting, yellowing, and shoot dieback, were found in *S. bumalda* at two localities in China (Gao *et al.* 2007). As to viral pathogens, Polák and Kontzog (1966) described mild mosaic of spirea caused by the cucumber mosaic virus.

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