Bacterial Problems in Belgian Pear Growing

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Two important bacterial diseases in Belgian pear orchards can cause serious economical losses on our main pear cultivar Conference: blossom blight caused by an infection of *Pseudomonas syringae* pv. *syringae* and fire blight caused by the bacterium *Erwinia amylovora*. In some years the losses due to *Pseudomonas* infections on the flower clusters are much more important than the losses caused by fire blight. *Pseudomonas* infections during bloom often completely destroy a crop on young pear trees while a fire blight infection is often limited to the infected trees and the immediate surroundings. In an early stage the symptoms of both bacterial diseases are very similar and only a diagnosis in the lab can distinguish (Moltmann, 1995). Infections of *Pseudomonas syringae* pv. *syringae* are often correlated with a weakness factor playing over the whole orchard. Fire blight infections are more local in appearance and often related with earlier *Erwinia* infections during the previous year. For both bacterial diseases some control measures will be discussed in this paper.

PSEUDOMONAS SYRINGAE PV. *SYRINGAE*: BLOSSOM BLIGHT

Symptoms of the Disease

Dead flower buds. During winter *Pseudomonas* bacteria can be found in the dead blossom buds on the trees. This phenomenon of dead buds is often linked with a sudden decrease in temperatures below 0°C (32˚F) on trees with an insufficient winter hardiness of the young shoots and fruiting spurs. A typical example of this type of frost injury was found in December 1995 when the minimal temperature decreased to a value of -11.2°C (11.8˚F) on December 28. Some days later, flower buds were examined for the presence of internal damaged tissue. About 80% of the flower buds on young Conference trees showed internal damaged tissue at the base of the flower buds over a length of 5 mm to more than 10 mm (.4 inches). The cambium itself was not visually damaged. At that moment it was very difficult to predict the further evolution of these flower buds. Although the result was very visible during bloom 1996, 50% of these damaged flower buds did not develop further and were killed by an internal multiplication of *Pseudomonas* bacteria on the damaged tissue.

Blossom blight symptoms. During primary bloom, a *Pseudomonas* infection can develop on the primary blossom cluster itself and can destroy the flower cluster partially or totally (Crosse, 1966). Frost damage on the flowers can increase the damage considerably when it is followed by a wet and cold (<5°C) blossom period. Typical for a *Pseudomonas* primary blossom infection is that the infected flower clusters stay on the fruiting branches and form a little canker on the bark. At this early stage of blossom infection, it is very difficult to distinguish a primary blossom infection caused by *Erwinia amylovora* from a primary blossom infection caused by *Pseudomonas syringae*. At that moment, fire blight infection on the primary blossom does not always exhibit the typical ooze formation on the young fruitlets or on the leaf stalks and only laboratory tests like isolation on nutrient medium or an immunofluorescence test or inoculation of other host plants can distinguish both bacterial diseases. Another type of blossom infection of *Pseudomonas syringae* on pear flowers is described by Crosse (1966) as a calyx cup infection. Some of the flowers in a cluster can be infected in the calyx while other flowers of the same flower cluster are not affected. There are no clear wilting symptoms for this type of *Pseudomonas* infection.

Sometimes the primary blossoms show wilting symptoms which can be connected

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with the presence of a *Nectria galligena* canker on the fruiting branches. Typical for this *Nectria* canker are the white points, "the sporodochium," on the canker surface. But it is not always clear whether the canker formation is really due to a *Nectria galligena* infection or to a *Pseudomonas* infection. Some cankers of *Pseudomonas syringae* are very long and can reach more than 0.5 m (20 inches) in length, with the typical curling of the epidermis on the canker surface (Moltmann, 1995). Normally a *Nectria* canker can be located on a leaf scar infection and is limited in length to a few centimeters.

Symptoms on leaves, fruits and shoots. Some weeks after flowering, *Pseudomonas* infections can be seen as red spots on the leaf surface or on the fruit skin. These red spots develop further to black spots and result in russeted spots on the fruit skin.

Young fruitlets sometimes show large black blotches in their fruit skin which indicate a *Pseudomonas* infection on these fruitlets. Sometimes these *Pseudomonas* infections on young fruitlets start from natural wounds on the fruit skin, e.g., on a crack after a rainy period. Also young shoots can be infected with *Pseudomonas* and form the typical black blotches with clear limited margins around the infection.

Causes

Vegetative growth pattern. One of the reasons young pear trees are more susceptible to *Pseudomonas* infections than older trees could be the difference in vegetative behavior. Young pear trees stop their vegetative growth very early in season but have often a regrowth tendency at the end of the season in August and September. This regrowth reaction results in typical late-growth yellow shootlets and in flower buds with insufficient winter hardiness. Maybe there are also differences in water content of these late regrowth reactions. Water content of the tissue could be an important factor for *Pseudomonas* infections (Vigoureux, 1994). Older pear trees of the same cultivar have less tendency for these regrowth reactions. On young pear trees of the cultivar Conference this late regrowth reaction is often combined with a late secondary blossom formation (Deckers and Daemen, 1993).

The same late vegetative regrowth reaction can occur on pear trees after a long dry period during summer, followed by excessive rainfall at the end of the season. This was the situation during the summer 1995 when the very dry months June, July and August were followed by warm and wet months of September and October. The winter hardiness of the trees was considered weak. The first visible frost damage on the flower buds was expected after the frost of November but was found only after the frost of December. The tissue just beyond the flower buds was damaged and colored brown to black over a length of about 1 cm. The cambium itself was not affected. This damage resulted in a high percentage of flower buds that did not develop further. In young plantations of Conference more than 50% of the flower buds died as a result of this frost damage.

The N nutrition plays an important role in the vegetative growth pattern of the trees. Normally, a standard N dose of 30 kg to 60 kg N/ha is given before bloom and the vegetative growth response on this nitrogen application is limited to some weeks after full bloom. Late N applications applied before harvest for a better fruit size and fruit quality are more risky. When these late N applications result in a late vegetative growth, the risk for insufficient winter hardiness increases. The same problem can arise with leaf applications of urea during late season or during leaf fall period. Urea treatments just before leaf fall are often advised for a faster leaf breakdown by earthworms but can be risky for *Pseudomonas* infections.

Treatments with growth retardants such as CCC (chloormequat) can also have an influence on the pattern of vegetative growth. When the vegetative growth is blocked completely in the postfloral period, there is a stronger tendency for regrowth during summer. The flower buds on these late regrowth reactions are considered more susceptible for *Pseudomonas* infections. A change of strategy where the growth retardants are placed later in the season can partially prevent late growth reactions and improve the winter hardiness of the terminal flower buds but increases the risk for a higher residue level at harvest.

Cultivar and rootstock. Not all pear cultivars are equally susceptible to *Pseudomonas* infections. The standard pear cultivars Duodena and Conference are more susceptible than Doyenné du Comice and Bearer Hardy. From the new pear cultivars, General Lecher is very susceptible, while Concorde can be classified between Conference and Doyenné. The susceptibility of new pear cultivars for *Pseudomonas* infections is a very important criterion and should be considered during selection. For the pear cultivars, this *Pseudomonas* susceptibility seems to be linked to the presence of a natural regrowth reaction during late season.

The rootstock also can be an important weakness factor that increases the risk for *Pseudomonas* infections. In Belgium we have four different types of quince rootstock: quince A, quince Sydo, quince Adams and quince C. The vegetative growth is strongest on quince Sydo and weakest on quince C. This difference in vegetative growth can be linked to the compatibility of the pear cultivar with the rootstock. The compatibility of the pear cultivar Conference on quince C rootstock is not optimal and for young trees this phenomenon is reflected by the presence of a dark brown line on the graft union and in a higher fertility. This problem of incomplete compatibility can be considered a risk factor for the increased susceptibility of the pear trees for *Pseudomonas* infections. A comparative study of the four pear rootstocks could give exact quantitative data on this relationship of rootstock-*Pseudomonas* susceptibility.

Frost and orchard site. Frost is the most important factor determining the disease development of *Pseudomonas syringae* in the pear orchard (Montesinos and Valdendell, 1991). This frost damaged tissue can occur in the flower buds at the end of the season or in developing flowers before or during bloom period. Very long wetness periods can increase the infection risk. Repeated frost protection with overhead water sprinkling can destroy a pear crop completely because it increases considerably the flower susceptibility for *Pseudomonas* infections.

Orchard site is a risk factor that should be judged before planting an orchard. It is known that some plots situated in the valley on soils rich in clay are not ideal for starting a new pear orchard. These sites also have more problems with frost damage. Orchard site is a risk that often has been underestimated during the last decade.

Flower bud quality. There are important differences in flower bud quality in pear orchards. On Conference pears, the best flower bud quality was found in the short brindle shoots with about 12 to 15 flowers per cluster while the good flowers on the 2-year-old wood contain between 5 to 7 flowers per bud. The best flower buds also have a higher number of leaves per cluster.

A typical example of a weak flower bud formation can be given when fruit growers plant a pear orchard starting with 2-year-old trees with about 10 feathers on the trees. When all the fruiting branches are left unpruned on these trees, the flower bud quality becomes too weak and the risk increases for *Pseudomonas* infection. A reduction in the number of fruiting branches to 2 to 4 branches/tree is indicated to guarantee sufficient flower bud quality on the remaining branches.

Gibberellin treatments. It is often suggested that gibberellin applications reduce the *Pseudomonas syringae* infections on young pear trees. A direct effect of gibberellin treatments on the *Pseudomonas* bacterium is unlikely but this effect could be an indirect consequence linked with the GA treatments. When a GA treatment is applied immediately after frost, the damaged tissue can continue its development easier and the young fruitlets can overgrow the damaged tissue in the core. Our own observations indicate that gibberellin treatments alone on young pear trees of the cultivars Conference and Durondeau cannot prevent *Pseudomonas* blossom infection sufficiently.

Control

Pseudomonas bacteria are epiphytical bacteria that are always present on the leaves, shoots and buds without causing direct damage. There are other host plants in addition to the pear fruit trees. It is also known that the *Pseudomonas* bacteria can play a role in the freezing process itself by acting as ice nucleating particles (Montesinos and Valdendell, 1991).

Copper treatments are considered to have a bacteriostatic effect on the populations of *Pseudomonas* bacteria (Andersen et al., 1991). They can be positioned in the leaf fall period or early in the season at the bud break stage (Garrett, 1982).

Copper treatments during fall synchronize the leaf fall process and improve frost resistance of internal tissues in the flower buds and shoot tips. Copper treatments during springtime can reduce the epiphytic bacterial populations in the beginning of the season. A control strategy for *Pseudomonas syringae* infections should always combine a reduction in host susceptibility through technical measures avoiding weakness factors and chemical treatments with copper.

ERWINIA AMYLOVORA: FIRE BLIGHT

Fire blight (*Erwinia amylovora* Burr. Winslow et al.) is a very important bacterial disease in apple and pear growing with devastating effects in some production areas. In Europe there was a strong extension of fire blight in the southern countries of Italy and Spain in recent years. Although the disease is present in the important pear producing areas, there are still regions in these countries where the disease is not present. Many efforts have been undertaken to limit the disease spread as much as possible.

Fire blight bacteria can be spread over a long distance through transport of infected plant material of fire blight host plants. EEC fire blight experts consider this an important risk of fire blight spread. In other regions the discussion about long distance fire blight spread concentrates more on the role of infected fruits. For infected host plants there are indications that there is an endophytic phase of a fire blight infection with possibility of a delay in symptom expression (Crepel et al., 1996) and this makes the situation of export of contaminated plants extremely dangerous. On the other hand, we can see that the strict phytosanitary measures applied around European fruit tree nurseries were able to prevent fire blight introduction in noncontaminated areas for many years. These phytosanitary measures consisted of the construction of a buffer zone around the fields of production of fire blight host plants where fire blight inspections are carried out every year by trained people. Once an infection has been found in or in the neighborhood of the nursery, this plant material cannot be exported from this contaminated area to a noninfected area. Finally we should not forget that birds or aerosols also can spread the fire blight bacteria over a long distance.

Short distance spread of fire blight is made by insects feeding on the bacterial ooze droplets or by wind driven rains that disperse the bacteria around the existing infections. Orchard workers can also be a very important risk factor for local spread of fire blight bacteria by inadequate disinfection of tools or by working on fire blight infections under wet weather conditions.

In general, pear trees are more susceptible for fire blight infections than apple trees. The main blossom time is the most risky period of the year for fire blight blossom infections. In many countries the climatological conditions are far from optimal at that moment: in many years temperatures are too low with some problems of frost during bloom and a general primary bloom infection does not take place. Later in the season there is a growing risk for secondary blossom infections. The late secondary blossoms can occur shortly before harvest time and can kill young pear trees in a very few weeks. A heavy thunderstorm with wind and hail damage is one of the most favorable infection conditions of the fire blight pathogen and can result in thousands of infected shoots and fruits in a very short time.

Fire blight primary bloom infections can be predicted by different warning systems: Billing's original system, Billing's revised system, Billing's integrated system, Parefeu, Maryblyt or Cougarblyt (Sobiczewski et al., 1997). These warning systems are not developed for fire blight shoot infections or for secondary blossom infections during season. Also for the fruit tree nurseries it would be useful to have a warning system for shoot infection on young trees.

Fire blight control is based today on a complex of measures starting with a copper treatment at bud break stage. The amount of copper will be reduced in the IFP production systems and this could have consequences for the fire blight development in the orchards. In some countries Streptomycin is allowed for use during primary blossom period under strictly controlled circumstances; this compound is strongly discussed on the European level and will probably disappear in the near future. Interesting

TABLE 1

Changes in host susceptibility after applications of Prohexadione-Ca, Bion and Carpropamid treatments: trial 2000 on secondary bloom Durondeau.

	TH3-value on 28/06/00	
Object	**Visual**	**under binoculair**
Untreated	22.65 a	29.20 b
Streptomycin (1 x 100 g a.i./ha)	13.10 a	15.29 ab
Prohexadione-Ca (1 x 125 g a.i./ha)	14.59 a	16.83 ab
Prohexadione-Ca (2 x 125 g a.i./ha)	9.63 a	13.48 ab
Prohexadione-Ca (4 x 125 g a.i./ha)	16.73 a	25.95 ab
Carpropamid (4 x 250 g a.i./ha)	18.52 a	25.56 ab
Bion (4 x 50 g a.i./ha)	5.63 a	4.51 a
Bion (4 x 100 g a.i./ha)	6.79 a	7.96 ab

results were obtained recently in the reduction of fire blight host susceptibility with molecules like Prohexadione-Calcium and Bion (Deckers and Daemen, 1999). Table 1 summarizes some results of Prohexadione-Ca, Bion and Carpropamid on secondary blossom protection on the pear cultivar Durondeau.

In this trial the different treatments with these compounds were positioned during the secondary bloom period starting at green cluster, balloon stage, beginning bloom and full bloom stage. Part of the flowers were harvested and brought to symptom expression without artificial inoculation in the climatic chamber. Under this natural infection pressure there is a clear effect in reduction of the host susceptibility after the Bion and the Prohexadione-Ca treatments. When only the flowers were treated and not the whole tree, the increased resistance was not confirmed.

In the biological control, bacteriocines produced by a strain of Serratia Plymutica are developed for fire blight control in Belgium. Some results of fire blight blossom control with bacteriocines are summarized in Table 2.

In this trial the concentration of the bacteriocin used was 3 x 10^3 arbitrary units in the 1999 trial on Crataegus and 1 x 10^4 in the 2000 trial on apple. The artificial inoculation was made with a strain of *Erwinia amylovora* isolated from Durondeau at a concentration of 10^8 CFU/ml. The bacteriocins were applied 30 minutes after inoculation. The flowers were followed in climatic rooms at 24°C and 85% RH by day and 95% RH by night. The results indicate good flower protection possibilities of these bacteriocins and indicate the need to formulate the solution. The results were comparable with the Streptomycin as reference.

The presence of fire blight has influenced the evolution of the pear production areas in many countries in the past but could not prevent the strong extension in production areas in Belgium. In Belgium the pear area was more than doubled during the last 10 years, all with the very susceptible pear cultivar Conference (Table 3).

CONCLUSIONS

Both bacterial diseases *Pseudomonas syringae* pv. *syringae* and *Erwinia amylovora* can cause serious problems in Belgian pear growing but cannot prevent the strong growth in total pear area. *Pseudomonas* infections can be correlated with some weakness factors and affect the whole orchard of the same cultivar. Fire blight infections are more local in appearance and spread slowly around earlier infected trunks. Streptomycin is worldwide the chemical control solution but will disappear in European countries under increasing ecological pressure. Other control strategies will be needed such as changes in the host susceptibility of the fruit trees or biological control methods with bacteriocins.

TABLE 2

Results of fire blight blossom control with bacteriocines (ns: no significance; *: significance of 95%; **: significance of 99%).

Object	dose	Trial on Crataegus 1999: infection degree	Trial on James Grieve 2000: infection degree
Untreated	-	29.46	22.96
Streptomycin	100 g a.i./ha (0.09 lb/acre)	11.00**	13.84*
Bacteriocine	100 liter/ha (10.7 gal/acre)	18.86**	16.70 ns
Bacteriocine	100 liter/ha (10.7 gal/acre)	12.96**	13.12*
+ Captan	1.5 liter/ha (0.16 gal/acre)		

TABLE 3

Pear growing area (ha) in Belgium for 1989 to 1999.

	Year										
Variety	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99
Conference	2280	2357	2570	2872	3200	3550	3900	4230	4410	4230	4900
Doyenné	700	711	745	773	780	820	890	900	910	900	925
Durondeau	350	350	364	375	400	430	470	480	450	480	445
Beurré Hardy	65	68	69	61	60	80	80	80	80	-	-
Triomphe de V	65	67	69	61	60	80	80	80	80	-	-
Others	90	95	112	98	80	40	40	30	70	190	230
Dwarf pear (ha)	3550	3648	3929	4240	4580	5000	5460	5800	6000	5850	6500

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