Pathogens on Japanese Quince (*Chaenomeles japonica*) Plants

I. Norin[a], K. Rumpunen[b*]

[a]Department of Crop Science, Swedish University of Agricultural Sciences, Alnarp, Sweden
Present address: Kanslersvägen 6, 237 31 Bjärred, Sweden
[b]Balsgård–Department of Horticultural Plant Breeding, Swedish University of Agricultural Sciences, Kristianstad, Sweden

*Correspondence to kimmo.rumpunen@vv.slu.se

SUMMARY

In this paper, a survey of pathogens on Japanese quince (*Chaenomeles japonica*) plants is reported. The main part of the study was performed in South Sweden, in experimental fields where no pesticides or fungicides were applied. In the fields shoots, leaves, flowers and fruits were collected, and fruits in cold storage were also sampled. It was concluded that Japanese quince is a comparatively healthy plant, but some fungi were identified that could be potential threats to the crop, which is currently being developed for organic growing.

Grey mould, *Botrytis cinerea*, was very common on plants in the fields, and was observed on shoots, flower parts, fruits in all stages and also on fruits in cold storage. An inoculation experiment showed that the fungus could infect both wounded and unwounded tissue in shoots. Studies of potted plants left outdoors during winter indicated that a possible mode of infection of the shoots could be through persisting fruits, resulting in die-back of shoots.

Fruit spots, brown lesions and fruit rot appeared in the field. Most common were small red spots, which eventually developed into brown rots. Fungi detected in these spots were *Septoria cydoniae*, *Phlyctema vagabunda*, *Phoma exigua* and *Entomosporium mespili*. The fact that several fungi were connected with this symptom indicates that the red colour may be a general response of the host, rather than a specific symptom of one fungus. Fungi found in brown lesions and rots were *Botrytis cinerea*, *Phlyctema vagabunda*, *Penicillium expansum*, *Colletotrichum gloeosporioides* and *Cryptosporiopsis curvispora*. *Phlyctema vagabunda* was often found in brown rots and also in red spots, indicating that this was the most common fungus.

Leaf spots were also a common symptom in the fields. The spots varied in size, shape and colour, and it was obvious that they were caused by several different fungi. From leaves sampled in Latvia, *Septoria cydoniae*, *Phoma pomorum*, *Asteromella* sp. and *Ramularia* sp. were detected. *Phoma pomorum* and *Alternaria alternata* were isolated from leaves sampled in Sweden. However, most of the fungi recorded were widely distributed saprophytes or secondary invaders and leaf diseases were not considered severe.

On flowers, the most commonly observed fungi were *Cladosporium* sp. and *Botrytis cinerea* but *Penicillium expansum, Alternaria alternata* and *Fusarium* sp. were also recorded.

Pests found were leaf weevils, *Phyllobius* spp., larvae of *Operophtera* sp., *Yponomeuta* sp., and *Caliroa* sp. Aphids and red spider mites were also observed, but these were not identified to species.

Differences in susceptibility to fruit spots were detected between populations derived from controlled cross-pollination. Plant breeding programmes aimed at developing varieties with resistance to fruit spots should therefore be successful.

INTRODUCTION

Japanese quince, *Chaenomeles japonica* (Thunb.) Lindley, belonging to the family Rosaceae, is grown in many countries around the world as an ornamental plant. The ornamental value of the different species and hybrids in the genus *Chaenomeles* Lindl. is also reflected in the common name of the genus sometimes used, flowering quince (Weber 1964). However, to avoid confusion, it would be better to use flowering quince as the common name for *C. speciosa* only. There has long been considerable taxonomic confusion in the genus *Chaenomeles*, and *Pseudocydonia sinensis* is still sometimes referred to as *Chaenomeles sinensis* in the literature. However, according to the checklist for the subfamily Maloideae (Phipps *et al*. 1990) the genus *Chaenomeles* comprises four East Asian species: *C. cathayensis*, *C. speciosa* and *C. thibetica* growing in China and neighbouring countries, and *C. japonica* growing in Japan.

In gardening books and other specialist literature, few diseases and pests are mentioned for Japanese quince and the other species in the genus. According to Jewell (1998): "fungal diseases are seldom troublesome but *Chaenomeles* is susceptible to the bacterial disease fire blight and this, and occasional fungal attack, should be controlled by pruning out affected branches". Brickell (1994) also mentioned fire blight as the main problem, as well as chlorosis on alkaline soils. Pests mentioned are aphids and scale, usually with only minor damage (Jewell 1998). Otherwise *Chaenomeles* is described as a genus with healthy ornamental plants.

However, there are scientific reports of diseases and pests, of which a few may be important for Japanese quince as a fruit crop. Diseases caused by fungi are the most frequently reported on *Chaenomeles* species (Table 1). In the early 1960s, Eliade & Barbu (1963) studied fungi on *Chaenomeles* plants in Romania. They reported fungi causing leaf spots (*Coryneum foliicola* and *Phyllosticta chaenomelina*), spots and rots on fruits (*Septoria cydoniae*, *Cytospora piricola*, and *Monilina fructigena*), and they also recorded several fungi on dried and dead twigs, *e.g*. *Sphaeropsis lichenoides, Diplodia cydoniae* and *Tubercularia vulgaris*. They found a rust fungus, *Gymnosporangium confusum*, mainly attacking leaves and grey mould, *Botrytis cinerea*, on flowers.

Monilinia species, causing blossom and twig blight and brown rot of fruits, occur not only in Europe (Werner & Fruzynska-Jozwiak 1999), but also in other parts of the world (Creelman 1962, Penrose *et al.* 1976, Heaton 1979). *Botrytis cinerea*, can also attack twigs and has been reported as causing cankers on *C. cathayensis* in England (Moore 1949). The fire blight bacteria, *Erwinia amylovora*, was reported from England in the late 1950s (Beer 1990), and inoculation experiments showed that pear isolates of fire blight were pathogenic to *Chaenomeles* plants (Anonymous 1960). Fire blight on *Chaenomeles* plants has also been reported from Germany (Zeller 1979). A virus, apple chlorotic leaf spot virus, has been reported from England (Sweet 1980).

Insects and other pests seem to be a minor problem on *Chaenomeles* plants (Table 2). Aphids have been reported from Poland (Jaskiewicz 1995), with *Aphis pomi* (the green apple aphid) as the dominant species. Aphids and scale were also noted by Eliade & Barbu (1963). Other insects reported on leaves are larvae of *Caliroa cerasi* (Raffa & Lintereur 1988) and the leaf miner *Lyonetia prunifoliella* in the USA (Schmitt *et al.* 1996). The fruit borer *Cydia* [*Grapholita*] *dimorpha* attacks fruits in Japan (Oku *et al.* 1988).

From the literature survey it was clear that fungal diseases predominated on *Chaenomeles* plants. If Japanese quince plants were to be cultivated on a large scale, they too would probably be attacked by some of the fungi that are already a problem on other crops belonging to the Rosaceae, *e.g.* blossom and twig blight caused by *M. laxa*, and brown rot of fruits caused by *M. fructigena*. Fungal symptoms such as leaf and fruit spots and rotting of fruits had previously been noted on Japanese quince plants in Sweden,

Table 1. Reports on fungi, bacteria and viruses causing diseases of *Chaenomeles* species.

Plant part and disease	Pathogen	Host	Author	Country
Fungi				
Shoots				
Shoot canker	*Botrytis cinerea*	*C. cathayensis*	Moore 1949	England
On dead shoots	*Diatrypella xanthostroma*	*C. japonica*	Eliade & Barbu 1963	Romania
On dead shoots	*Diplodia cydoniae*	*C. japonica*	Eliade & Barbu 1963	Romania
On dead shoots	*Phoma chaenomelis*	*C. japonica*	Eliade & Barbu 1963	Romania
On dead shoots	*Sphaeropsis lichenoides*	*C. japonica*	Eliade & Barbu 1963	Romania
Coral spot	*Tubercularia vulgaris*	*C. japonica*	Eliade & Barbu 1963	Romania
Shoots and flowers				
Blossom blight	*Monilinia fructicola*	*C. japonica*	Heaton 1979	Australia
Blossom blight	*Monilinia laxa*	*C. japonica*	Creelman 1962	Canada
Blossom blight	*Monilinia [Sclerotinia] laxa*	*C. japonica*	Penrose *et al.* 1976	Australia
Blossom blight	*Monilinia [Sclerotinia] laxa*	*C. lagenaria*	Penrose *et al.* 1976	Australia
Blossom blight	*Monilinia laxa*	*Chaenomeles* spp.	Werner & Fruzynska-Jozwiak 1999	Poland
Shoot canker	*Monilinia [Sclerotinia] laxa*	*C. japonica*	Penrose *et al.* 1976	Australia
Shoot canker	*Monilinia [Sclerotinia] laxa*	*C. lagenaria*	Penrose *et al.* 1976	Australia
Flowers				
Grey mould	*Botrytis cinerea*	*C. japonica*	Eliade & Barbu 1963	Romania
Leaves				
Rust	*Gymnosporangium asiaticum*	*C. speciosa*	Huang & Chen 1997	Kina
Rust	*Gymnosporangium confusum*	*C. japonica*	Eliade & Barbu 1963	Romania
Leaf spots	*Phyllosticta chaenomelesicola*	*C. speciosa*	Yu & Bai 1995	China
Leaf spots	*Phyllosticta chaenomelina*	*C. japonica*	Eliade & Barbu 1963	Romania
Fruits				
Brown rot	*Monilinia fructigena*	*C. japonica*	Eliade & Barbu 1963	Romania
Brown rot	*Monilinia fructigena*	*Chaenomeles* spp.	Werner & Fruzynska-Jozwiak 1999	Poland
Fruit spots	*Cytospora piricola*	*C. japonica*	Eliade & Barbu 1963	Romania
Fruit spots	*Septoria cydoniae*	*C. japonica*	Eliade & Barbu 1963	Romania
Bacteria				
Fire blight	*Erwinia amylovora*	*Chaenomeles* sp.	Anonymous 1960	England
Fire blight	*Erwinia amylovora*	*Chaenomeles* sp.	Zeller 1979	Germany
Virus				
Apple Mosaic	Apple chlorotic leaf spot virus	*Chaenomeles* sp.	Sweet 1980	England

Table 2. Reports on pests occurring on *Chaenomeles* species.

Plant part and pest	Pest	Host	Author	Country
Leaves				
Aphid	*Aphis pomi*	*C. japonica*	Jaskiewicz 1995	Poland
Aphid	*Aphis fabae*	*C. japonica*	Jaskiewicz 1995	Poland
Aphid	*Brachycaudus helichrysi*	*C. japonica*	Jaskiewicz 1995	Poland
Slug worm	*Caliroa cerasi*	*Chaenomeles* spp.	Raffa & Lintereur 1988	USA
Leaf miner	*Lyonetia prunifoliella*	*Chaenomeles* spp.	Schmitt *et al.* 1996	USA
Fruits				
Fruit borer	*Cydia* [*Grapholita*] *dimorpha*	*C. japonica*	Oku *et al.* 1988	Japan
Fruit borer	*Cydia* [*Grapholita*] *dimorpha*	*C. speciosa*	Oku *et al.* 1988	Japan

Latvia and Lithuania. Die-back of shoots and of entire plants was sometimes evident. The aim of this investigation was therefore: 1) to make a survey of pathogens, especially fungi, on Japanese quince plants in the field, 2) to study fungi of specific interest, and 3) to study the genetic potential for resistance breeding against fungi, especially fruit spots.

MATERIALS AND METHODS

Survey of symptoms and fungi in the field

Plant material

During a four year period, plants of Japanese quince (*Chaenomeles japonica*) and of other species in the genus *Chaenomeles* (*C. cathayensis*, *C. speciosa* and *C. thibetica*), were surveyed for potential plant pathogens. The fields were located at Balsgård–Department of Horticultural Plant Breeding, in southern Sweden. A few samples were also collected from Japanese quince plants at Dobele Horticulture Plant Breeding Experimental Station, Latvia. In the experimental fields no pesticides or fungicides were applied.

The survey was carried out throughout the season (from May to November), 1998–2001. Samples of shoots, leaves, flowers and fruits were collected in the field. In addition, fruits were put into cold storage and examined for storage rots. The samples were studied directly under the microscope, and fungi were identified after incubation of plant parts in moist chambers or after isolation on various solid media in petri-dishes. The presence of insects feeding on the plants was also noted. Photographs of various symptoms were taken throughout the season by IN.

Isolation and identification of fungi

Before isolation of fungi, samples of leaves and shoots were rinsed under tap water, surface-sterilized in 70% ethanol or 0.5–1.0% NaOCl and dried on sterile filter paper. Fungi were isolated from leaves by cutting small pieces from the margins of leaf spots using a sterile scalpel. The bark of shoots was first removed and pieces from the margins of discoloured wood tissue were cut out. The pieces were then placed on potato dextrose agar (PDA) or malt extract agar (Merck).

The skin of fruits was wiped with 70% ethanol, opened with a sterilised scalpel, and pieces of the flesh or skin were placed on PDA. Samples of leaves and fruits and pure cultures of fungi were also sent to Dr Ovidiu Constantinescu, Mikrosvampkonsult, Uppsala for identification of fungi to species.

Studies on symptoms and fungi of specific interest

Prior to this survey, it had been noted that shoots or entire plants sometimes died during the winter. Earlier suspicions of *Monilia laxa* as the cause of this die-back were not verified during 1998, as this fungus was not observed in any samples. By contrast *B. cinerea* was found sporulating on all kinds of plant parts, including dead or cankered shoots. Since there were previous reports of *B. cinerea* infecting woody plant parts (Moore 1949, Gupta 1979, Müller 1988, Michailides 1991), attention was drawn to this fungus as a possible cause of the die-back. During the following years, investigations were carried out to further study *B. cinerea* in association with Japanese quince.

Inoculation experiment with B. cinerea

Two selected clones of Japanese quince, C3 and C7, were micro-propagated in November 1998, and after six months were planted out in 2.0 litre pots. At that time, most of the plants had one main shoot. The experiment comprised four treatments, with two plants of each clone per treatment: A) a scar approx. 10 mm in length was made on the shoot with a scalpel and an agar plug (5 mm in diameter) with mycelium and conidia of *B. cinerea* was placed on the scar, B) an agar plug without the fungus was placed on the scar as a control, C) an agar plug with the fungus was placed on an unwounded shoot, and D) an agar plug without the fungus were placed on an unwounded shoot as a control. In addition, 4 uninoculated plants of each clone were included in the experiment as untreated controls.

Before inoculation, the shoots were surface-sterilized with 0.5% NaOCl. The inoculations were then covered with Parafilm M. Inoculation took place on 25 May 1999 and the plants were examined on three occasions: 4 June, 14 June and 23 June. Reisolation attempts from the shoots were carried out as previously described.

Study of potted plants

The die-back of shoots seemed to be connected with fruits remaining on the plant during the winter (Figure 1A). To further investigate the possible connection between remaining fruits and the die-back phenomenon, 8 potted plants were collected in October 1999 and put outdoors during the winter. One of the plants was examined in February 2000 and the remaining plants were examined in June. Fungi from cankered shoots were isolated as previously described.

Field experiment

To further study the fungus *B. cinerea*, its connection with the die-back plants, and its mode of infection, a field experiment was laid out in the autumn of 1999. The experiment comprised 3 micropropagated clones (C13, C20, C27), 3 treatments and 7 replications in a randomised block design. Thus the experiment included 3 x 3 x 7 = 63 plants. The treatments were a) flowers removed in spring, b) fruits removed when ripe in the autumn, c) fruits left over winter.

The plants were examined for two years, 2000–2001, from May to November. The flowers were removed in May-June, fruits were removed in late September-October, and the number of remaining fruits was recorded in November. In 2000, removed fruits and fruits that had fallen prematurely were kept in cold storage during the winter and examined in January 2001. In spring 2001, the plants were investigated with regard to cankers and die-back of shoots, and samples were taken. Flowers were also sampled to investigate the presence of fungi.

Leaf spots and their prevalence over years

Assessments of leaf spots were made during three years on plants in two previously planted trials. The trials were established as 1) a study of weed control by means of synthetic mulching, and 2) a study of impact of nitrogen fixing species in the sward.

Leaf spots were assessed on 160 plants in each trial on 7 October 1998, 1 July and 27 August 1999 and 9 June and 28 September 2000. Leaf spots on the entire plant were scored from 0 to 4, where 0 meant no spots were recorded on the leaves, and 4 that most of the leaves on the plant had spots.

Study on the genetic potential for resistance breeding against fruit spots

In 2000, fruit spots were examined on fruits harvested from 14 populations (comprising 670 plants) in a field planted in 1994 for a genetic study of plant and fruit traits (Rumpunen 2001). The fruit spots mostly consisted of rather small red spots, a symptom very common in the field (Figure 1B). The spots seldom covered the entire fruit, but were mostly located on the upper (exposed) side. The spotted area of affected fruits was scored from 0 to 4, where 0 meant no spots on the peel, and 4 more than 50% of the peel was covered with spots. Fruit spots were scored on an average basis for all fruits of each plant. The fruits were kept in cold storage from harvest until the time of assessment. In 2001, the assessment instead took place in the field and the presence of red spots was scored as above. In both years the assessments were made in October.

Statistics

Statistical analyses of the genetic study (investigating the potential for resistance breeding against fruit spots) were performed using SPSS statistical software (SPSS version 10.0 for Macintosh, SPPS Inc.).

Table 3. Fungi recorded on shoots, flowers and leaves of Japanese quince (*C. japonica)* plants at Balsgård, Sweden in 1998–2001. Leaves were also sampled at Dobele, Latvia.

Plant part and disease	Comments
Shoots	
Botrytis cinerea	Grey mould, shoot canker, isolated from shoots in the field, observed on dead shoots in the fields, causing die-back of plants in a greenhouse
Fusarium sp.	Observed on shoot bases of potted plants, on shoots in the field
Tubercularia vulgaris	Coral spot, observed on dead shoots in the field
Flowers	
Alternaria alternata	Isolated from stamens
Botrytis cinerea	Isolated from petals, observed in the field
Cladosporium sp.	Isolated from pistils, observed in the field
Fusarium sp.	Observed on receptacle and petals in a moist chamber
Penicillium expansum	Isolated from petals
Leaves	
Alternaria alternata	Isolated from leaf spots (Sweden)
Arthrinium sp.	Isolated from leaf spots (Sweden)
Aureobasidium pullulans	Isolated from leaf spots (Sweden)
Asteromella sp.	Detected in leaf spots (Latvia)
Cladosporium cladosporioides	Isolated from leaf spots (Sweden)
Epicoccum nigrum	Isolated from leaf spots (Latvia, Sweden)
Penicillium expansum	Isolated from leaf spots (Sweden)
Phoma sp.	Isolated from leaf spots (Latvia)
Phoma exigua	Isolated from leaf spots (Sweden)
Phoma herbarum	Isolated from leaf spots (Latvia, Sweden)
Phoma pomorum	Isolated from leaf spots (Latvia, Sweden)
Ramularia sp.	Isolated from leaf spots (Latvia)
Septoria cydoniae	Detected in leaf spots (Latvia)
Ulocladium botrytis	Isolated from leaf spots (Sweden)

RESULTS

Survey of symptoms and fungi in the field

The fungus most frequently found in the fields was grey mould, *B. cinerea* (Tables 3 and 4). In 1998, a year with high precipitation and moist weather conditions, the fungus was often observed sporulating on flower parts and on fruits in all stages, from early spring to autumn (Figures 1C, 1D and 1E). In addition, the fungus was recorded every year on stored fruits. *Botrytis cinerea* was also observed sporulating on dead or cankered living shoots. Die-back of shoots and plants was found to be one of the main problems, and the possible role of *B. cinerea* in this phenomenon was therefore further investigated. Another problem observed was leaf spots, which sometimes caused premature leaf fall, though the severity varied with the weather conditions (Figure 1F).

Fungi on shoots

Whole plants or shoots sometimes died during the winter. Examinations of damaged but still living shoots in the spring 1998 revealed a brown discoloration of the cambium just beneath the bark. Sometimes this brown discoloration girdled the shoot, and the part above the damage was dead. The brown areas often originated from fruit spurs where fruits had been attached during the winter (Figure 2A). *Botrytis cinerea* was also isolated from cankers in shoots. In addition, a heavy attack of *B. cinerea* occurred on young plants of *C. japonica* in the greenhouse, showing that the fungus was able to attack woody parts of the plant.

This was also evident in early summer 1999, when young plants were once again attacked and killed by *B. cinerea* in the greenhouse. The fungus invaded the leaves and grew into the shoots (Figure 2B). Plants were also infected at the bases of their stems (Figure 2C).

In previous years a connection between death of the shoots and persisting fruits had been noticed. Japanese quince fruits, if not harvested, often remained on the plants during the winter. By the following spring these fruits were brown, hollow inside, and had a papery texture. In 1999, *B. cinerea* was found sporulating on brown and rotted fruits on the plants, both in the spring and in the autumn. The mycelium of the fungus was also observed growing from the surface of the fruit onto the twig (Figure 2D).

On dead shoots coral spot, *Tubercularia vulgaris* (the conidial state of *Nectria cinnabarina*), was observed in the field. This fungus mainly invades dead or dying tissue and usually indicates that the plants have been under some kind of stress.

Fungi on flowers

The most common fungus and the first isolated from flowers was *Cladosporium* sp., collected in May 1998. This fungus was isolated from pistils in flowers at all stages, even from buds. Growth of *Cladosporium* sp. was also noticed on the stigmas of pistils in the field (Figure 3A). Other fungi isolated from flowers were *Botrytis cinerea* and *Penicillium* sp.

In early June 1999, wilted flowers were found on plants in one of the fields. The symptom resembled blossom blight caused by *Monilia laxa*. After incubation in moist air for a week, the flowers were examined by microscope. *Cladosporium* sp. was found on 94% and *Botrytis cinerea* on 56% of the flowers. *M. laxa*, which is easy to diagnose since it usually sporulates on wilted flower parts, was never found.

Fungi on leaves

Leaf spots were common on Japanese quince plants, though the severity depended on the weather conditions. Severe attacks of leaf spot fungi caused yellowing of the leaves and premature leaf fall.

In 2001, fungi were isolated from leaves sampled in both Latvia and Sweden. On leaves from Latvia, sampled in the field in early September, the spots were 5–10 mm in diameter, mostly brown but some had a silver-like appearance (Figure 3B). The spots were usually covered with small, dark pycnidia (asexual fruiting bodies). The brown spots contained two fungi, *Phoma pomorum* and *Septoria cydoniae*, and the silver spots an *Asteromella* species (anamorph of *Mycosphaerella*). Through isolation various anamorphic fungi (*i.e.* imperfect states) were detected: *Epicoccum nigrum*, *Phoma herbarum*, *Phoma pomorum*, *Phoma* sp. and *Ramularia* sp.

On dry leaves sampled in Sweden, no typical fungal structures could be detected in the spots by the macroscopic examination. The presence of fungi had to be confirmed by isolation. The leaf spots varied in size (0.1–10 mm in diameter) shape and colour, but no correlation was found between a particular symptom and the fungi isolated: *Alternaria alternata, Arthrinium* sp. (anamorph of *Apiospora montagnei*), *Aureobasidium pullulans, Cladosporium cladosporioides, Epicoccum nigrum, Penicillium expansum, Phoma exigua, Phoma herbarum, Phoma pomorum*, and *Ulocladium botrytis.*

Fungi on fruits

In 1998, *B. cinerea* was very common in the field, sporulating on flower parts, shoots and fruits in all stages from early spring to autumn. Sometimes the fungus grew into unripe fruits via wilted infected petals. By the end of July, a large number of young fruits showed brown rots and fell to the ground (Figure 1D). When incubated in a moist chamber, most of these fruits developed *B. cinerea*. Other fungi recorded on young fruits incubated in moist air were *Penicillium* and *Fusarium* species. *Penicillium* was also observed on fruits in the field. *Monilia fructigena,* causing brown rot, appeared in one of the fields at the beginning of August (Figure 4A).

A symptom often noticed on fruits in the field was relatively small, red spots (Figure 1B), mostly

Table 4. Fungi recorded on Japanese quince (*C. japonica*) fruits at Balsgård, Sweden in 1998–2001.

Plant part and pathogen	Comments
Fruits, young	
Botrytis cinerea	Grey mould, observed in the field on brown young fruits
Fusarium sp.	Observed in moist chamber
Penicillium spp.	Blue mould, observed in moist chamber
Fruits, mature	
Alternaria alternata	”Brown lesions”, isolated
Alternaria tenuissima	”Black spots”, isolated
Botrytis cinerea	Grey mould, observed in the field
Cladosporium cladosporioides	Isolated
Colletotrichum gloeosporioides	Bitter rot, detected by microscope, isolated
Cryptosporiopsis curvispora	Bulls-eye rot, detected by microscope
Entomosporium mespili	Detected by microscope
Leptothyrium pomi (anamorph of *Schizothyrium pomi*)	Flyspeck, detected by microscope
Monilia fructigena	Brown rot, observed in the field
Myriellina cydoniae	Brown lesions, detected by microscope
Penicillium brevicompactum	Isolated
Penicillium expansum	Blue mould, isolated, observed in the field
Penicillium islandicum	Isolated
Penicillium rugulosum	Isolated
Phlyctema vagabunda	”Red spots”, ”Brown lesions” and ”Black spots”, isolated
Phoma exigua	”Red spots” and ”Black spots”, isolated
Phoma glomerata	”Black spots”, isolated
Pilobolus sp.	Isolated
Schizothyrium pomi	Flyspeck, detected by microscope
Septoria cydoniae	”Red spots”, isolated
Trichoderma viridae	Isolated
Fruits, in cold storage	
Botrytis cinerea	Grey mould, observed
Penicillium expansum	Blue mould, observed and isolated
Phlyctema vagabunda	”Gloeosporium rot”, observed by microscope

located on the exposed (upper) side of the fruit. Some of these spots later developed into brown rots, starting in the middle of the red spot. When the rots developed the red colour finally disappeared. There seemed to be a difference in susceptibility among seedlings, as some of the plants could be severely attacked, with a large number of spotted fruits, while other plants next to them showed no symptoms at all.

Besides the red fruit spots, another symptom consisting of small, brown, concentric rots was very common in the field. These rots differed in appearance from rots caused by *B. cinerea* by being smaller with dark margins. Usually there were several rots of this kind on one fruit, whereas damage caused by *B. cinerea* mostly consisted of one rot, often originating from the stem or calyx ends or a wound, enlarging until the whole fruit became brown and rotted.

In 1998 *Septoria cydoniae*, *Phlyctema vagabunda* and *Phoma exigua* were isolated from red spots, and *Alternaria alternata* and *Phlyctema vagabunda* from brown lesions. Another kind of fruit spot, less common but very conspicuous, also appeared in the field. These spots were black, gradually becoming greyish in the middle. They varied from some millimetres to a couple of centimetres in size (Figure 4B).

Four fungi were isolated from fruits affected with these spots: *Phoma glomerata*, *Phoma exigua*, *Alternaria tenuissima* and *Phlyctema vagabunda*. This symptom occurred mainly in 1998, while in the following years it was rarely observed. In 2000, the fungus *Phlyctema vagabunda* was found in both the small brown rots and in developing rots in red spots.

In 2001, the following fungi were identified through macroscopic and microscopic examinations of the fruits: *Colletotrichum gloeosporioides*, *Cryptosporiopsis malicorticis* (synonym *C. curvispora*), *Entomosporium mespili*, *Myriellina cydoniae*, *Schizothyrium pomi* and its anamorph *Leptothyrium pomi*, and *Penicillium expansum*. Isolation attempts gave the following results: *Cladosporium cladosporioides*, *Colletotrichum gloeosporioides*, *Penicillium brevicompactum*, *P. expansum*, *P. islandicum*, *P. rugulosum*, *Phoma exigua*, *Pilobolus* sp. and *Trichoderma viride*. *Colletotrichum gloeosporioides* was found in three samples. The symptoms consisted of more or less round, depressed lesions approx. 20 mm in diameter, sometimes covered with salmon coloured conidial masses. *Cryptosporiopsis malicorticis* was found in round, depressed lesions 5–8 mm in diameter. *Myriellina cydoniae* occurred in ochreous spots, approx. 6 mm in diameter, with dark brown to black acervuli (type of asexual fruiting body) irregularly distributed over the spot surface. *Entomosporium mespili* was found in one fruit where almost half of the surface was covered with numerous dark brown depressed lesions, 2–3 mm in diameter, larger by coalescing. Black, shiny fruiting bodies appeared in the centre of each lesion.The other half of the fruit was covered with 0.1–1 mm black spots surrounded by a reddish halo, which seemed to be the first stages of the larger lesions (Figure 4C). *Schizothyrium pomi* was identified through its small, black, superficial stroma-like fruiting bodies (Figure 4D), and the anamorph *Leptothyrium pomi* through its typical sterile hyphae.

Fungi on stored fruits

Fruits harvested in 1997 were examined for storage rots in June 1998. Three fungi predominated: *Phlyctema vagabunda* (Figure 5A), *B. cinerea* (Figure 5B), and *Penicillium expansum* (Figure 5C).

Fruits harvested in 1998 were examined in May 1999. *Botrytis cinerea* was found on 7.7% of the fruits, while 6.0% of the fruit had rots resembling those caused by *P. vagabunda*. It was not possible to draw any conclusions from this study, since the storage conditions were probably too dry.

Fruits harvested in October 2000 were examined for storage rots on 31 January 2001. *Botrytis cinerea* was found on 1.4% of the fruits. Small brown lesions corresponding to symptoms of *P. vagabunda* were seen on 6.1% of the fruits, and 6.4% of the fruits were attacked by *Penicillium* sp. This assessment was based on the appearance of the rots, or the presence of sporulating mycelia and/or sclerotia visible to the naked eye, as shown in Figures 5A, 5B, and 5C. Rotted fruits without such typical symptoms were grouped into 'other rots' and comprised 20% of the fruits. This figure also include fruits probably attacked by *B. cinerea*, which did not sporulate on this occasion. 'Other rots' were mostly connected with wounds on the fruits.

Pests

Insects and other pests observed in the fields

Pests observed in the fields are presented in Table 5. In May, larvae of *Operophtera* sp. (Figure 6A) were often seen feeding on leaves and buds. Leaf weevils (*Phyllobius* spp.) frequently occurred from May into June, feeding on leaves and buds and mating on the plants (Figure 6B). In June, larvae of ermine moths, *Yponomeuta* sp., were common (Figure 6C). The larvae fed on the leaves and lived in colonies inside a web. At this time larvae of *Orgyia antiqua* (Figure 6E) were also observed feeding on the plants. In July 1999, red spider mites (possibly *Panonychus ulmi*) were found on some plants. Late in September 1998, some young plants with deformed and cup-shaped leaves were noted (Figure 6D). As aphids were observed on the plants, it was assumed that these were the cause of the symptoms. The aphids were, however, never identified. On the same occasion, larvae of *Caliroa* sp. were also recorded, feeding on leaves (Figure 6F).

Table 5. Pests on Japanese quince (*C. japonica*) plants at Balsgård, Sweden 1998–2000. Common names according to Buczacki & Harris 1981.

Pests	Comments
Aphids	Deformed and cup-shaped leaves, aphids were not identified to species
Phyllobius spp.	Leaf weevils eating on leaves and buds
Yponomeuta sp.	Ermine moth, probably *Y. malinella*, larvae were living in colonies inside a web
Caliroa sp.	Probably pear and cherry slugworm, *C. cerasi*
Operophtera sp.	Probably winter moth, *O. brumata*, eating on leaves, buds and shoots, early injuries on fruits
Orgyia antiqua	Vapourer moth, larvae were eating on leaves
Panonychus sp.	Red spider mites, probably *P. ulmi*, sucking injuries of leaves

Studies on symptoms and fungi of specific interest

Inoculation experiment with B. cinerea

All four plants, two of each clone, that were wounded and inoculated with *B. cinerea* (treatment A) showed a brown discolouration of the inoculated tissue under the bark within 4 weeks. Only ten days after inoculation, on 4 June, one of the plants of clone C3 showed wilted leaves and a brown rot under the bark. The three remaining plants of this treatment were examined on 23 June. The second plant of clone C3 had a rot 18 mm in length, girdling the shoot. The two plants of clone C7 had rots extending 16 mm and 40 mm in length, respectively. Of the unwounded and inoculated plants (treatment C), only the plants of clone C7 showed symptoms. One of these plants, examined on 14 June, had a slight discolouration of the wood. The other plant, examined on 23 June, had a brown rot 5 mm in length under the bark. The plants of clone C3 from this treatment showed no discolourations of bark or wood, nor did the controls in treatments B and D. Isolations were made on 14 June from one plant of clone C3 in treatment A, from one plant of clone C7 in treatment C and from one control plant of clone C3 in treatment B. *Botrytis cinerea* was reisolated from the inoculated plants from treatments A and C, but not from the control plant.

Study of potted plants

During winter, fruits remained on the branches of every potted plant and *B. cinerea* was noticed sporulating on some of the fruits. One of the plants was examined in February. It was then still alive, but a brown discolouration was observed in the wood at the base of the shoot. Isolations were attempted from the discoloured wood, but were not successful.

The remaining plants were examined in June. At this time three plants were still alive, four plants were dead. On the dead plants, *B. cinerea* was noticed sporulating on the surface of the fruits, and often on the stem ends and on fruit stems. *Botrytis cinerea* was also found on the shoots, and in some case at the base of the shoots. On three plants *Fusarium* sp. was also found at the bases of the shoots. No isolations were made from the dead plants. On the surviving plants, *B. cinerea* was found on the fruits, stem ends and fruit stems. On two of the plants there was a brown discolouration in the wood in connection with attacked fruits. Isolations were made from the discoloured wood, and *B. cinerea* was successfully isolated from one of the plants.

Field experiment

In the field experiment, plants were examined for *B. cinerea* on 6 occasions in 2000. In the treatment where the fruits remained on the plants over winter, fruits were still attached to most of the plants on 17 October. Some fruits had fallen before this date, and fruit set had failed in four plants. By 22 November, most of the fruits had fallen in this treatment and fruits still remained on only 8 plants out of 21. *Botrytis cinerea* was seen sporulating on some fruits. The fungus was also found on fallen or removed fruits kept in cold storage.

Table 6. Assessments of leaf spots on Japanese quince (*C. japonica*) plants in a field planted in spring 1998. Leaf spots were scored from 0 to 4 and percentages of plants in each class were calculated.

Score /Date	Plants (%) 7 Oct. 1998	1 July 1999	27 Aug. 1999	9 June 2000	28 Sept. 2000
0	11.0	28.6	5.4	42.3	0.6
1	31.3	55.9	26.3	53.0	23.6
2	47.8	13.2	42.4	4.7	58.1
3	8.5	2.1	25.2	0.0	17.3
4	1.3	0.1	0.7	0.0	0.4

On 15 May 2001, all 63 plants in the trial were investigated with regard to cankers and die-back of shoots. Dead and desiccated shoots were noted on eleven plants, and one plant died during the winter. However, dead shoots were found in all treatments, and some plants with fruits remaining late in November 2000 seemed to be completely healthy. Examination by microscope of dead shoots did not reveal any presence of *B. cinerea*. In a few shoots a pink mycelium, which turned out to be *Fusarium* sp., was found in cracks in the bark. On the dead plant, which consisted of one shoot only, three old fruits had remained during winter. *Botrytis cinerea* had been recorded on these fruits on 22 November the year before, but since the plant was dead no isolation attempts were made. A wound at the base of the shoot was observed.

In June 2001, flowers were sampled in the same field experiment. The flowers did not show any particular symptoms, but when placed in moist chamber, the presence of fungi was revealed. The most frequently found fungi were *B. cinerea, Penicillium expansum* and *Cladosporium* sp., growing on all parts of the flowers. Other fungi were *Fusarium* sp. on receptacles and petals, and *Alternaria alternata* on stamens.

Leaf spots and their prevalence over years

Leaf spots were studied during three years. The assessment of leaf spots in October 1998 on young plants showed that 11% of the plants had no visible spots at all and only about 1% had spots on most of the shoots or on all leaves (Table 6). The plants looked surprisingly green and healthy, only a few had begun to show autumn colours and leaf fall.

In 1999 leaf spots were common on Japanese quince plants, as in many other plant species in that year, due to a wet spring. The proportion of plants with no visible leaf spots was less in August 1999 (5.4%), compared to October 1998 (11%).

In 2000 leaf spots were not particularly serious during the season. April and May were dry and unusually hot, and precipitation was below average during June, July and August. In early June, 95% of the plants showed no or just a few leaf spots. By the end of September the proportion of plants with leaf spots had increased, but most of the plants showed only slight to moderate symptoms. A statistical analysis revealed no significant difference in attacks of leaf spots on plants for the different treatments in the two trials surveyed.

Study of the genetic potential for resistance breeding against fruit spots

Statistical analyses of the genetic trial showed that there was a significant difference in susceptibility between populations for red spots (Table 7). In 2000 the mean scores for the populations 9392, 9380, 9390, 9384, 9383, 9385 and 9376 ranged from 1.10 to 1.32, and were significantly lower than the mean scores for the populations 9391, 9387 and 9388, which ranged from 1.74 to 2.06.

In 2001 the incidence of fruit spots was low, but some differences were noted between populations. The populations 9384, 9383 and 9385 had significantly fewer fruit spots than 9387 and 9388. Although the level of fungal attack was very low, the results are in agreement with the results in 2000, in that these

Table 7. Assessments of red fruit spots in a field trial with Japanese quince (*C. japonica*) plants. The study populations consisted of full sib seedlings derived from controlled cross-pollination. Fruit spots were scored using a scale 0–4.

	Fruit spots (average score)	
Population	2000	2001
9376	1.32 ab	0.64 abcd
9380	1.15 a	0.79 bcd
9381	1.49 abcd	0.76 abcd
9382	1.55 bcd	0.89 bcd
9383	1.22 ab	0.45 ab
9384	1.16 ab	0.33 a
9385	1.25 ab	0.50 ab
9386	1.40 abc	0.79 bcd
9387	1.83 de	0.98 cd
9388	2.06 e	1.06 d
9389	1.49 abcd	0.65 abcd
9390	1.15 ab	0.57 abc
9391	1.74 cde	0.83 bcd
9392	1.10 a	0.58 abc

Means followed by the same letter(s) within columns do not differ significantly (p=0.05) according to Fisher´s Protected LSD test.

Table 8. Impact of seed- and pollen-parent on the incidence of red spots on Japanese quince (*C. japonica*) fruits. The study populations consisted of full sib seedlings derived from controlled cross-pollination. Fruit spots were scored using a scale 0–4.

	Fruit spots (average score)			Fruit spots (average score)	
Seed-parent	2000	2001	Pollen-parent	2000	2001
9217	1.16 a	0.52 ab	9226	1.36 a	0.64 a
9218	1.62 c	0.74 abcd	9241	1.49 a	0.76 a
9219	1.28 ab	0.57 abc			
9221	1.15 a	0.45 a			
9222	1.95 d	1.02 d			
9260	1.48 bc	0.84 cd			
9261	1.32 ab	0.77 bcd			

Means followed by the same letter(s) within columns do not differ significantly (p=0.05) according to Fisher´s Protected LSD test.

same populations were among the least and the most susceptible, respectively.

The parental impact on fruit spots in 2000 and 2001 are shown in Table 8. In 2000, the seed-parents 9221 and 9217 contributed significantly higher resistance against fruit spots than 9260, 9218 and 9222. Seed-parent 9222 contributed significantly less resistance against fruit spots than all the other seed-parents this year.

In 2001, seed-parent 9221 again contributed significantly higher resistance against fruit spots than seed-parents 9261, 9260 and 9222, whereas seed-parent 9222 contributed significantly less resistance than 9221, 9217, and 9219. Thus, in both years seed-parent 9221 contributed the highest resistance to its offspring whereas 9222 contributed the least resistance to its offspring. There was no significant difference between pollen-parents, although pollen-parent 9226 tended to contribute the highest resistance (Table 8).

DISCUSSION

The overall impression based on four years observations of Japanese quince plants in the field is that Japanese quince really is a comparatively healthy fruit crop. However, some symptoms that can be potential threats to the crop in the future were observed.

Fungi on shoots

Prior to this survey it had been observed that sometimes whole plants or parts of plants died during the winter. Earlier suspicions about *Monilinia laxa* as the cause of the die-back were, however, not verified. *Monilia laxa* (conidial state of *Monilinia laxa*) causes blossom and twig blight of *Prunus* spp., *Malus* spp. and *Pyrus* spp. and brown rot of *Prunus* fruits. It has also been reported as causing blossom blight and die-back of shoots of Japanese quince in Canada (Creelman 1962) and Australia (Penrose *et al*. 1976). Penrose *et al.* found that ”infected flowers showed severe blossom blight. Often the fungus sporulated extensively on the base of the flowers. Cankers up to 3 cm long were associated with dead buds and dieback of shoots was general.” *Monilia laxa* is usually easy to diagnose, since it most often sporulates on wilted flower parts. Blossom blight caused by *M. laxa* was, however, never recorded on any *Chaenomeles* plant in the present survey.

Instead, grey mould, *Botrytis cinerea*, was noticed sporulating on dead twigs and on flowers and fruits in all stages. *Botrytis cinerea* appears world-wide and has a very wide host range. This fungus mainly attacks senescent tissue, from where it is able to continue growth into healthy tissue. Although attack by *B. cinerea* is often associated with soft parts of plants, infection of woody parts has also been reported for many plants. The fungus can kill rose twigs (Gupta 1979), and cause cankers and die-back of gooseberry and black currant shoots (Müller 1988). Moore (1949) reported that the fungus caused cankers on young apple trees through pruning wounds, and on *Prunus besseyii* and *C. cathayensis*. On *C. cathayensis* the flowers were attacked and branches were “cankered through growth of the fungus back along the flowering spur, as with *Sclerotinia (Monilia) laxa*”. Moore also reported symptoms associated with *B. cinerea* on other hosts “that leave little doubt of its pathogenicity”, *e.g.* the death of *Magnolia* buds and shoots, rose buds, young shoots of *Prunus triloba* and black currant, and gooseberry branches.

Botrytis cinerea shows different modes of infection and causes various symptoms, depending on the host. Fruits of strawberry, raspberry and apple are infected through the flowers, resulting in fruit rots. Raspberry canes are infected when the fungus invades senescent leaves and grows through the petiole (Williamson & Jennings 1992). In pistachio, *B. cinerea* causes blossom and shoot blight (Michailides 1991), and differences in susceptibility between male cultivars have also been observed.

In the inoculation experiment it was shown that *B. cinerea* can infect intact as well as wounded lignified tissue in shoots of Japanese quince plants. This was also evident when young plants in a greenhouse were severely attacked by *B. cinerea*, resulting in wilted shoots and plants. The fungus entered the nodes of the shoots via wilted leaves. It should, however, be remembered that in the experiment the points of inoculation were covered with para-film, which increases humidity, and that greenhouse plants are often more susceptible to fungal attack than plants in the field.

From observations in the field and the study of potted plants left outdoors during winter, a possible mode of infection of *B. cinerea* could be that the fungus invades persisting fruits. *Botrytis cinerea* may then grow into the shoot via the fruit stalk. A brown discolouration was observed in the wood of shoots emanating from fruit stalks and grey mould was sometimes isolated from this area. Low temperature may also be a factor, since tissue damaged by frost becomes more susceptible to infections by *B. cinera* (Jarvis 1980). Although it seems most likely that *B. cinerea* is the fungus associated with die-back phenomenon of Japanese quince plants, further studies in the field would be necessary to corroborate this hypothesis. Studies of several plants at short intervals during the autumn and winter, perhaps with other methods, would be necessary.

Fungi on leaves

Leaf spots were common on Japanese quince plants, and severe attacks of fungi caused yellowing of the leaves and premature leaf fall. The severity of the attacks differed between the years and was dependent on the weather. Sometimes leaf spots appeared early in the season on Japanese quince plants, but nevertheless leaf fall due to leaf spots mostly occurred rather late in the season. The plants had often green foliage far into October. Observations in the field indicated that there were genetic differences in susceptibility to leaf spots. Susceptible plants which repeatedly suffer from premature leaf fall would be weakened and more prone to frost damage. Leaf spots and the susceptibility of plants would thus be of special importance in years with high precipitation. Therefore, less susceptible genotypes should be selected in breeding programmes aimed at developing varieties of Japanese quince for cultivation by organic field management methods.

Leaf spots varied in size, shape and colour, and it was obvious that the spots were caused by different fungi. On the samples of leaves obtained from Latvia, four parasitic fungi known to cause leaf spots on plants were detected: *Septoria cydoniae*, *Phoma pomorum, Asteromella* sp. and *Ramularia* sp. *Septoria cydoniae* causes both leaf and fruit spots on *Cydonia* sp. and has been reported on Japanese quince in Romania by Eliade & Barbu (1963). The fungus was also isolated from a fruit in the present investigation. *Phoma pomorum* causes spots on leaves and fruits of apple, but is known as a weak wound pathogen and secondary invader (Pennycook 1990). *Asteromella* and *Ramularia* are known anamorphs (conidial states) of the Ascomycetes genus *Mycosphaerella*.

Of the fungi isolated from leaf samples collected in Sweden, *Alternaria alternata* as well as *Phoma pomorum* are known to cause leaf and fruit spots on apple (Sawamura 1990, Spotts 1990). However, most of the fungi found are widely distributed saprophytes or secondary invaders, and can also live endophytically within many plants. To further verify a connection between leaf spot symptoms and the fungi detected, it would be necessary to perform inoculation experiments, especially with the fungi not previously reported on Japanese quince plants.

Fungi on fruits

Fruit spots and fruit rots were very common symptoms on ripening Japanese quince fruits. Superficial spots may not be important in a crop that is intended for processing, but, particularly in wet seasons, the spots developed into rots that destroyed the fruit flesh. Red spots and brown lesions were common symptoms noted already in the fields, and rots were also common on fruits in cold storage. From the examination of fruits in cold storage, it was evident that Japanese quince was attacked by the same fungi that also cause storage rots in apple, *i.e. Phlyctema vagabunda*, *Penicillium expansum* and *B. cinerea*.

Phlyctema vagabunda (syn. *Gloeosporium album*) is one of three fungi responsible for the most serious storage disease of apple in many European countries, the so-called 'gloeosporium rot'. The two other fungi responsible for this disease (Olsson 1965) were also detected, namely *Cryptosporiopsis malicorticis* (syn. *Gloeosporium perennans*) and *Colletotrichum gloeosporioides* (syn. *Gloeosporium fructigenum*). The latter is, however, rare in cold storage of apples in Sweden, probably due to its relatively high temperature requirements. *Phlyctema vagabunda* is the most frequently found in Sweden, but *Cryptosporiopsis curvispora* (the correct name of *C. malicorticis* according to Verkley 1999) also occurs.

According to Grove (1990), hosts of *Cryptosporiopsis curvispora* other than apple within the Rosaceae family are *e.g.* quince (*Cydonia oblonga*) and flowering quince, *Chaenomeles* sp., while *P. vagabunda* has many other hosts, *e.g. Rubus* and *Sambucus*. In addition, herbaceous plants are also hosts among others *Erigeron* (Verkley 1999). *Colletotrichum gloeosporioides* causes 'bitter rot' of apples (Sutton 1990) and cherries and 'anthracnose' of many other plants.

The studies of fruit spots and brown rots in Japanese quince indicated that the fungus *P. vagabunda* was the main cause of these symptoms. The fungus was found in brown rots, and in developing rots in red spots examined under the microscope, and was also isolated from these symptoms. On apple, infection by *P. vagabunda*, as well as *C. curvispora*, is usually latent and is seldom seen on fruits in the field. The rots develop later when the fruits have been stored for a while and are beginning to mature. The infections of the fruit derive from infection sites in the tree, where the fungi mostly live as saprophytes in dry and dead parts of branches, fruit spurs, mummified fruits, etc. (Olsson 1965). Conidia from these sites are dispersed to the fruits by rain splash. The conidia survive dry periods in the lenticels of the fruits and later cause rots under storage conditions.

Botrytis cinerea and *Penicillium expansum* are also a serious problem on stored apples, as well as pears, and were often found on stored Japanese quince fruits and on flowers. *Botrytis cinerea* was sometimes seen on wilted flowers from where the fungus grew into young fruits, a common mode of infection in other host plants. *Penicillium expansum* is common in soil and in all sorts of organic material and is particularly common on apple, but also on other fruits. It is spread by air-borne or soil-borne conidia and usually infects fruits through wounds but can also penetrate via lenticels.

Monilia fructigena, causing brown rot of fruits of *Prunus* spp., *Malus* spp. and *Pyrus* spp. and also reported on Japanese quince, was particularly common in one of the fields. This fungus attacks ripening fruits through wounds and is spread by wind, water splash and insects. In this particular field, the rows were narrow and machines easily injured the fruits. The field was also situated close to plantations with apple, pear and cherry. This probably explains why the disease was so common. Eliade and Barbu (1963) showed that inoculum from apples could also infect and cause rots in fruits of Japanese quince.

Red spots on the fruits was a very common symptom in the field. Some of these spots eventually developed into brown rots. The fact that several fungi were associated with this symptom indicates that the red colour is a general response of the host, rather than a specific symptom of one fungus. Three fungi were isolated from red spots on the fruits, *Septoria cydoniae*, *Phlyctema vagabunda* and *Phoma exigua.* Kennel and Weiler (1984) found that 'red lenticel disease', generally regarded as a physiological disorder of yellow cultivars of apple, is actually caused by the fungus *Phlyctema vagabunda*. The appearance of the red spots on Japanese quince in the present investigation agrees well with the description of 'red lenticel disease'. *Colletotrichum gloeosporioides* sometimes causes brown lesions surrounded by a red halo on apples (Sutton 1990). In this investigation, initial stages of fruit spots caused by *Entomosporium mespili* also had reddish margins.

Fungi associated with black spots were *Phoma glomerata*, *P. exigua*, *A. tenuissima* and *Phlyctema vagabunda*. *Phoma glomerata* and *P. exigua* are associated with leaf and fruit spots of apple (Pennycook 1990). As this symptom is more distinct and probably caused by one fungus only, it should be further investigated.

Other fungi detected on the fruits were *Entomosporium mespili* and *Schizothyrium pomi* ('flyspeck') and its anamorph *Leptothyrium pomi*. In addition, *Myriellina cydoniae* was isolated from brown lesions. These are fungi found on closely related plants like *Cydonia* and other plants of Rosaceae but *E. mespili* has also previously been reported on *Chaenomeles* plants (van der Zwet 1990).

Pests

No pests or pest damage of any great importance was recorded on Japanese quince plants. Pests identified that are also common on other fruit crops were leaf weevils, *Phyllobius* spp., larvae of *Operophtera* sp., *Yponomeuta* sp. and *Caliroa* sp. Aphids and red spider mites were also noted, but were not identified to species. Among the pests found in other countries, all the aphids are present in Sweden, as are *Caliroa cerasi* and *Lyonetia prunifoliella*. *Aphis pomi* is the most common aphid on apple, and *Aphis fabae* overwinters on various ornamental bushes and later moves on to herbaceous plants. Larvae of *Caliroa cerasi* feed on plants of the Rosaceae family, and were in fact illustrated by Buczacki & Harris (1981 plate 7) feeding on a *Chaenomeles* leaf! The larvae of *Lyonetia prunifoliella* are known to cause blister mines on leaves of *Prunus spinosa* in Sweden (Svensson 1993).

Study of the genetic potential for resistance breeding against fruit spots
The analyses of the genetic trial showed that genetic differences in susceptibility to fruit spots existed in Japanese quince. Plant breeding and selection aimed at developing varieties with a high tolerance against fruit spots could therefore be successful. A resistance breeding programme should, in addition to fruit spots, consider leaf spots, fruit rots at harvest time and rots on stored fruits.

CONCLUSIONS

The overall impression is that Japanese quince is a species with comparatively healthy plants that should be well suited for organic growing. It has become evident that *Chaenomeles* species have several fungal diseases in common with related species in *Malus* and *Cydonia*. However, Japanese quince seems to be free from serious diseases such as scab (*Venturia* spp.) and powdery mildew (Erysiphales), diseases of great economic importance in *e.g.* apple production. For Japanese quince, the main problems could be fruit spots, rotting of fruits and die-back of shoots and plants.

Botrytis cinerea, was the fungus most frequently discovered. Apart from being the possible cause of die-back of shoots, the fungus can also directly affect fruit yield. The fungus was found on flowers, from which young fruits were infected. A great number of young fruits were found rotting in the fields, particularly in wet seasons. *Botrytis cinerea* also destroyed fruits in cold storage. In addition to *B. cinerea*, *Penicillium expansum* and *Phlyctema vagabunda* were the fungi most often found on fruits in cold storage. These fungi also cause storage diseases in apple. For instance, on apple *P. vagabunda*, ‘gloeosporium rot’ is subject to several chemical sprayings during the season, before the fruits are stored. *Botrytis cinerea* and *P. expansum* are prevented by other means *e.g*. cultural measures and optimal handling of the fruits during harvest and storage.

Fruit spots and brown rots and lesions appearing in the field were caused by several fungi, among which *P. vagabunda*, *Cryptosporiopsis curvispora* (also causing storage rot) and *Colletotrichum gloeosporioides* were important. As long as the fruits are processed immediately after harvest and the fruit spots are superficial, this symptom is of minor importance, but the fruits should not be put in cold storage for a long period.

To be able to grow Japanese quince by organic field management, some cultural measures are proposed to prevent fungal attacks. Most fungi thrive under humid conditions and therefore good air circulation is most important. This can be achieved through sufficient plant spacing and efficient control of weeds, *e.g*. by mulches. *Botrytis cinerea* and many other fungi overwinter in the field on plant debris. Cleaning fields of old fruits, leaves and other debris in the autumn, removing dead plants and pruning out dead shoots in the spring can reduce the inoculum to a large extent. Clones that drop their fruits easily are not only desirable from a harvest point of view, but also prevent fruits from being attached to the plants during the winter and thus reduce the risk for fungal attacks.

If fruits must be stored, only carefully picked, healthy fruits without lesions, wounds or bruises should be selected. *Botrytis cinerea* and *P. expansum* spread in the store, both by airborne conidia and by growing over from infected to healthy fruits. Careful handling during harvest, rapid cooling and optimal storage conditions are very important. Machine harvested fruits should be processed immediately and not be stored. However, the most important preventive factor would be the use of varieties that are tolerant against pests and diseases. This investigation has shown that it would be possible to improve Japanese quince by plant breeding and selection since the differences detected among populations could be attributed to genetic factors.

ACKNOWLEDGEMENT

The authors are most grateful to Dr Ovidiu Constantinescu for the identification of fungi to species. The authors also wish to thank Dr Tomas Jonasson for identification of insects.

LITERATURE

Anonymous 1960. Annual report 1959. East Malling Research Station, England.

Beer S.V. 1990. Fire Blight. In: Jones A.L. & Aldwinckle H.S. (Eds.) Compendium of Apple and Pear diseases. APS Press 61–63.

Brickell C. 1994. The Royal Horticultural Society Gardeners' Encyclopedia of Plants and Flowers. Dorling Kindersly Limited and BCA, London.

Buczacki S., Harris K. 1981. Collins Guide to the Pests, Diseases and Disorders of Garden Plants. William Collins Sons & Co Ltd, London.

Creelman, D. W. 1962. Summary of the prevalence of plant diseases in Canada in 1961. Canad. Plant Disease Survey 42: 23–102.

Eliade E., Barbu V. 1963. [Diseases of Japanese quince (*C. japonica*) and their control.] Bolile Gutuiului Japonez (*Chaenomeles japonica* Lindl.) si combatera lor. Studii Cerc. Biol. 15: 531–540.

Grove G.G. 1990. Anthracnose and perennial canker. In: Jones A.L. & Aldwinckle H.S. (Eds) Compendium of Apple and Pear diseases. APS Press 36–38.

Gupta G.K. 1979. Bud and twig blight of rose as caused by *Botrytis cinerea* Pers. ex Fr. Indian Journal of Horticulture 36: 473.

Heaton J.B. 1979. A new record of *Monilinia fructicola* on flowering quince at Stanthorpe, Queensland. Autralasian Plant Pathology 8: 47.

Huang Y., Chen Y.L. 1997. Hyperparasitism and biocontrol of *Chaenomeles speciosa* rust by *Tuberculina vinosa* from pear rust. Chinese Journal of Biological control 13: 10–13.

Jarvis W.R. 1980. Epidemiology. In: Coley-Smith J.R., Verhoff K., Jarvis W.R. (Eds) The Biology of Botrytis. Academic Press 219–250.

Jaskiewicz B. 1995. The species composition of the aphids feeding on *Chaenomeles japonica* Lindl. in the Academy Park in Lublin. Annales Universitatis Mariae Curie Sklodowska. Sectio EEE, Horticultura 3: 145–158.

Jewell D. 1998. Fiery flowers of spring. The Garden 123: 90–93.

Kennel W., Weiler R. 1984. Zur Ursache der Lentizellenröte beim Apfel (A study of the red lenticel disease in apples). Zeitschrift für Pflanzenkrankheit und Pflanzenschutz 91: 552–555.

Michailides T.J. 1991. Susceptibility of pistachio male cultivars to botrytis blossom and shoot blight caused by *Botrytis cinerea*. Plant Disease 75: 410–415.

Moore M.H. 1949. Note on the association of *Botrytis cinerea* with an apple canker, and with various symptoms on sundry other hosts. Report 1948 East Malling Research Station 101.

Müller R. 1988. Botrytis-Rindenbrand (*Botrytis cinerea* Pers.). Nachrichtenblatt für den Pflanzenschutz in der DDR 43: 9.

Oku T., Ohira Y., Wakou M. 1988. Preliminary notes on a plum fruit moth, *Grapholita dimorpha* Komai (Lepidoptera: Tortricidae). Bulletin of the Fruit Tree Research Station, Series C, Morioka 15: 49–64.

Olsson K. 1965. A study of the biology of *Gloeosporium album* and *G. perennans* on apples. Medd. Statens växtskyddsanstalt 13: 187–259.

Penrose L.J., Tarran, J., Wong A.-L. 1976. First record of *Sclerotinia laxa* Aderh. & Ruhl. in New South Wales: Differentiation from *S. fructicola* (Wint.) Rehm. by cultural characteristics and electrophoresis. Australian Journal of Agricultural Research 27: 547–556.

Pennycook, S.R. 1990. Phoma leaf and fruit spot. In: Jones A.L. & Aldwinckle H.S. (Eds.) Compendium of Apple and Pear diseases. APS Press 26.

Phipps J.B., Robertson K.R., Smith P.G., Rohrer J.R. 1990. A checklist of the subfamily Maloideae (Rosaceae). Canadian Journal of Botany 68: 2209–2269.

Raffa K.F., Lintereur G.L. 1988. New host records and developmental notes on the pear slug *Caliroa cerasi* (Hymenoptera: Tenthredinidae), feeding on *Cotoneaster* and *Chaenomeles* species. The Great Lakes entomologist 21: 75–79.

Rumpunen K. 2001. Diversity in the plant genus *Chaenomeles*. Doctoral thesis, Swedish University of Agricultural Sciences, Agraria 293.

Sawamura K.1990. Alternaria blotch. In: Jones A.L. & Aldwinckle H.S. (Eds.) Compendium of Apple and Pear diseases. APS Press 24.

Schmitt J.J., Brown M.W., Davis D.R. 1996. Taxonomy, morphology, and biology of *Lyonetia prunifoliella* (Lepidoptera: Lyonetiidae), a leafminer of apple. Annals of the Entomological Society of America 89: 334–345.

Spotts R.A. 1990. Alternaria rot. In: Jones A.L. & Aldwinckle H.S. (Eds.) Compendium of Apple and Pear diseases. APS Press 56–57.

Sutton T.B. 1990. Bitter rot. In: Jones A.L. & Aldwinckle H.S. (Eds.) Compendium of Apple and Pear diseases. APS Press 15–16.

Svensson I. 1993. Fjärilkalender. Lepidoptera-calendar. Ingvar Svensson, Kristianstad, Sweden.

Sweet J.B. 1980. Fruit tree virus infections of ornamental rosaceous trees and shrubs. Journal of Horticultural Science 55: 103–111.

Weber C. 1964. The genus *Chaenomeles* (Rosaceae). Journal of the Arnold Arboretum 45: 161–205, 302–345.

Verkley G.J.M. 1999. A monograph of the genus *Pezicula* and its anamorphs. Studies in Mycology 44. Centraalbureau voor Schimmelcultures, Baarn/Delft, The Netherlands.

Werner M., Fruzynska-Jozwiak D. 1999. Brown rot on stone fruit and ornamentals of the family Rosaceae. Ochrona Roslin 43: 31

Williamson B., Jennings. D.L. 1992. Resistance to cane and foliar diseases in red raspberry (*Rubus idaeus*) and related species. Euphytica 63: 59–70.

Yu L., Bai J.K. 1995. New species and new records of *Phoma* and *Phyllosticta* from China. Acta Mycologica Sinica 14: 192–195.

Zeller W. 1979. Fireblight: a serious bacteriosis on plants of the Rosaceae. Bericht über Landwirtschaft 57: 521–533.

van der Zwet T. 1990. Fabraea leaf spot. In: Jones A.L. & Aldwinckle H.S. (Eds.) Compendium of Apple and Pear diseases. APS Press 23–24.