Bachelor project in the Danish-Swedish Horticulture programme 2008-1, 10 p (15 ECTS)

The distribution of *Gymnosporangium fuscum* and its implication on pear cultivation in Sweden

- based on a literature study and a questionnaire

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Title: The distribution of *Gymnosporangium fuscum* and its implication on pear cultivation in Sweden
(Päronrostens spridning och betydelse för päronodlingen i Sverige)

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Title page photos:
Left: Pear leaf with characteristic symptoms of pear rust (by author)
Middle: Aecia formed on the underside on the leaf (by author)
Right: Telial horns on the juniper host (by Stanislaw Kalt)

ABSTRACT

The European pear rust is caused by the fungus *Gymnosporangium fuscum* which like rusts in general require a winter host for survival, in this case species within the genera of *Juniperus*. The infections are perennial on the juniper host on which it in spring at favour climate develops the characteristic telial horns. These occur as yellow-brown tongue-shaped swellings and distribute spores at moist conditions infecting young pear leaves within a distance of 500m. The symptom on the pear leaves begin as yellow spots which gradually increase during the summer and become bright orange with a red boarder. Opposite this lesion, on the underside of the leaf, are cluster cups formed in groups onto small swollen areas of tissue. From these are spores distributed that cause primary infections on the juniper host and thereby enclosing the life-cycle of the pathogen. The pear infections are only annual and spores developed from the spore stage on the pear leaf may not re-infect within the same host. Severe infections on the tree repeated during several years may decrease its vitality and affect its fertility rate resulting in poor fruit set or premature fruit drop.

This is a literature study to achieve a broad picture of the pathogen *G. fuscum* and its biology, host plants, environmental demands and control measures. As a compliment, a questionnaire study was implemented to evaluate the geographical spread and the general estimation of its symptoms and control measures. It also requested the supply of susceptible junipers in nurseries and garden centres.

The supply of susceptible junipers could be considered as the major cause of spread. Old plantings but also newly established ones since the supply of these junipers still occur according to the result of the questionnaire. Single observations of pear rust have been done in Arvika and Gävle which represents zone III respectively IV of plant hardiness. Other factor affecting the development and the infection pressure of the pathogen is the environmental conditions during spring when the telial horns develop and distribute spores. Thus, the only possibility to reduce the spread of pear rust is to rupture its life-cycle by eliminate the infected juniper host and avoid new plantings of these. The supply of resistant cultivars could be considered large. However, a voluntary cooperative effort of must be made to prohibit the development of new infestations.

SAMMANFATTNING

Päronrosten orsakas av svampen *Gymnosporangium fuscum* och likt andra rostsvampar värdväxlar den genom att övervintra på andra arter, i detta fall olika sorter av *Juniperus* som vissa kinesiska enar och sävenbom. På enarna är infektionen flerårig där den på våren vid gynnsamt väder bildar den karaktäristiska gelérosten. Denna består av gul-bruna tunglika geléklumpar som sväller vid fuktigt väder och vid det tillfället sprider sporer som infekterar unga päronblad inom en radie av 500m. För att sjukdomen skall utvecklas krävs därför att mottagliga enar och päron växer i närheten av varandra. Päronbladens symptom uppträder i början som gula fläckar vilka under sommaren blir orangeröda med små svarta prickar. På undersidan av bladet utvecklas senare under hösten skålrost, som ser ut som spetsiga utskott. Dessa sprider i sin tur sporer som infekterar enarna och fullbordar på det sättet livscykeln för svampen. Angreppen på päronbladen är annuella och infekterade blad kan inte smitta andra päronblad. Upprepande starka angrepp kan komma att sätta ner trädets kondition samt minska kartsättningen.

Uppsatsen utgörs av en litteraturstudie för att ge en helhetssyn av svampen och klargöra runt dess biologi, värdväxter, dess krav på yttre förhållanden samt åtgärder. Studien kompletteras även av en enkätundersökning för att försöka ta reda på dess spridning i Sverige samt utvärdera den generella uppfattningen om päronrostens symptom och åtgärder. Enkäten efterfrågade också tillgången på mottagliga enar i plantskolor och växtbutiker.

Resultatet visar att spridningen förmodligen främst beror på tillgången av mottagliga enar, dels gamla odlingar men också nyplanteringar eftersom utbudet av dessa enar fortfarande finns. Enstaka observationer av päronrost har gjorts ända uppe i Arvika och Gävle vilka representerar odlingszonerna III respektive IV. Andra faktorer som påverkar utvecklingen och infektionstrycket av svampen är klimatförhållandena under våren när gelérosten utvecklas och sprider sporer. Så, den enda möjligheten att minska angreppen och bromsa päronrosten är att bryta livscykeln genom att ta bort angripna enar helt samt undvika nyplanteringar av mottagliga sorter, det finns resistenta. Men, för att detta ska lyckas så måste detta bli en gemensam angelägenhet.

PREFACE

The purpose of writing this report was to evaluate the reason to the expeditious distribution of pear rust. It also intended to evaluate the geographical distribution of the pathogen by sending out a questionnaire. The project was initiated by FOR, Fritidsodlingens Riksorganisation and performed as a Bachelor of Science degree in the frame of the Danish-Swedish Horticulture Programme of the Swedish University of Agriculture, Alnarp.

I would like to thank everyone who responded to the questionnaire and for their excellent answers which all contributed to this report. A special thanks to my supervisor Guy Svedelius, for the encouragement and constructive criticism and my examiner Birgitta Rämert for the positive attitude and inspiration. I would also like to thank Göran Svanfeldt at FOR, for initiating this study and for his generous help in the development process of the questionnaire regarding vocabulary and content. Finally, I am very thankful for the encouragement provided by my friends and family.

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INTRODUCTION

Gymnosporangium fuscum, the European pear rust has become a pathogen of concern for the Swedish gardeners in allotments and gardens. The unattractive leaf symptoms and its negative effect on fruit set and tree vitality has resulted in dissuasion of the cultivation of pears. This because no curative chemical control measures are available for the individual gardener and therefore they prefer to eliminate either host. Within the commercial orchards has the pathogen no affect, however, it is expected to emerge in organic production (Gebauer *et al.,* 2001; Svanfeldt, 2006).

As many *Gymnosporangium* species, *G. fuscum* requires a primary host in the genus of *Juniperus* and predominantly cultivars within *Juniperus sabina* and *J. chinensis.* Plantations of these junipers were especially popular in Sweden during the 1970´s and contributed to a source and spread of pear rust.

Unfortunately is the statistics and history documentation of the disease and its spread in Sweden diminutive. One of the earliest Swedish publications describing infections of pear rust is from 1927. This declared it as an alternating parasite which was controlled by eradicating the juniper host, commonly *J. sabina* (Lindfors, 1927). The alternating behaviour was not discovered until 1865 by A. S. Ørsted, who confirmed it to be between juniper and pear. Thereby have the pathogen been described under various names (Gram and Weber, 1944).

The annual documentation of the plant protection year declared pear rust infections the first time in 1994, when unusually severe infections were verified in Skåne (Pettersson, 1995). The main distribution of pear rust has until previously been limited to some locations in the southern part of Sweden. However, in recent years the infection pressure has increased and observations of pear rust have extended north.

The aim of this report is to provide an overview of the pathogen *G. fuscum* through gathering the essential information from the literature regarding life-cycle, host plants, climate requirements and recommended control measures. As a compliment, a questionnaire study was implemented to evaluate the geographical spread by organise the answers subsequent to Riksförbundet Svensk Trädgård´s zone map system of plant hardiness. The questionnaire also requested the general

estimation of symptoms and control measures of the pest and the supply of susceptible junipers in nurseries and garden centres.

BACKGROUND

In this chapter is the elementary information regarding *Gymnosporangium fuscum* gathered from the literature study. It includes the organism of cause, distribution in Sweden, host plants, symptoms, biology, influence on host, its importance and control measures.

Causal organism

The European pear rust is caused by the fungi *Gymnosporangium fuscum* DC (syn. *Gymnosporangium sabinae* (Dicks) Wint.) and belongs to the Bacidiomycetes of the order Uredinales and family Pucciniaceae (Laundon, 1977; Agrios, 1997). This is a genus primarily of northern temperate climate and there are about six species in northern Europe (Cummings and Hiratsuka, 2003). In a taxonomic account of the genus implemented by Kern (1973), 57 species of *Gymnosporangium* were recognized. Of species evaluated, 38 of them required *Juniperus* as host genera and 10 *Pyrus* (Kern, 1973). The genus of *Gymnosporangium* is unusual since its telial state occur on gymnosperms and the aecial state on dicotyledonous, predominantly on the Pomoideae of the Rosaceae. The gelatinizing pedicles of the teliospores characterize nearly all species (Cummings and Yasuyuki, 2003).

G. fuscum is an obligate parasite and alternates between species of *Pyrus* and *Juniperus* to complete its lifecycle (Laundon, 1977; Agrios, 1997). The pathogen is heteroecious and cause perennial infections on the juniper host and annual infections on the pear host (Laundon, 1977). It is widely distributed throughout Europe with observations extending to Asia Minor (Lebanon, Syria and Turkey) and North Africa (Algeria and Morocco). The pathogen has also been introduced to North America (California, Washington, and British Columbia) probably through the importation of junipers from Europe (Laundon, 1977; Hollebone, 2006).

Distribution in Sweden and climatic requirements

In Sweden has the distribution of pear rust been limited to the southern parts with expansions up on the western coast line (Pettersson and Åkesson, 1998; Svanfeldt, 2006). Since pears have, in contrast to apples, considerably higher demands on the climatic conditions are their cultivation limited to the lower zones of plant hardiness. The majority of pear cultivars are recommended to zone I and II. Only a few cultivars, nine according to RST's zone map, are hardy up to zone IV or in favour conditions in zone V (Carlsson and Lundberg, 1982; Fernqvist, 1993). However, the majority of junipers cultivars within *J. sabina* are hardy up to zone V (Fernqvist, 1993). This access of host plants is a possible source for a further distribution of pear rust throughout the country. Thereby the northern border of the pathogen could be expected to be the same as for pear cultivation, somewhere within the zones IV and V.

The climate differs considerably between the northern and southern parts of Sweden and within this span are eight zones of plant hardiness represented (figure 1). The general pattern would be with increasing zone towards the north. However, this is adapted through the influence from the seas, the large lakes, and the altitude, which is the most affecting factor. An example is Småland which represent zones within the span of II-V. In the interior upland parts of Småland, Småländska höglandet, the influence of continental climate and its altitude causes relatively late frosts which limits the growing season. These areas correspond to zone V and within these, problems with pear cultivation could be expected (Fernqvist, 1993).

The climatic conditions are the primary determining factor of were a plant may grow. A zone of plant hardiness is a coarse classification of the climate in a region. Originally, when the zones were established in 1910, the definition was based on meteorology observations only, as isotherms of the coldest months mean value. Currently, practical experiences of cultivation in combinations with statistical meteorology are included in the definition as well. Another factor affecting the definition is the number of days with frost during the year which correlates to the length of the growing season. Though, the zones of plant hardiness do not take precipitation, snow cover and soil type into consideration (Ullström, 1961).

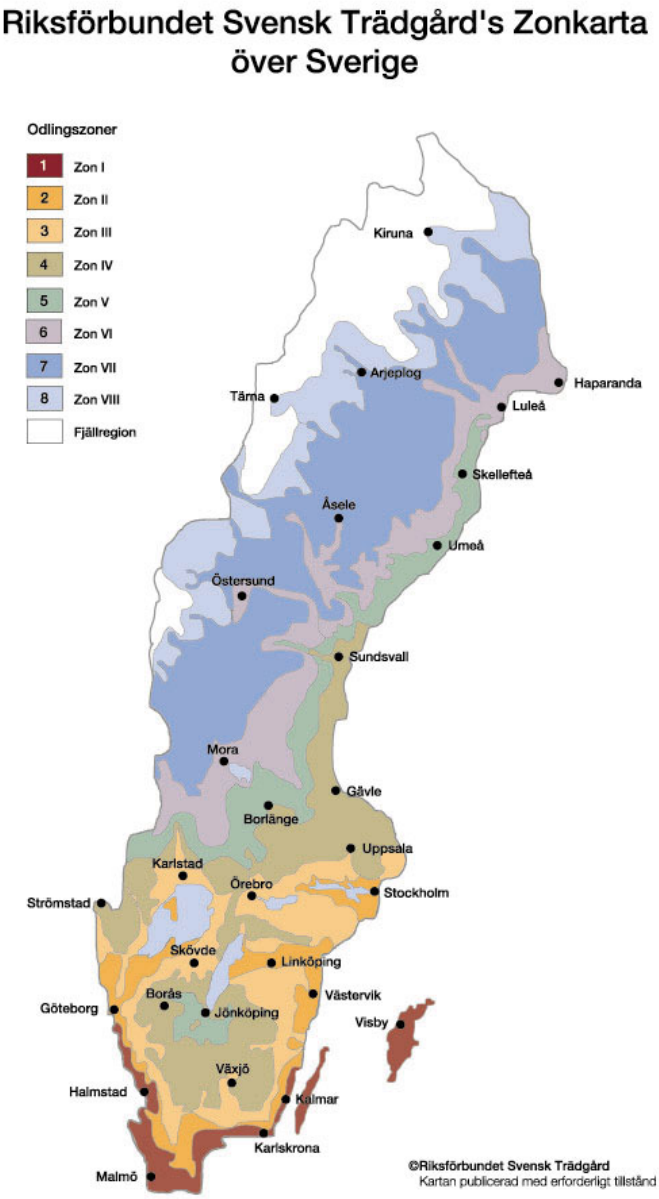

Figure 1. Riksförbundet Svensk Trädgård´s zone map system of plant hardiness. Published with permission from the association received 20071108.

Host plants

G. fuscum is known to occur on various species of juniper, predominantly on cultivars within *Juniperus sabina*, *J. chinensis, J. media, J. scopulorum* and *J. virginiana* (Laundon, 1977). *Thuja* and *Chamaecyparis* are unaffected of pear rust as well is the common Swedish juniper, *Juniperus communis*. At the Swiss Federal Research Station for Fruit-Growing, Viticulture and Horticulture at Wädenswil, has Hilber and Siegfried (1997; 2002) performed infection trials during several years to evaluate the variation of infection sensitivity of different species and

cultivars of junipers. These trials were implemented by exposing the junipers to infected pear trees which distributed spores during late summer causing primary infection on the junipers. The study showed that the majority of the cultivars within the species *J. chinensis*, *J. sabina* and *J. scopulorum* were found to be slight to highly susceptible to pear rust (these are presented in table 1 and 2). While no infections were to be observed on the cultivars of *J. conferta*, *J. horizontalis*, *J. squamata* and *J. procumbens* (presented in table 3). Several cultivars of *J. communis* were tested as well. However, they remained free of infection. This method also revealed that the incubation time of the infection could be two to three years (Hilber and Siegfried, 1997; Siegfried, 2002). These results from the Swiss study agrees with a previous with similar observations by Ormrod *et al* (1984) in British Columbia, conducted on cultivars of *J. communis, J. horizontalis, J. chinensis, J. sabina* and *J. virginiana* (Ormrod *et al*., 1984).

The fact that the common Swedish juniper appear to be resistant or even immune to pear rust is of particular interest since it is a species native to Sweden (Anderberg, 2006). It is hardy up to zone VIII of plant hardiness and occurs throughout the country and would have become a well distributed source of infection (Ullström, 1961). Although the common Swedish juniper is resistant towards pear rust, it is receptive to another species of *Gymnosporangium*, the European hawthorn rust, *Gymnosporangium clavariiforme*. The hawthorn rust alternates between the common Swedish juniper and hawthorn. The spermagonia and aecia occur primarily on hawthorn but occasionally also on the fruit of pear (Laundon, 1977; Pettersson and Åkesson, 1998).

Table 1. Slight receptive cultivars of junipers according to Siegfried (2002). Within parenthesis is the former nomenclature presented.

J. chinensis 'Parsonii' (*J. duvarica* 'Expansa')
J. sabina 'Broadmoor'
J. sabina 'Buffalo'
J. sabina 'Rockery Gem' (*J. chinensis* 'Rockery Gem')
J. sabina 'Tamariscifolia Select'
J. scopulorum 'Moonglow'
J. scopulorum 'Skyrocket' (*J. virginiana* 'Skyrocket')
J. scopulorum 'Wichita Blue'
J. virginiana 'Grey Owl'

Table 2. Moderately to highly receptive cultivars of junipers according to Siegfried (2002). Within parenthesis is the former nomenclature presented.

J. chinensis 'Keteleeri'
J. chinensis 'Robusta Green'
J. media 'Gold Sovereign'
J. media 'Pfitzeriana' (*J. chinensis* 'Pfitzeriana')
J. media 'Pfitzeriana Aurea' (*J. chinensis* 'Pfitzeriana Aurea')
J. media 'Pfitzeriana Compacta' (*J. chinensis* 'Pfitzeriana Compacta', *J. media* 'Nick's Compact')
J. media 'Swissgold'
J. media 'Mathot' (*J. chinensis* 'Mathot')
J. media 'Old Gold' (*J. chinensis* 'Pfitzeriana Old Gold')
J. sabina 'Blaue Donaube' (*J. sabina* 'Blaue Donau')
J. sabina 'Tamariscifolia'
J. sabina 'Arcadia'
J. scopulorum 'Blue Haven'

Table 3. Resistant cultivars of Junipers according to Siegfried (2002). Within parenthesis is the former nomenclature presented.

J. chinensis 'Blaauw' (*J. chinensis* 'Blaauws Varietät')
J. chinensis 'Blue Alps'
J. chinensis 'Kaizuka' (*J. chinensis* 'Torulosa')
J. chinensis 'Obelisk'
J. chinensis 'Plumosa Aurea' (*J. chinensis* 'Shimpaku')
J. chinensis 'San Jose'
J. communis 'Depressed Star' (*J. communis* 'Prostrata')
J. communis 'Hibernica' (*J. communis* 'Stricta')
J. communis 'Hornibrooki'
J. communis 'Oblonga Pendula'
J. communis 'Repanda'
J. communis 'Sentinel' (*J. communis* 'Pencil Point')
J. communis 'Suecica'
J. communis 'Green Carpet'
J. communis 'Wallis'
J. conferta 'Blue Pacific'
J. horizontalis 'Blue Chip' (*J. horizontalis* 'Blue Moon')
J. horizontalis 'Emerald Spreader'
J. horizontalis 'Hughes'
J. horizontalis 'Youngstar'
J. horizontalis 'Prince of Wales'
J. horizontalis 'Webber' or *J. horizontalis* 'Webberi'
J. horizontalis 'Wiltonii' (*J. horizontalis* 'Glauca', *J. horizontalis* 'Blue Rug')
J. procumbens 'Nana' (*J. procumbens* 'Green Mound')

J. squamata 'Blue Carpet'
J. squamata 'Blue Star'
J. squamata 'Holger'
J. squamata 'Loderi'
J. squamata 'Meyeri'
J. virginiana 'Canaertii'
J. virginiana 'Glauca'
J. virginiana 'Grey Owl'
J. virginiana 'Tripartita'
J. virginiana 'Blue Arrow'
J. virginiana 'Kim'
J. virginiana 'Hetz' (*J. media* 'Hetzii', *J. chinensis* 'Hetzii')
J. virginiana 'Tripartit'

Symptoms

Symptoms on the juniper host

The pathogen has shown to infect young and succulent shoots of the juniper host but also woodier sections. The first symptoms of infection occur as small telia of a few millimetres. Old infections of the pathogen survive the winter as mycelium which breaks through the surface of the infected tissue in spring (Borno and van der Kamp, 1975). The mycelium stimulates increased cell formation of the cambium which in time distends the stem tissue. This appears as gall-like swellings on the branches (Vukovits, 1980). According to a study of occurrence and harmful effects of *G. fuscum* conducted by Juhásova and Praslièka (2002), the size of these stem swellings were observed to range from a few millimetres up to 70-80cm. These can probably be considered as very old infection (Juhásova and Praslièka, 2002).

From these stem swellings, bright yellow-brown tongue-shaped telial horns (figure 2;1) appear in spring as columns on the branches and in some case also between the needles (Vukovits, 1980). During moist conditions from April to the beginning of June, these swell up and become gelatinized, sizing about 10mm in width and 20mm in high (Vukovits, 1980; Hilber and Siegfried, 1997). However, the size of these individual columns has been observed by Juhásova and Praslièka (2002), to be as large as 5-10 x 12-15cm (Juhásova and Praslièka, 2002).

At dry conditions these jellylike swellings contract and become brown and hard. When shed, they leave small depressions in the distended stem tissue (figure 2;2) from which new swellings appear the next spring (Vukovits, 1980).

Generally, the needles on the infected branches turn yellow and discarded. Occasionally also the stems above the infection dry off and perish, although, it is most common on thinner branches (Vukovits, 1980; Juhásova and Praslièka, 2002).

Figure 2. The telial horns are bright orange (1) and emerge on the juniper in spring when conditions are favourable (photo G. Svedelius). When the telial horns are shed, scars appear on the juniper branch (2) (Karlsson, 2007).

Symptoms on the pear host

Within two to three weeks after the infection the first symptoms appear on the upper side of the leaves as small yellow spots. These lesions gradually increase with time to about one centimetre in diameter and become bright orange with a red boarder (figure 3;1). These lesions are very conspicuous and are not to be confused with other pathogens (Ormrod *et al*., 1984). One individual leaf may have several lesions depending on the infection pressure and the susceptibility of the variety. These may fuse and almost cover the whole leaf surface (Juhásova and Praslièka, 2002).

In the centre of the lesions, black dots of fruiting bodies (spermagonia) are formed (figure 3;2). These appear within 13-17 days after infection (Vulkovits, 1980). Opposite the lesion, aecia are formed in groups of 4-16 (figure 3;3), onto small swollen areas of tissue on the underside of the leaf (Heinze, 1978). These appear from the end July to September or October, depending on when the

infection occurred. The aecia require four month for development and release spores from late August until November or until all infected pear leaves are shed in fall (Ormrod *et al.*, 1984).

Figure 3. The characteristic bright orange lesions caused by *G. fuscum* (1) with black dots of spermagonia in the centre (2). Cup shaped aecia are formed on the underside on the leaf (3). (Karlsson, 2007)

The fruits, shoots and petioles of the pear may also become infected. Though, this occurs most frequent when the infection pressure is severe and the appearance of aecia is considered to be uncommon (Vulkovits, 1980; Siegfried and Viret, 2004). Young infected fruits generally become mummified or drop prematurely. However, occasionally are aecia developed in the end of the summer as cup shaped structures covering the fruit, which usually becomes malformed and inhibited in development (figure 4;1). The infected tissue of shoots and buds develop volcano-like formations of hypertrophic tissue which become brownish and swollen (figure 4;2). The infected buds appear dead, resulting in a decrease of yield. Though, the tissue beneath the infected pear bud is typically alive, even though slightly corky (Naqvi, 2004; Siegfried and Viret, 2004).

Figure 4. A mummified young fruit of pear covered with cup shaped aecia (1). Infected pear bud with hypertrophic tissue which has become brownish, swollen and corky (2). (Karlsson, 2007)

Biology

Life-cycle

G. fuscum survives the winter as perennial dikaryotic mycelium on stems of its juniper host which produce telia annually in spring. At moist and favourable conditions, the telial horns swell and form the characteristic yellow-brown, tongue-shaped structure, formed by columns of teliospores (figure 5;1) (Phillips and Burdekin, 1992; Butin, 1995; Agrios, 1997).

The teliospores (42-56 x 22-32µm) are yellowish and thick-walled with an ellipsoid shape and are mostly two-celled by transverse septum. They are borne singly on long pedicles which absorb water and cause the gelatinized swellings. These contain two germ pores per cell (Laundon, 1977; Cummings and Yasuyuki, 2003). The teliospores germinate in free water in place when mature, producing a four-celled and club-shaped basidia, from which four basidiospores are produced (Phillips and Burdekin, 1992).

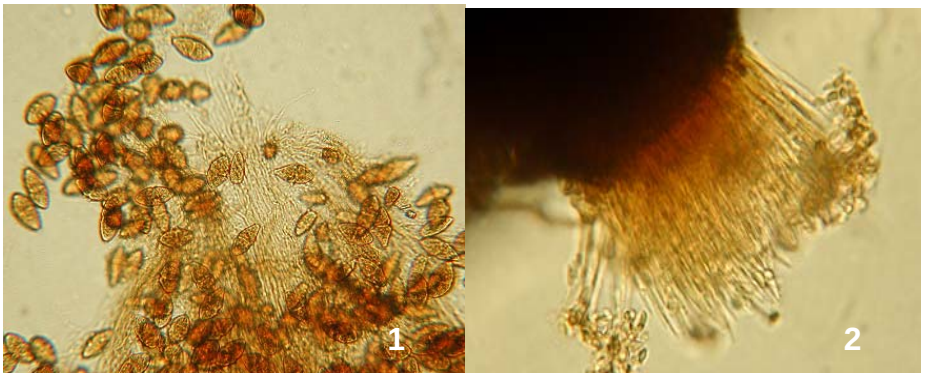

Figure 5. Column of teliospores (1). Spermagonia with receptive hyphae (2). (Karlsson, 2007)

The basidiospores are dispersed by air and infect succulent parts of the pear host as young leaves but incidentally also fruits, shoots and petioles (Vulkovits, 1980; Butin, 1995; Hilber and Siegfried, 1997).

When infection occurs, haploid mycelium is produced that forms spermagonia on the upper side of the pear leaves. The spermagonia are immersed in host tissue and apparent as small black sticky dots in the centre of the lesion (Phillips and Burdekin, 1992; Agrios, 1997). These contain haploid spermatia and receptive hyphae (figure 5;2). Insects are involved in the distribution of these haploid spermatia since they are attracted to the lesions by the nectar with sticky content

excreting from the spermagonia (Kotte, 1958; Heinze, 1978). The spermatia fertilize the particular hyphae which result in the production of dikaryotic mycelium and dikaryotic spores (Agrios, 1997).

The mycelium forms aecia on the underside of the leaves that appears like pale coloured, cylindrical structures which are aggregated in cluster cups opposite the spermagonia. These are 2-5mm high, 1-3mm wide and produce powdery rusty-brown coloured aeciospores enclosed in a thick wall. The aeciospores are one-celled (23-37μm diameter) and are broadly ellipsoid (Laundon, 1977; Sinclair and Lyon, 2005). They are dispersed during late summer and fall and germinate soon after deposition on the winter host where it causes new infection and complete the life cycle. Very few infections, if any, take place in spring on the juniper host (Borno and van der Kamp, 1975).

In areas of severe pear leaf infections, the pathogen may spread into the petiole and infect the pear buds at the point of attachment, developing hypertrophic tissue. Though, leaves from these infected buds are rarely expanded entirely and are commonly shed premature. In this hypertrophic tissue the pathogen may survive the winter as haploid mycelium from which spermagonia are produced the next coming spring and throughout the summer. During the end of summer, aecia are produced directly from the hypertrophic tissue of the pear bud and develop characteristic cylindrical cup shaped structures. This occurrence could be considered to be some sort of over wintering of the pathogen on the secondary host. However, this over wintering stage does not cause any reinfections on the pear host the next coming spring and no production of telia and telial horns has been confirmed on the pear host (Hunt and O'Reilly, 1978; Vulkovits, 1980; Butin, 1995).

For a rust to reinfect the same host that produced it, the uredial stage is necessary. The urediospores are produced on the secondary host, which in this case would be the pear, and repetitively cause infection within the same over the growing season. However, *G. fuscum* lack this stage, resulting in that infected pear tissue may not infect other pear tissue previously free from infection. The lack of this stage has been confirmed by many studies, most recently in Slovakia by Juhásova and Praslièka (2002) (Heinze, 1978; Juhásova G and Praslièka, 2002).

An illustrated overview of the life-cycle is presented in figure 6. The illustration also includes the distribution of aeciospores from infected pear bud with hypertrophic tissue (Hunt and O'Reilly, 1978).

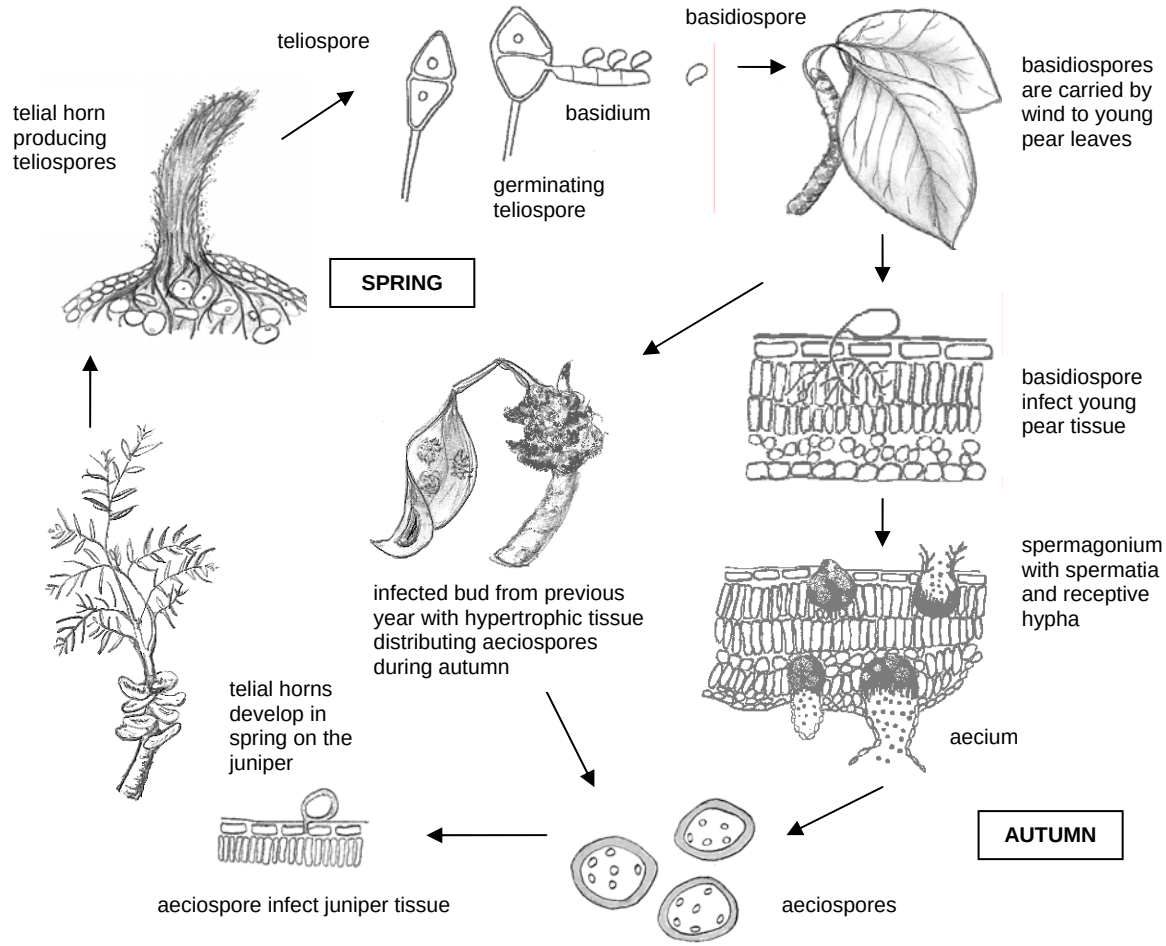

Figure 6. Illustrated life-cycle of *G. fuscum* including the infected bud with hypertrophic tissue distributing aeciospores. Figure redrawn and modified with inspiration from Agrios (1997), Butin (1995) and Siegfried and Viret, (2004). © Karlsson, 2007

Dispersal of spores

The basidiospores are released from the juniper host at the time of maturation of basidia during moist conditions in spring. The releasing occurs several times since only a small portion of teliospores germinate to form basidium during each gelatinization. The basidiospores are dispersed primarily at night when humidity is high and require free water on plant foliage to germinate. If deposited on dry foliage their vitality remains for approximately a day if humidity is high (Wayne and Howard, 2005).

For basidiospores to cause an infection on the pear leaves, the infected juniper has to be present in the surrounding. Though, no investigations have been conducted concerning for how long distances the basidiospores may be carried by wind without losing their vitality. However, it could be expected to be over rather long distances, about 300-500 meters, but only with small infections as a result. The infections are thought to increase with decreasing distance between infected juniper and pear. Within a radius of 50 meter it is thought to cause severe infections. Other factors that influence the distribution of basidiospores is wind direction, topography and the severity of the infection on the juniper host (Gram and Weber, 1944; Hilber and Siegfried, 1997; Siegfried and Viret, 2004).

The aeciospores are released from the pear leaves at the time of maturation of aecium until all infected leaves are shed. The aeciospores appear dry and are dispersed by wind in the morning in response to drying of foliage. High humidity inhibits their dispersal since the wall of the aecium absorbs water which swells and restricts the opening (Wayne and Howard, 2005). The wind speed may as well influence the fluctuations of aeciospore release (Ormrod *et al.,* 1984). The aeciospores conductivity for dispersal is of less concern since the infection of juniper is permanent. However, the pathogen could be introduced to new localities previous free of infection by circulation of pear trees with mature aecia through garden centres or nurseries (Hunt and O'Reilly, 1978).

After the aeciospores have been released, the mycelium in the infected pear tissue normally dies out. But, occasionally it survives the winter at the base of the pear buds (Hunt and O'Reilly, 1978; Vulkovits, 1980; Butin, 1995). The infection will not develop further on leaves that are shed from the tree due to the fact that the pathogen is an obligate parasite. However, leaves with mature aecia may continue to release aeciospores after the leaf has shed (Ormrod *et al.*, 1984; Hilber and Siegfried, 1997).

Infection biology

A Swiss study has been conducted by Hilber *et al.* (1990) to evaluate the influence of temperature on telio- and basidiospore germination of *G. fuscum* in vitro. The study also evaluated the effects of temperature, inoculums concentration

and leaf wetness periods (LWP) on potted seedlings of pear, grown in plastic pots in the greenhouse.

The most favourable temperature for teliospores to germinate occurred between 10-25˚C with an optimum at 15-20˚C. Germination of the basidiospores occurred between 5-25˚C, with an optimum at 20˚C with a germination rate >90% after eight hours. No germination was observed at 0˚C and 5˚C for the teliospores and at 0˚C and 30˚C for basidiospores.

The infection rate of the pear seedlings increased with increasing LWP and increasing inoculums concentration. Infections could be considered severe even at temperatures as low as 0-4˚C, but it required an increasingly longer LWP. This Swiss study resulted in a broader temperature range which expanded to lower temperatures than previous studies have shown. This was evaluated to be an indication of an adaptation of the pathogen to lower temperatures (Hilber *et al.,* 1990).

Influence on the host

G. fuscum cause damage of little importance on the juniper host on which it may kill slender branches. The gall-like swellings and bare branches may also decrease the horticultural value of the juniper (Juhásova and Praslièka, 2002).

The pathogen is of greater significance on its alternate host, the pear tree. If infection pressure is high over many years the tree may lose its vitality which may predispose it to attacks by secondary pathogens. The fertility rate of the tree could be affected as well, resulting in poor fruit set or premature fruit drop (Gram and Weber, 1944; Phillips and Burdekin, 1992; Hilber and Siegfried, 1997). If the fruits are infected their quality may be reduced or inhibited in growth (Butin, 1995; Siegfried and Viret, 2004). Heavy infected leaves may curl and drop prematurely (Hilber and Siegfried, 1997; Naqvi, 2004).

Importance of pear rust in Sweden

The economic importance of *G. fuscum* is considered to be limited by the distribution of its juniper host. In fruit-growing areas in Sweden it is not considered to be a problem due to the absence of juniper hosts and the chemical control. However, the disease can be locally severe if not controlled (Jones and Aldwinckle, 1990; Pettersson and Åkesson, 1998).

According to the inventory charts of pests and diseases in Sweden provided by the Board of Agriculture (2001), was the distribution of pear rust throughout Sweden evaluated as uncommonly. The economical importance was evaluated as insignificant in commercial production but as disastrous in organic production (SJVFS 2001:7B).

For the private home gardener the issue of pear rust is more severe. Pear trees and susceptible cultivars of junipers are frequently planted and if not in the same, in a garden nearby or in the locality. Chemical control rarely is an option and undesired in non-commercial production. So, the easiest and only control measure is to eliminate either host, in many cases the pear tree (Hilber and Siegfried, 1997; Pettersson and Åkesson, 1998).

Control

Cultural control

The most effective management of pear rust is to remove the primary host plants, in this case every susceptible juniper within a distance of at least 500m (Butin, 1995). This could however cause that non receptive cultivars of *Juniperus* are removed as well. Behold that cultivars within the genera of *Thuja* and *Chamaecyparis* are unaffected of pear rust. It would not be possible to cure the diseased junipers but affected branches could be pruned. The branch should be pruned next to the stem and before the time of spore release. However, pruning could expose it to secondary pathogens and decrease the ornamental value of the shrub. The discarded debris from pruning could be put in the compost without risk for further spread of disease (Hilber and Siegfried, 1997).

There is no use to remove the infected leaves on the pear tree since the infection is annual and the tree will be reinfected the next spring if diseased

junipers are within the locality. Since the shed leaves are no source of infection, they could be left on the ground without further processing. Pear shoots with hypertrophic tissue could be pruned, however it is considered to be of no use since it is impossible to cover it all if the tree is large. But it could be preferred in the nurseries since it would avoid further distribution and infection of junipers previous free of the disease when retailed (Hunt and O'Reilly, 1978; Hilber and Siegfried, 1997).

Cultural control and healthy plants are important factors for preventing fungal attacks in general. Select a planting site with good soil drainage and air circulation to promote faster drying of plant foliage and fruit. Proper pruning is essential since an open tree crown generates air movement within the canopy. This avoids humid conditions which would favour the germination and penetration of the fungi. Drip irrigation is recommended in field production, may not be an option in home gardens, since it keeps the foliage dry. Avoid excessive fertilization with nitrogen which promotes succulent and unnecessary dens foliage (Agrios, 1997).

Host resistance

A successful way to suppress the disease for non-commercial growers would be by planting host cultivars resistant to *G. fuscum*. By this, the disease cycle of the fungi would be broken and the pathogen would thereby be controllable. Studies have been conducted regarding the susceptibility of junipers. But, unfortunately have no further controlled investigation been conducted concerning the resistance of pear cultivars (Hilber and Siegfried, 1997). However, there are suggestions of less susceptible cultivars which are thought to be 'Bunte Juli', 'Concorde', 'Clapps Liebling', 'Condo' and 'Trevoux'. Cultivars as 'Conference', 'Verdi' and 'Cascade' are on the other hand considered to be highly susceptible (Wauer and Franz, 2003; Fitzner and Fischer, 2005). Of these is 'Conference' the only commonly cultivated cultivar in Sweden, concerning the commercial fruit production (Persson, 2003).

During the years of 1999 and 2001, a study was conducted in Germany by Fitzner and Fischer (2005), who evaluated 16 species and hybrids of *Pyrus* for ornamental use according to infection susceptibility. Neither of the evaluated species indicated resistant traits, but they differed greatly in degree of their susceptibility. The species with the lightest degree of infection was *P. korzhinskyi,*

P. betulifolia, P. cordata and the hybrid *P. salicifolia* 'Pendula'. Unfortunately are these species most adequate for landscaping, however, their traits could be used for breeding (Fitzner and Fischer, 2005).

The Swedish breeding programme of pear aims primarily towards producing cultivars adequate for the commercial production. The most desired characters are adaptation to the Scandinavian growing conditions, abundant cropping and quality as appearance. The desired disease resistance is mainly towards scab (Nybom, 1995; Bellini and Nin, 2002). According to the Italian report by Bellini and Nin (2002), regarding the breeding of new traits in pear cultivation, is Japan the only country aiming for minor diseases as rust (Bellini and Nin, 2002).

Control in fruit production

Chemical control is an important pest management tool of fungal attack in commercial and IP production. In the organic production measured application of sulphur in spring ought to decrease infections of pear rust (Juhlin, 2006a). The fungicides approved and registered in Sweden for control of fungal diseases in fruit production has shown to have an affect on *G. fuscum* as well, especially those for control of *Venturia* sp. (Juhlin, 2006b).

Fungicides with a preventative effect are to be preferred since the pathogen easily develops resistance. It is also recommended to use different fungicides subsequently (Agrios, 1997; SJVFS 2001:7A). Delan WG is today the only available fungicide for fruit production with preventative effect. Topas 100 EC has a curative effect and Candit and Scala have a curative combined with local systemic effect. Because the risk of resistance development is high within these products each should only be used maximum three times every season (SJVFS 2001:7A; Juhlin, 2006b). Baycor and Tilt are curative respectively systemic fungicides for control of rusts but they are only approved for application in nurseries (Rudin, 2006).

Start treatment early in the spring at bud break to protect new emerging shoots and leaves of pear. It is important to gain a good coverage of the plants since the fungicides operate by contact. Repeat treatment approximately once a week or according to weather conditions during four weeks (Rudin, 2006).

Important to consider is that the fungicides do not serve as a complete protection towards infections. Especially not through cool and rainy growing seasons. Moreover, they are generally not effective unless they are timed properly and combined with accurate cultural practices (Agrios, 1997). The chemical protection of pear rust would become more efficiently if the timing of the fungicide application could be in accordance with its infection periods in spring (Jones and Aldwinckle, 1990).

Foreign regulations to control *G. fuscum*

The pear rust disease has occurred in the south coastal region of British Columbia since the 1960's and has been regulated by the Canadian Food Inspection Agency (CFIA) since 1972. In 1973, quarantine was established in the region to prevent further distribution. Even though was the disease reported at previous rust-free areas, threaten to spread to commercial plantings. To overcome this problem a certification programme was started in 1975 through cooperative efforts of the British Columbia Landscape and Nursery Association, the Ministry of Agriculture and Food and Agriculture Canada. This programme implicated that only rust free junipers should be grown and planted. In order to develop this, an integrated control programme was developed that involved inspections of pear trees, fungicides and destruction of infected junipers (Ormrod *et al*., 1984; Ormrod and Elmhirst, 1998).

At present, CFIA has taken steps to deregulate pear rust by regulations intended for commercial growers. It prohibits entry of plants and plant parts of junipers for propagation originating from countries where the disease is known to occur. The same regulations pertains plants and plant parts of pear trees unless they are transported in a dormant, defoliated condition at the time of delivery. Imported plants and plant parts require as well a permit for import and a foreign Phytosanitary Certificate. For domestic movements of pear and juniper from the infested area in British Columbia, the CFIA will issue a master Movement Certificate to commercial growers. These regulations are thought to prevent the spread of disease until it is completely deregulated (Hollebone, 2006).

Another country is Switzerland, where the pear rust became an increasing problem in the end of the 1980's. This was thought to be due to the wet and cold

springs in combination with plantations of susceptible junipers. To control the disease an integrated control program was developed, similar to that known from British Columbia (Hilber *et al*., 1990). However, the only effective method to eradicative the pear rust was evaluated to be by eliminate and replace the susceptible cultivars with non-susceptible. So, to prohibit the development of new infestations, a voluntary cooperative effort of landscape architects, nurseries, garden centres and wholesalers were developed. This implicated that pear rust susceptible junipers should not be recommended or planted, produced, sold or imported (Hilber and Siegfried, 1997).

METHOD

Literature

The information about *G. fuscum* presented in the background part was obtained from searching the library catalogue LUKAS and the available databases, Web of Knowledge and WebSPIRS, at the library in Alnarp. Information was also gained from the World Wide Web by the search engine Google.

Questionnaire and selection of respondents

The questionnaire was formulated and developed to obtain an estimation of the distribution of pear rust and the supply of susceptible junipers in Sweden. It included ten questions and was distributed by e-mail with one reminder within approximately ten days if the answer was defaulted. The respondents were selected with concerns in pear cultivation as nurseries and garden centres but also private home gardeners. Their e-mail addresses were attained through membership lists of organisations from homepages on the World Wide Web. The questionnaire is presented in appendix.

RESULTS

In the following chapter the results from the questionnaire study is presented. Regarding the distribution of pear rust, susceptible junipers and the general estimation concerning symptoms, infection pressure and control strategies. The results of each question are presented under its subtitle and the figures illustrate an overview of the replies expressed in percent. The questionnaire was sent to 83 selected respondents. Of these, 45 replied and 21 of these replies were from nurseries and garden centres.

The supply of susceptible junipers in nurseries and garden centres

In this section are the replies presented regarding the supply of pear rust susceptible junipers in nurseries and garden centre. It also gives an overview of which susceptible cultivars that are occurring in their current assortment of 2006/2007.

21 of the replies were from nurseries and garden centres. Of these, 13 replied that they supplied at least one cultivar from the presented list of pear rust susceptible junipers in the questionnaire. The most frequent occurring susceptible cultivars were *Juniperus scopulorum* 'Skyrocket' (9) and *J. media* 'Old Gold' (8). The result and the list of susceptible cultivars added in the questionnaire are presented in table 4.

The questionnaire also requested other varieties of junipers with a resemble variety name, or with another species name. The majority of these were identified as varieties resistant to rust. However, five of them could not be found as evaluated in the literature. Varieties reported are listed in table 5. There were two comments concerning selection and recommendation of variety:

> "Previously we also cultivated many of the above mentioned varieties on your list but stopped 3-5 years ago. At that time it was due to the fungi *Kabatina juniperi*"

"We supply our customers with the susceptible varieties by order but we inform them about the problem"

Table 4. The table presents the list of susceptible cultivars of junipers added in the questionnaire and gives an overview of the result from nurseries and garden centres. Results are presented as the number of nurseries that supply the specific cultivar.

No. of nurseries/ garden centres	Rust susceptible cultivar
1	*J. chinensis* 'Keteleeri'
0	*J. chinensis* 'Parsonii'
0	*J. chinensis* 'Robusta Green'
0	*J. media* 'Gold Sovereign'
3	*J. media* 'Pfitzeriana'
4	*J. media* 'Pfitzeriana Aurea'
3	*J. media* 'Pfitzeriana Compacta'
0	*J. media* 'Mathot'
0	*J. media* 'Nick´s Compact'
8	*J. media* 'Old Gold'
0	*J. media* 'Swissgold'
0	*J. sabina* 'Blaue Danube'
0	*J. sabina* 'Arcadia'
0	*J. sabina* 'Blaue Donau'
0	*J. sabina* 'Broadmoor'
0	*J. sabina* 'Buffalo'
5	*J. sabina* 'Rockery Gem'
1	*J. sabina* 'Tamariscifolia'
0	*J. sabina* 'Tamariscifolia Select'
0	*J. scopulorum* 'Blue Haven'
0	*J. scopulorum* 'Moonglow'
9	*J. scopulorum* 'Skyrocket'
1	*J. scopulorum* 'Wichita Blue'
4	*J. virginiana* 'Grey Owl'

Table 5. Other cultivars or varieties of junipers with a resemble variety name, or with another species name included in the nurseries assortment of 2006/2007. The majority of the junipers mentioned are considered to be resistant to infections.

Variety of *Juniperus*	Rust susceptibility
J. chinensis 'Blaauw'	Resistant
J. chinensis 'Blue Alps'	Resistant
J. chinensis 'Stricta'	Resistant
J. communis 'Repanda'	Resistant
J. media 'Gold Coast'	Not evaluated
J. media 'Gold Star'	Not evaluated
J. media 'Mint Julep'	Resistant
J. sabina 'Hicksii'	Not evaluated
J. scopulorum 'Blue Arrow'	Not evaluated
J. squamata 'Blue Carpet'	Resistant
J. squamata 'Blue Star'	Resistant
J. squamata 'Blue Swede'	Not evaluated
J. virginiana 'Hetz'	Resistant

Observations of pear rust on the juniper host

This section presents the replies regarding observations of pear rust on the juniper host. It is also specified on which variety the observation was made.

The observations of rust infection on the juniper host were few, only two replied that they had seen infections on the juniper host susceptible to pear rust. The observations were made on *J. media* 'Pfitzeriana', *J. media* 'Pfitzeriana Aurea', *J. sabina* 'Tamariscifolia' and *J. sabina* 'Hicksii'. There was one comment concerning the supply of junipers:

"I have only ordered a few"

Observations of pear rust on another variety of juniper

In this section are the replies presented regarding observations of pear rust on another variety of juniper, not obtained in the questionnaire study.

There was only one report of pear rust infection on another variety. The species reported was *J. sabina* but unfortunately was no variety name mentioned.

The distribution of pear rust

In this section is the result presented regarding observations of the occurrence of pear rust. It also presents the evaluated northern border of its geographical distribution estimated from the replies.

Of the 45 replies that were received, 24 (53%) replied that they have observed pear rust in their surroundings. 14 (31%) have not observed any pear rust while 7 (16%) were unsure. The most northern observations occurred in Arvika (zone III) and Gävle (zone IV). An overview of the results is presented in table 6. There was one comment about the occurrence of pear rust:

> "The answer is yes, if the tree infections we have in the nursery are included. These trees originate from Skåne and have nearly always infections of pear rust"

Table 6. The table shows an overview of the distribution of the reply regarding the observations of pear rust in the surrounding area. 45 replies were received of totally 83 distributed. The majority of these have observed pear rust.

24 (53%)	Yes
14 (31%)	No
7 (16%)	Unsure
45 (54%)	Replies in total

The context in which pear rust occur

In this section is the result presented regarding in which context the rust infected pear trees were observed.

The major part of the pear rust infected trees has been observed in private gardens (18) and garden centres (8). Observations were also made in nurseries (7), public gardens (4) and fruit cultivation (3). However, the fruit growers were no target group for this study.

Other coherence of observations mentioned was Brunstorps gård, Fredriksdal´s collection of fruit trees and in Visby. Three further comments about pear rust were given as follows:

"All our cultivars are infected. Even our wild variety, *Pyrus communis*, is infected"

"I am a garden consultant/FOR adviser, people reports the rust but not about the junipers"

The context in which the infected junipers occur

In this section is the result presented regarding in which context the infected junipers were observed.

The majority (18) of the replies have not experienced any infected junipers. However, observations were made in private gardens (4) whereas single observations were made in public gardens, nurseries and churchyards. Other alternatives mentioned were all around in the society and at Brunstorps gård. Further comments given were:

"Do not have any junipers on my own and have not observed others either"

"I have observed hawthorn rust on the common Swedish juniper in the meadows. We supply hawthorn on our yard"

"I do not believe that anyone within reasonable distance provide these junipers"

"Within our facility at 3.6 ha, there are only *Juniperus communis*. Within a distance of more than 500m from our cultivations are allotments fully capable to contain the current varieties of junipers"

Evaluation of trees viability

This section presents the results regarding the general evaluation of the affect of pear rust infections on the trees viability.

The majority replied that they estimated a strong affect (10) of the trees viability or a moderate affect (8) when it was infected with pear rust. Three considered it to have no affect on the trees while two were unaware of its affect and could not evaluate its consequences. Only one estimated that the infections have very strong affect on the trees viability. An overview of the results is presented in table 7. Further comments were given concerning the impact of pear rust on the trees:

"Severe infection of pear rust but very good yield of pear anyway"

"Ugly to sell, sometimes impossible!"

"I think most people have more trouble with scab"

Table 7. The table shows an overview of the results regarding the estimation of how the trees viability is affected by the rust infection. The majority experienced the rust to have strong or moderate affect on the trees viability.

2	Unaware
3	No affect
8	Moderate affect
10	Strong affect
1	Very strong affect

The appearance of symptom

This section presents the results regarding the general estimation of when the first symptoms of pear rust emerge on the pear leaves.

The majority (17) experienced the symptoms to appear during June and July, at fully developed leaves. Single observations were made in April and May, at bud break as well in August and September. Five were not aware of when the symptoms developed. The results are presented in table 8.

Table 8. An overview of when the first symptoms of rust infection occur. The majority have spotted the first symptoms during June-July, at fully developed leaves.

1	April-May, at bud break
17	June-July, at fully developed leaves
5	Unaware
1	Other, August- September

Infection pressure

This section presents the results regarding the infection pressure and its impending increase.

12 replied that they have experienced an increase of pear rust infections. Three have not and nine were unsure. The results are presented in table 9. Further comments were given concerning the expansion of infections:

"Did not occur five years ago, has developed within the four recent years"

"Seen over the last five to ten years so has there been an increase"

"Now we have over wintering pear rust in our trees (ever since a couple of years ago have we ascertained this). There are distinct swells on the branches. We have discussed it with Maj-Lis Pettersson. The fruit seems suspiciously affected as well"

Table 9. The table shows an overview regarding the experiences of an increase of the infection pressure.

12	Yes
3	No
9	Unsure

Control strategies

In this section are the results regarding the implemented control measures against pear rust presented.

Ten replied that they have some kind of control measures. Commonly used methods were chemical control, pruning and collection of infected plant tissue. Destruction of infected trees and junipers were mentioned as well.

Nine replied that no measures were done while five were not aware of which control strategies that were given. An overview of the results is presented in table 10. Further comment regarding the control measures were given as follows:

"Chemical control and remove infected leaves"

"I removed a 60 year old pear tree in my neighbour's garden"

"Then you have to remove all the junipers and who decide that?"

"My chemical control of scab and *Monilia* keeps the infections down"

"Chemical control in the nursery, picking of infected leaves. At home we have removed *Juniperus sabina* to decrease the infections"

"Juniperus chinensis and *J. sabina* occur relatively common in the gardens around here in the southern parts of Värmland. A lot of them have been removed due to *Kabatina juniperi*. It should only be a matter of time before the pear rust occurs here as well. In Värmland, very few pear trees are cultivated since they do not benefit from our locations"

"Do not know what the public do, hopefully they remove the junipers"

Table 10. The table shows an overview if any control measures on the infected pear or juniper is achieved.

10	Yes
9	No
5	Unsure

DISCUSSION

In the discussion part are the results from the questionnaire study evaluated and compared with the related literature and influenced by my own opinion. Unfortunately was it difficult to make any significant conclusions from the answers of the questionnaire due to the limited replies. It was sent to 83 selected respondents, but only 45 replies were received. This restricted numbers of replies could be due to many factors, but the most limiting would be the time of the year when it was distributed. The questionnaires were distributed during November making it difficult investigate if the leaves of the pear trees were infected.

The distribution of pear rust

Of the 45 replies that were received, 24 replied that they have observed pear rust in their surroundings. Prominent observations, apart from those made in the southern part of Sweden, were made in Uppsala, Sollentuna, Eskilstuna, Jönköping, Lidköping, Linköping, Sundbyberg and Hallstahammar. But, the most northern observations of pear rust came from Gävle and Arvika. These locations are situated not far from the same latitude. However, they represent different climatic zones of plant hardiness. Arvika correspond to zone III and Gävle zone IV. The definition of zones is influenced by practical experiences of cultivation and statistical meteorology as mean temperature during the coldest month. The normal mean temperature of January is approximately -5.4˚C in Arvika and -4.8˚C in Gävle. Due to the big lake Vänern and the sea, the last spring frost occurs relatively early in both locations, in the beginning of May (Alexandersson *et al.,* 1991).

From these it may be evaluated that pear rust would occur and spread within the range of climatic zone I-IV, which also represent the possible zones of pear cultivation.

Environmental factors

In recent years has an increase of the infection pressure been estimated in southern Sweden and up on the western coast line. In some areas is it a major

problem which impend the pear cultivation (Svanfeldt, 2006). The explanation regarding the increased infection pressure of *G. fuscum* could be a combination of environmental factors as it coincides well to the literature. The previous mild winters as well as the humid spring times has provably been beneficial for the development of the rust on the juniper host and for the distribution of spores. According to the Swiss study by Hilber *et al.* (1990), environmental factors as temperature, leaf wetness periods (LWP) and inoculums concentration affected the infection rate considerable. At temperatures between 10-25˚C, germination of teliospores occurred with an optimum at 15-20˚C. The germination of basidiospores occurred between 5-25˚C with an optimum at 20˚C. The leaf wetness periods and increased inoculums concentration also affected the infection rate significantly. At the optimal temperature, 15˚C, only three hours LWP was required to achieve a light infection on the pear leaf.

The Swiss study resulted in a broader temperature range which expanded to lower temperatures than previous studies have shown. This is of great interest since this could be an indication of an adaptation of the pathogen to lower temperatures (Hilber *et al.,* 1990). This could also partially explain the increase of pear rust infections here in Sweden. The Swiss study also indicated that the temperature is not a limiting factor in spring when the basidiospores from the juniper are to cause infection on the pear tissue. The key limiting factor is to be rain fall, followed by a sufficient LWP on pear tissue surface. Another possible factor to this could be the timing of rain fall. According to the literature concerning Apple-cedar rust, are the apple leaves most susceptible to infection when they are young (before maturation), approximately 4-8 days old.

Access and supply of the juniper host

The accessibility and supply of the susceptible junipers is an issue and could be considered an important cause of distribution. Thereby the intensity of the pathogen could be expected to vary as a consequence of the distribution of these. It could also be one explanation to why the conventional cultivation not experience pear rust as a problem as junipers rarely are grown in the surrounding area

(Pettersson and Åkesson, 1998). However, according to the answers have the majority not experienced infected junipers, only infected pear trees. This could be due to lack of knowledge of the pathogens alternating character, and thereby not relating the symptoms on the juniper host to pear rust. Also, the symptoms, in this case the telial horns could be small as a result of recent infections or could be expected on less susceptible cultivars. They are often limited to a single branch, well hidden within the plant or close to the ground since it develops in moist conditions. Another cause of concealment could be that the symptoms only appear within a limited time period, normally in humid spring times.

According to the answers from the questionnaire, the supply of susceptible junipers could be considered as common. Unfortunately were there only 21 replies from nurseries and garden centres, though, 13 of these included the junipers in their assortment. The most common occurring cultivars were on the other hand only slight receptive. These were *J. scopulorum* 'Skyrocket', *J. sabina* 'Rockery Gem' and *J. viginiana* 'Grey Owl'. However, cultivars as *J. media* 'Pfitzeriana', *J. media* 'Pfitzeriana Aurea' and *J. media* 'Pfitzeriana Compacta', all shown to be highly susceptible occurred as well. This could be evaluated as that the awareness of pear rust continuing is poor and therefore are the susceptible junipers still supplied in the nurseries and garden centres. Another issue is that nowadays are plants commonly supplied in the supermarkets (not included in the questionnaire), very available for the consumer. However, these stores often distribute quantities of imported plants without proper knowledge increasing the risk of supplying susceptible cultivars of junipers.

Control strategies

According to the few replies regarding the undertaken control measures were chemical control, pruning and collection of infected plant tissue as well as destruction of infected trees and junipers mentioned. Since chemical control is no option for the home gardener other measures must be made. The best strategy is to remove the source of spread, the juniper host. This is an issue since all infected junipers within a radius of at least 500m must be removed and it would probably become to involve an entire neighbourhood. It is not possible to cure the diseased

juniper, but, if the ornamental value is high, infected branches could be pruned. Another issue is to identify an infected juniper since apparent symptoms only occur in spring. Therefore could it be an advantage to look through the juniper during rainy days in spring when the yellow-brown tongue-shaped telial horns occur. However, these could even at this time be difficult to discover since they commonly occur within the compact vegetation and close to the ground. Another issue is the incubation time for the rust to cause symptoms on the juniper host which has been evaluated to be up to three years. By this could infected branches without doubt be failed to distinguish. Therefore should precautions as eliminations of all junipers be preferred but behold that *Thuja* and *Chamaecyparis* are unaffected of pear rust. This would though imply that resistant cultivars of juniper are removed as well.

Since the pathogen is of no economical importance no regulations from the authorities is to be expected. But, it could be worth to investigate the possibility to deregulate pear rust by control the import by establish a claim of plant passport concerning the juniper host. A similar directive of plant protection is stated within the European Union to control *Erwinia amylovora* which host plants all demands plant passport when distributed within the union (SJVFS 2007:69). The plant passport would assure healthy juniper plants free from rust. Plant passport also state relevant information, in this case would the susceptibility of the particular cultivar be of interest.

Suggestions on continued research

In this report has an overview of pear rust been provided through a literature study and a questionnaire was implemented to evaluate its distribution. A further topic for investigation would be how the environmental fluctuations during the growing season influence the development of the pathogens different spore stages and how this would correlate with the infection pressure. For example the claims of conditions the telial horns on the juniper host have for development and survival. These results would contribute to an increase awareness of pear rust and its infection biology.

Another important topic to study is the host resistance to pear rust. A continuous research and evaluation of the juniper host is essential concerning newly introduced cultivars. It would also be interesting to investigate if there is any variation of susceptibility between different pear cultivars. These cultivars would be of particular interest for the non-commercial and organic pear growers.

CONCLUSION

The European pear rust is and will continue to be a pathogen of concern for the Swedish home gardener. With the unattractive leaf symptoms and negative effect on fruit set it will in time demolish the interest for pear cultivation. At present it has been observed in zone I-IV and infection pressure probably involves environmental factors as favour climate in spring. However, the major issue is the accessibility of susceptible juniper host plants and that the general awareness of pear rust is poor which has contributed to its distribution. This due to the fact that the susceptible junipers still is supplied in nurseries and garden centres. Probably new planting of these junipers has contributed and introduced the pathogen into new areas. But, also infected pear trees in the garden centre could have contributed to the introduction to areas previously free of infection since these trees distribute aeciospores causing primary infections on the juniper host.

To constrain the spread and infection pressure the awareness of pear rust must be increased through information. This by illuminate about the problem and host issue and urge people to avoid, lock for and remove infected junipers. Propositions have been made by FOR, Fritidsodlingens Riksorganisation, to manage the issue of pear rust in Sweden equal to the Swiss procedure. There were a voluntary cooperative effort of landscape architects, nurseries, garden centres and wholesalers developed. This implicated that susceptible junipers should not be recommended or planted, produced, sold or imported (Hilber and Siegfried, 1997). Nurseries and garden centres can contribute to limit the spread by eliminate these susceptible cultivars from their assortment and only supply the resistant varieties. Still, a mutual effort is necessary including all concerned parts to eliminate occurring junipers and to avoid new plantings.

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APPENDIX

Enkät rörande förekomsten av päronrost och päronrostkänsliga enar

Frågorna 1-3 avser det egna sortimentet, medan övriga avser miljön i de närmaste omgivningarna.
Enskilda svar behandlas konfidentiellt.

Fråga 1: Ingår några av nedanstående enar i ert sortiment år 2006 eller 2007? Om ja, kryssa för dessa i sortlistan nedan av enar.

☐ **Ja, kryssa i sortlistan nedan**

☐ **Nej**

Sortlista över *Juniperus* som anses känsliga för päronrost

	J. chinensis 'Keteleeri'		*J. sabina* 'Blaue Danube'
	J. chinensis 'Parsonii'		*J. sabina* 'Blaue Donau'
	J. chinensis 'Robusta Green'		*J. sabina* 'Broadmoor'
	J. media 'Gold Sovereign'		*J. sabina* 'Buffalo'
	J. media 'Pfitzeriana'		*J. sabina* 'Rockery Gem'
	J. media 'Pfitzeriana Aurea'		*J. sabina* 'Tamariscifolia'
	J. media 'Pfitzeriana Compacta'		*J. sabina* 'Tamariscifolia Select'
	J. media 'Mathot'		*J. scopulorum* 'Blue Haven'
	J. media 'Nick´s Compact'		*J. scopulorum* 'Moonglow'
	J. media 'Old Gold'		*J. scopulorum* 'Skyrocket'
	J. media 'Swissgold'		*J. scopulorum* 'Wichita Blue'
	J. sabina 'Arcadia'		*J. virginiana* 'Grey Owl'

Övriga *Juniperus* i ert sortiment med **liknande sortnamn** eller med ett **annat artnamn** som inte är med i listan ovan:

Fråga 2: Har ni sett rostangrepp på någon av sorterna i listan ovan? Markera genom understrykning av sortnamn ovan.

☐ **Ja, markera ovan i sortlistan genom understrykning**

☐ **Nej**

Övriga kommentarer:

Fråga 3: Har det förekommit angrepp av päronrost på någon annan sorts en än ovan nämnda?

☐ **Ja, sorten:**_____

☐ **Nej**

Övriga kommentarer:

Övriga frågor avser miljön i de närmaste omgivningarna.

Fråga 4: Förekommer det päronrost i ditt närområde?

☐ **Ja**

☐ **Nej**

☐ **Har inte tittat på eller känner inte till några päronträd häromkring**

Om svaret är Ja så var snäll att besvara även frågorna 5-10 nedan. Men övriga svarsalternativ är lika viktiga för min undersökning så jag ber dig skicka tillbaka enkäten oavsett svar!

Fråga 5: I vilket sammanhang finns de angripna ***päronträden***? Kryssa gärna flera alternativ.

☐	**Egen fruktproduktion**	☐	**I grannens trädgård/koloni**
☐	**Växtförsäljning**	☐	**I kommunal park**
☐	**Egen plantskoleproduktion**	☐	
☐	**I den egna trädgården/kolonin**	☐	**Annat:**

Övriga kommentarer:

Fråga 6: I vilket sammanhang finns de angripna ***enarna***? Kryssa gärna flera alternativ.

☐	**Har inte sett några infekterade enar**	☐	**I grannens trädgård/koloni**
☐	**Egen plantskoleproduktion**	☐	**I kommunal park**
☐	**Växtförsäljning**	☐	**På kyrkogård**
☐	**I den egna trädgården/kolonin**	☐	**Annat:**

Övriga kommentarer:

Fråga 7: Hur omfattande bedömer du att angreppen på päronträden är?

☐ **Obetydliga, *ingen synlig inverkan på päronträden***

☐ **Måttliga, *ringa inverkan på päronträden***

☐ **Rikliga, *med synlig inverkan på päronträden***

☐ **Mycket rikliga, *angreppen hotar odlingen av päronträd***

Övriga kommentarer:

Fråga 8: När uppträder de första symtomen på päronträdens blad?

☐ **April-maj,** ***redan vid knoppsprickningen***
☐ **Juni-juli,** ***vid fullt utvecklade blad***
☐ **Vet ej**

Övriga kommentarer:

Fråga 9: Har man kunnat se en ökning av angreppen på päronträden från år till år?

☐ **Ja**
☐ **Nej**
☐ **Kan inte bedöma**

Övriga kommentarer:

Fråga 10: Görs det något för att bekämpa angreppen på träden respektive enarna?

☐ **Ja, i så fall vad:**_____
☐ **Nej**

Övriga kommentarer:
