# EVALUATION OF EUROPEAN PEAR RUST SEVERITY DEPENDING ON AGRO-ECOLOGICAL FACTORS

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**Abstract**
Pear (*Pyrus communis* L.) fruits in Latvia are very popular, although orchard areas are not large. In the commercial orchards the control of plant pathogens mainly is performed using a plant protection plan, based on long-term observations. European pear rust caused by *Gymnosporangium sabinae* (Dicks.) G. Winter has become during recent years one of the most important diseases in Latvian pear orchards. Pathogen *G. sabinae* has a complex development cycle, with four types of spores on two different plants: pear and junipers. Favourable development of each stage depends on the specific environmental conditions. The aim of the study was field evaluation of the disease severity depending on agro-ecological factors.
The study was performed at the Latvia State Institute of Fruit-Growing from 2008 to 2012. The severity of European pear rust infection on leaves of cultivars was evaluated in points 0–5, where: 0 – a tree has no infected leaves; 5 – 81% to 100% infected leaves. The disease severity during these years, impact of tree planting year, rootstock, cultivar and tree location in the plot were analyzed.
Results gave the opportunity to determine which factors have positive influence on the development of pathogen and severity of disease. Severity of disease was not directly dependent on cultivar, their country of origin, rootstock and planting year. Severity of disease was influenced by tree location in the orchard; higher severity was observed on larger and more vigorous trees, located in outer rows, exposed to the prevailing wind carrying pathogen spores.
**Key words:** *Gymnosporangium sabinae*, weather conditions, cultivars, rootstocks.

## Introduction

Rusts are important plant diseases, which agents belong to the order *Uredinales* of phylum Basidiomycota. According to the morphology of spore *Gymnosporangium* genus belongs to the *Pucciniaceae* family (Aime, 2006). Causal agent of European pear rust *Gymnosporangium sabinae* (Dicks.) G. Winter is distributed in Canada, North Africa, Asia and also in Europe (Farr et al., 1995). This disease is becoming an important problem also in Latvia – in 2007 symptoms of European pear rust were found in more than half of 33 assessed pear orchards (Rancane et al., 2012). *Gymnosporangium sabinae* has an incomplete development cycle requiring both pear (*Pyrus communis* L.) and juniper (*Juniperus* L.) (Jones and Aldwinckle, 1997). Development of disease starts in early spring on the junipers (Hilber et al., 1990). Teliospores germinate to form basidiospores which infect pears. Critical period for pear orchards is the time when the average air temperature is rapidly increasing and long-term rainfalls occur (Митрофанова, 1970; Hilber et al., 1990). Late and dry spring is unfavourable for development and release of basidiospores. The infection period may continue from April to the end of May (Митрофанова, 1970).

Viability of basidiospores is low, and they are unable to distribute for long distances by the wind (Agrios, 1997). For example, basidiospores of related species - apple rust pathogen *Gymnosporangium juniperi-virginianae* are able to distribute in distances over 3 - 5 km (Agrios, 1997). Massive infection occurs when the pear trees and juniper grow no more than 300 - 500 m away from each other (Митрофанова, 1970). Research has been done in British Columbia to compare the infection rate of pears depending on the location of juniper. It was stated that in distance of 30 m from the juniper 100% of pear leaves were infected, whereas in distance of 150 m - 50% of pear leaves, but in distance of 300 m - signs of rust infection were not found on the leaves (Ormrod et al., 1984).

After some time the first symptoms of the disease – spots on pear leaves appear. Under leaves fruiting bodies - aecia form and after some time aeciospores produce (Митрофанова, 1970; Hilber et al., 1990). Aeciaspores cannot infect the plant on which they were developed; therefore, the spores are spreading back to the junipers and infect those, where pathogen is overwintering in the infected branches (Cummins and Hiratsuka, 2003).

Knowledge about the development cycle of *Gymnosporangium sabinae* and its dependency on agro-ecological factors is quite limited, since there are no long-term evaluations of environmental influence, previous studies mostly are performed *in vitro* conditions. Systematic, long-term studies on the development of pathogen as well as on disease severity in the field conditions have not been performed. Therefore, the aim of this investigation was to perform field evaluation of the European pear rust severity depending on agro-ecological factors: weather conditions, tree planting year, rootstock, cultivars and their country of origin, and tree location in the plot.

## Materials and Methods

The study was performed at the Latvia State Institute of Fruit-Growing (LSIFG) (56°36’39.37” N 23°17’48.86” E). The European pear rust severity on twenty five cultivars of different origin was evaluated for five years (2008 – 2012). In the trial, pear cultivars included their origin, planting years, cultivar-rootstock combinations as well as the number of pear trees per planting year. All these parameters are described in Table 1.

Table 1

**Pear cultivars, rootstocks and tree planting years used in the evaluation of European pear rust severity**

| Cultivars | Country of origin | Rootstocks | Planting years | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 2001 | 2002 | 2003 | 2004 | 2005 | 2007 |
| AMD-42-5-28 | Latvia | Pyrodwarf | × | × | 13 | × | × | × |
| Belorusskaya Pozdnyaya | Belorussia | Pyrodwarf | × | 9 | 10 | × | × | × |
| | | Kazraušu seedling | × | 10 | × | × | × | × |
| | | BP-30 | × | 5 | × | × | × | × |
| Bere Kievskaya | Ukraine | BA-29 | × | × | × | × | 3 | × |
| BP-8965 | Sweden | BA-29 | × | × | × | × | 5 | × |
| Cheremshina | Ukraine | Pyrodwarf | × | × | 10 | × | × | × |
| Concorde | United Kingdom | BA-29 | × | × | × | 12 | 2 | × |
| Condo | Netherlands | Pyrodwarf | × | × | × | 10 | × | × |
| Conference | United Kingdom | BA-29 | × | × | × | × | 2 | × |
| Duhmyanaya | Belorussia | BA-29 | × | × | × | × | × | 5 |
| Fritjof | Sweden | Pyrodwarf | × | × | × | 12 | × | × |
| Harrow Delight | Canada | BA-29 | × | × | × | × | 1 | × |
| Mlievskaya Rannyaya | Ukraine | Pyrodwarf | × | 4 | 8 | × | × | × |
| | | Kazraušu seedling | × | 4 | × | × | × | × |
| Mramornaya | Russia | Pyrodwarf | × | 9 | 9 | × | × | × |
| | | Kazraušu seedling | × | 9 | × | × | × | × |
| | | BA-29 | × | × | × | × | 2 | × |
| Orcas | Canada | Pyrodwarf | × | × | × | 10 | × | × |
| Orlas-3-8-17 | Russia | BA-29 | × | × | × | × | × | 2 |
| | | Plauža kompaktā | × | × | × | × | × | 13 |
| Paulina | Latvia | BA-29 | × | × | × | × | 5 | × |
| Platonovskaya | Russia | BA-29 | × | × | × | × | × | 7 |
| Rescue | Canada | Pyrodwarf | × | × | × | 11 | × | × |
| Striyskaya | Ukraine | BA-29 | × | × | × | 11 | × | × |
| Suvenirs | Latvia | Kirchensaller Mostbirne | 9 | × | × | × | × | × |
| | | OH × F 333 | 9 | × | × | × | × | × |
| | | Pyrodwarf | 10 | 8 | × | 10 | × | × |
| | | BA–29 | × | × | × | 11 | × | × |
| | | Kazraušu seedling | × | 8 | × | 9 | × | × |
| | | OH × F 87 | × | × | × | 15 | × | × |
| | | Circeņa cidonija | × | × | × | × | × | 2 |
| | | K-TE-E | × | × | × | × | × | 3 |
| | | Plauža kompaktā | × | × | × | × | × | 22 |
| | | PU–20495 | × | × | × | × | × | 3 |
| | | *Pyrus ussuriensis* | × | × | × | × | × | 5 |
| Tavricheskaya | Ukraine | BA-29 | × | × | × | × | 4 | × |
| Vasarine Sviestine | Lithuania | Pyrodwarf | × | 4 | × | × | × | × |
| | | Kazraušu seedling | × | 4 | × | × | × | × |
| Vizhnitsa | Ukraine | Pyrodwarf | × | × | 8 | × | × | 9 |
| | | BA-29 | × | × | × | × | × | 12 |
| | | Plauža kompaktā | × | × | × | × | × | 17 |
| Zemgale | Latvia | Pyrodwarf | × | × | 9 | × | × | × |

Adapted scale was used similar to scab (*Venturia* Sacc.) spreading evaluation, in points 0–5, where: 0 – a tree has no infected leaves; 5 – 81% to 100% infected leaves from G.C. Percival and colleagues (2009). The response of cultivars to European pear rust was assessed in natural conditions of infection, with fungicide treatment.

The distance between rows was 4 m. Soil management consisted of frequently mowed grass in the alleyways, while 1 m wide strips were treated with herbicides. The soil at the trial site was sod-podzolic sandy loam, the humus content – 3.2%, the soil pH KCl – 6.4, plant available $P_2O_5$ – 234 mg kg$^{-1}$, and $K_2O$ – 293 mg kg$^{-1}$ (data of 2010).

Applications of fungicides in 2008, 2009 and 2010 were carried out as for the pear scab (*Venturia pyrina* Aderh.) control. In 2011 and 2012 application scheme in April and May was modified to adapt it for the control of European pear rust, based on basidiospore release observed on junipers (*Juniperus sabinae*) near to the orchard and weather conditions.

Weather information was collected by the meteorological station 'Lufft' at the LSIFG. Weather conditions were recorded every half-hour and analysed by decades. The weather conditions among study years were different. The drier vegetation period was in 2008, but the vegetation period of 2010 had the highest precipitation and temperatures among years of study. During the winter time, low air temperatures were observed in 2010 (the lowest air temperature was in February, -28 °C) and 2011 (the lowest air temperature was in January, -23 °C), whereas in 2008 and 2009 they were the highest ones (up to -17 °C).

Statistical analysis of the data was performed using SPSS v. 15 program modules for descriptive statistics and analysis of variance, correlation analysis and multiple comparison tests. Evaluation of European pear rust severity among years, tree planting year, rootstock and cultivar impact in the plot was performed.

## Results and Discussion

*Evaluation of European pear rust severity depending on years*

Total precipitation (TP), relative humidity (RH) and average air temperature are the most important factors for the development of fungal diseases (Hardwick, 2006), therefore, they were analysed in this study. Meteorological conditions were analysed for the period from 2008 to 2012 (Table 2). Detailed analysis was done for periods which are the most important in the development of the pathogen - 2nd decade of April to the end of May.

Table 2

**Characterization of total precipitation, relative humidity and average air temperatures in spring from 2008 to 2012**

| Year | Month | Decade | Total precipitation, mm m$^{-2}$ | Relative humidity, % | Average air temperature, °C |
|---|---|---|---|---|---|
| 2008 | April | 3 | 0.0 | 51.8 | 10.1 |
| | May | 1 | 2.8 | 70.1 | 12.2 |
| | May | 2 | 8.6 | 66.2 | 10.4 |
| | May | 3 | 0.0 | 53.7 | 13.6 |
| 2009 | April | 3 | 0.0 | 49.9 | 11.1 |
| | May | 1 | 0.0 | 60.4 | 11.7 |
| | May | 2 | 8.3 | 69.0 | 11.3 |
| | May | 3 | 7.1 | 66.1 | 14.8 |
| 2010 | April | 3 | 7.6 | 67.1 | 7.4 |
| | May | 1 | 50.0 | 82.5 | 8.5 |
| | May | 2 | 10.9 | 85.0 | 16.5 |
| | May | 3 | 14.3 | 73.1 | 13.4 |
| 2011 | April | 3 | 0.0 | 56.8 | 12.5 |
| | May | 1 | 7.3 | 63.5 | 8.7 |
| | May | 2 | 35.2 | 77.5 | 13.2 |
| | May | 3 | 11.1 | 73.4 | 14.4 |
| 2012 | April | 3 | 16.0 | 75.5 | 11.6 |
| | May | 1 | 11.6 | 68.9 | 11.1 |
| | May | 2 | 10.7 | 74.7 | 11.7 |
| | May | 3 | 21.8 | 72.7 | 14.4 |

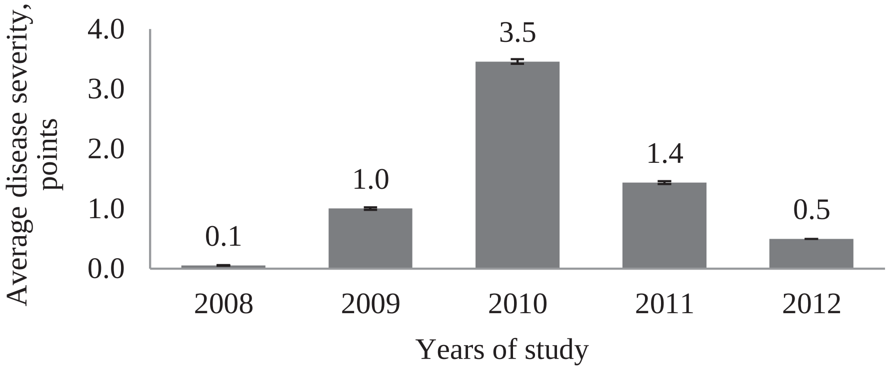


Figure 1. Average disease severity on all cultivars in the years of study
(severity scale: 0 - no infected leaves, 5 - 81% to 100% infected leaves).

Overall, the driest periods were in 2008 and 2009 (TP was 11 and 16 mm $m^{-2}$, respectively). The highest rainfall was observed in 2010 - 82.8 mm $m^{-2}$. Level of rainfall in the last decade of April and May, 2011 and 2012 was similar (TP was 53.6 and 60.1 mm $m^{-2}$, respectively). The highest RH during the period analyzed in study years was in 2010, in the second decade of May – 85.0% (Table 2). Statistical analysis showed significant differences between all weather parameters among the study years ($p<0.001$). The highest total precipitation (82.8 mm $m^{-2}$) and average relative humidity (77%), and the lowest air temperature (11.4 °C) were observed in 2010. Thus, this combination caused the highest severity of disease (3.5 points in average) among the study years.

Analysis of data showed correlation between severity of disease and weather conditions ($p<0.01$). Air temperature had negative correlation to severity of disease ($r = -0.021$, $p = 0.047$). Precipitation and relative humidity had low positive correlation to severity: 0.048 and 0.179, respectively ($p<0.001$).

Average disease severity was statistically different ($p<0.001$) among the years of study and it correlated with the time of the first fungicide application (Fig. 1).

Severity of European pear rust in 2008 was low – only some trees were infected and symptoms were observed only on the leaves. The spring of 2008 could be described as warm and dry; therefore, possibility for development of pathogen was limited. Research in New York about pathogen *Gymnosporangium juniperi-virginianae* Schw., which causes the cedar apple rust on apple (*Malus pumila* Mill.) showed that precipitation is a critical factor that is determining the duration of spore release period (Pearson et al., 1980). Applications of fungicides in 2008 and 2009 were carried out as for pear scab control, and that limited also the severity of European pear rust. Severity of European pear rust in 2009 increased, since environmental conditions in this year was more favourable for pathogen development – during the period of spore release there was heavy rainfall and air temperature was 15 °C. According to U. Hilber and colleagues (1990), such conditions are optimal for infection of pear trees. In 2010, all pear trees were infected by European pear rust, and severity of disease was high – 3.5 points on average. That year symptoms of disease were found not only on fruits but also on branches. Applications of fungicides in 2010 were carried out as for pear scab control. The first application of fungicides was only on May 10, but the first rainfall was on May 3. During the last decade of April and first decade of May the average air temperature was low, – 8.5 °C; therefore, primary infection could occur. In 2011 and 2012, severity of disease decreased. In this period fungicides were applied depending on pathogen live cycle that significantly decreased the disease severity.

*Evaluation of European pear rust severity depending on cultivar*

Evaluation of European pear rust severity showed that none of the tested pear cultivars (cvs.) has complete resistance to this pathogen, but have differences in susceptibility level. Similar results were obtained also by M. Fischer and H.J. Weber (2005). Lack of complete resistance was found also in a study of related species *Gymnosporangium juniperi-virginianae* on apples, which showed that each of fifty-eight cvs. and hybrids artificially infected by pathogen showed symptoms of disease (Aldwinckle et al., 1977). The severity of disease did not show significant differences among tested cvs. ($p=0.812$), it ranged from 0.8 and 0.9 points on average (cvs. 'Līva', 'Duhmyanaya' and 'Harrow Delight') to 1.4 points on average (cvs. 'Mlievskaya Ranyaya', 'Fritjof', 'Conference', 'Belorusskaya Pozdnyaya', 'Zemgale', BP-8965, 'Bere Kievskaya', 'Concorde', 'Condo', 'Mramornaya'). The highest variability among years was observed for cvs. 'Harrow Delight', 'Tavricheskaya', 'Platonovskaya', 'Conference', 'Zemgale', 'BP-8965', 'Bere Kievskaya' (Fig. 2). Cultivar 'Suvenirs' had medium symptom severity –

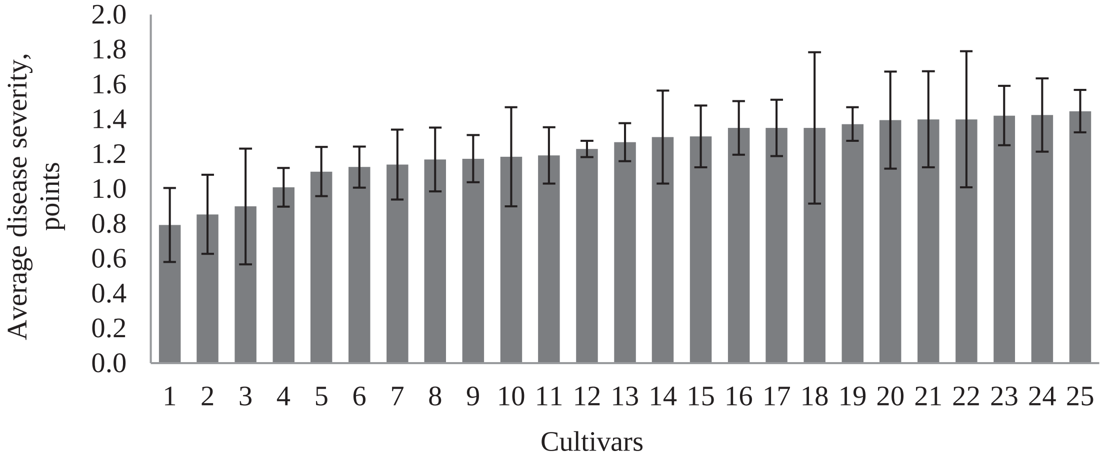


Figure 2. Average disease severity depending on cultivars in all years of study (severity scale: 0 - no infected leaves, 5 – 81% to 100% infected leaves), where: 1 – 'Liva', 2 – 'Duhmyanaya', 3 – 'Harrow Delight', 4 – AMD-42-5-28, 5 – 'Vasarine Sviestine', 6 – 'Striyskaya', 7 – 'Paulina', 8 – 'Cheremshina', 9 – 'Orcas', 10 – 'Tavricheskaya', 11 – Orlas 3-8-17, 12 – 'Suvenirs', 13 – 'Vizhnitsa', 14 – 'Platonovskaya', 15 – 'Rescue', 16 – 'Mlievskaya Ranyaya', 17 – 'Fritjof', 18 – 'Conference', 19 – 'Belorusskaya Pozdnyaya', 20 – 'Zemgale', 21 – BP-8965, 22 – 'Bere Kievskaya', 23 – 'Concorde', 24 – 'Condo', 25 – 'Mramornaya'.

1.2 points on average and the lowest variability among years of evaluation. The favourite cultivar of home gardeners 'Mramornaya' was characterized as highly susceptible to European pear rust. Cultivars used in this trial originated from nine different countries (Table 1), and data analysis did not show significant influence of cultivar origin or their possible genetic background to the disease severity (p = 0.632).

*Rootstock impact on European pear rust severity*

In the trial, pear cultivars were grown on twelve different rootstocks. Statistical analysis of data showed significant differences among rootstocks according to the severity of disease (p = 0.046). The highest severity of disease had cultivars on seedling rootstock Kirchensaller Mostbirne (originated in Germany) and clonal rootstock OH × F 333 (USA) – 1.6 and 1.5 points on average, respectively. Cultivars on these rootstocks were located in the first row of trial block and had larger,vigorously growing crown that possibly increased the severity of disease. Dwarfing rootstock BP 30 (selected at the SLU-Balsgård, Sweden) forms smaller and less vigorous trees. Pear trees on BP 30 were located inside the block behind trees of larger and vigorous size, but severity of disease was high – 1.4 point on average. Trees on BP 30 showed also high variability among years. This phenomenon could

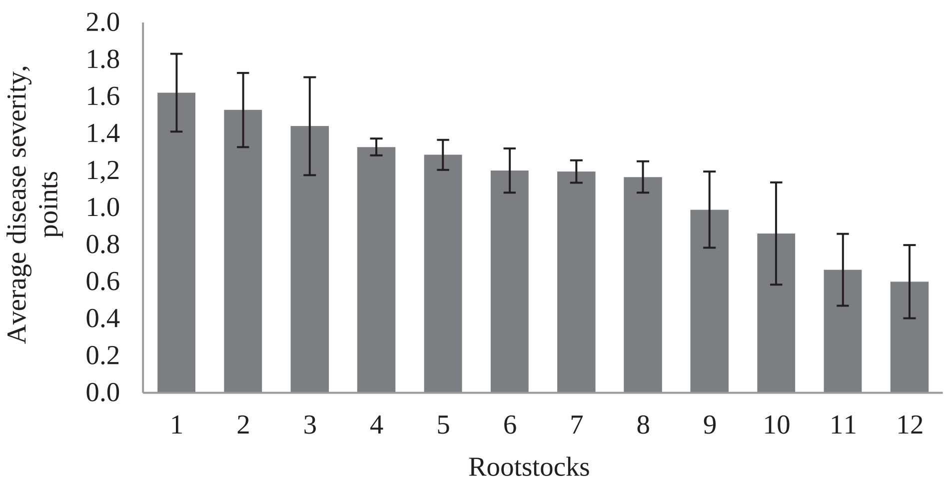


Figure 3. Impact of rootstock to average disease severity in all years of study (severity scale: 0 - no infected leaves, 5 - 81% to 100% infected leaves), where: 1 - Kirchensaller Mostbirne, 2 - OH × F 333, 3 - BP 30, 4 – Pyrodwarf, 5 – Kazraušu seedling, 6 - OH × F 87, 7 – BA-29, 8 – Plauža Kompaktais, 9 – *Pyrus ussuriensis*, 10 – Circeņa cidonija, 11 – K-TE-E, 12 – PU 20495.

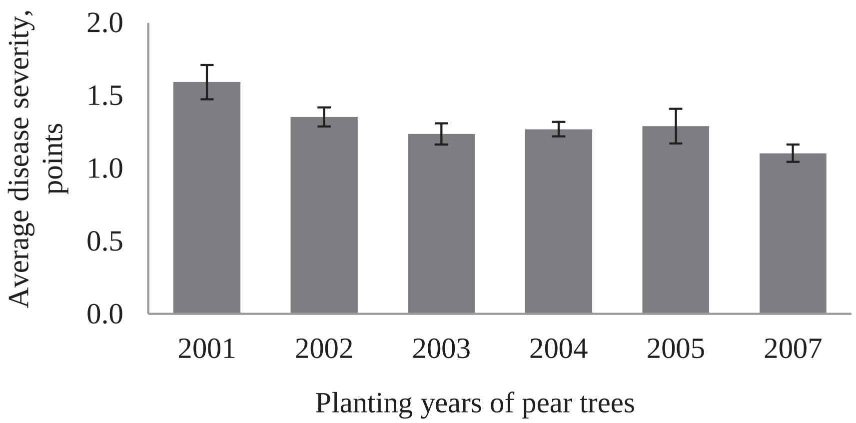


Figure 4. Average disease severity depending on planting year in all years of study (severity scale: 0 - no infected leaves, 5 - 81% to 100% infected leaves).

be explained by only one cultivar grafted on BP 30 – 'Belorusskaya Pozdnyaya', which is very susceptible to disease and had high symptom severity – 1.4 point on average (ranging from 0.0 to 4.0 points). The lowest severity was observed on rootstocks K-TE-E (Czech Republic) and PU 20495 (Latvia), 0.7 and 0.6 point on average, respectively (Figure 3). Pear trees on these rootstocks were located in the middle of the plot, it was the youngest planting and their crowns were smaller.

*Planting year impact on European pear rust severity*

Statistical analysis of data showed significant influence of tree planting year (corresponds to the age of plant and size of tree canopy) on the disease severity ($p = 0.002$). According to the results shown in Figure 4, average value of severity was higher for trees planted in 2001 (1.6 points).

These differences could be explained by location of trees planted in 2001 as well as by the size of tree. In 2001, the first and second rows of the trial were planted, which are located at the edge of the block, adjacent to the highway, and across the road there is a residential district with ornamental junipers in almost every home yard. These junipers were probably one of the sources of infection due to prevailing winds in the spring, which can transfer spores from junipers to pear trees. Trees in the first lines were larger and vigorous; therefore, they ensured the protection for next rows of pear trees. The trees planted in 2002 and 2003 are located in the middle of the block and were smaller and less vigorous, and thus allowed spores transferred by wind reach more distant rows, where stronger and larger sized trees (planted later, in 2004 and 2005) grow. Severity of disease in both years 2004 and 2005 were 1.2 points. The block planted in 2007 was the youngest one and was bordered on all sides by more vigorous trees, probably therefore severity of disease was the lowest – 1.1 point on average. Low disease severity was found also for orchards bounded by windbreaks. Although statistical analysis of data did not show significant influence on tree location ($p = 0.999$), more infected trees were located at the edges of trial block, whereas in the middle of planting the severity was lower regardless of cultivar.

Cultivar 'Suvenirs' grown in different places of pear trial had different tree planting years (2001, 2002, 2004 and 2007) and combinations with different rootstocks. Statistical analysis of data for this trial showed just the same results as previously named in this study. The data showed significant impact of tree planting year ($p < 0.001$) and rootstock ($p = 0.007$) (both correspond to the size of tree canopy) to the disease severity, but did not show significant influence to tree location ($p = 0.983$).

**Conclusions**

1. Severity of European pear rust was significantly influenced by weather conditions, showing great variation among years. The highest severity of disease could be observed in years with high total precipitation and average relative humidity as well as moderate air temperature in the period of 3$^{rd}$ decade of April to the end of May.
2. Severity of European pear rust was not directly dependent on pear cultivar or its origin as well as rootstocks and planting year.
3. Severity of disease was influenced by pear tree location in the orchard block, higher severity was observed on larger and more vigorous trees, located in outer rows, which are more exposed to the prevailing wind carrying pathogen spores.

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