Stem decay by *Stereum sanguinolentum* after red deer damage in the Českomoravská vrchovina Highlands

P. Čermák, M. Strejček

Faculty of Forestry and Wood Technology, Mendel University of Agriculture and Forestry Brno, Brno, Czech Republic

ABSTRACT: Damage caused by bark peeling and browsing by red deer to *Picea abies* was investigated in two localities in the Českomoravská vrchovina Highlands. 127 experimental plots of 50 × 50 m in size were monitored in stands aged from 15 to 93 years. In total, 44% of 16,700 inspected trees were damaged by bark peeling and browsing. The area of gaping wounds varied from 50 to 1,650 cm^2. Stem decay affected 68% of the damaged trees. Some properties of the decay were analysed from 200 sample trees felled on the plots. Bark peeling damage occurred when the trees were 4 to 48 years old. Decayed wood accounted for 22–70% (mean 42%) of the merchantable stem volume of sample trees. The mean rate of the vertical decay spread was 17.4 cm per year (ranging from 4–63 cm per year). Mean decay volume correlated positively and mean spreading rate correlated negatively with the time elapsed from the bark peeling damage occurrence.

Keywords: *Picea abies*; wound rot; stem decay; red deer; bark peeling damage; browsing damage; *Stereum sanguinolentum*

Damage to trees caused by bark peeling, browsing and subsequent stem decay are important issues for spruce stand management in the Czech Republic. A detailed inventory carried out in 1970 showed that an area of 70,000 ha of spruce stands was damaged by browsing, bark peeling and subsequent rot. In the mid 1980s, this figure rose to 106,000 ha. The last inventory in 1999 showed a total of 220,000 ha of damaged stands (Balek 2001).

At the end of the 1990s and at the beginning of the 21st century, more than 20% of the total cut of wood was damaged by rot every year, i.e. about 1.4 million m^3 (Pulpán 2001) of the forest property of the Forests of the Czech Republic, state enterprise (Lesy České republiky, s. p.). Rot caused by *Stereum sanguinolentum* dominated. Increment losses in stands damaged by bark peeling were estimated to be at least 20% at the beginning of the 1990s. When comparing the curves of development of the average height of peeled and non-peeled stands in the region of the Jeseníky Mts., Simon and Kolář (2001) found a loss in the stand growing stock amounting to approximately 20–30%, expressed as the loss in wood price at a truck landing.

In the Czech Republic, the majority of surveys carried out so far were aimed at the quantification of damage. Data on the occurrence of *Stereum sanguinolentum* in wounds and the character of its development were usually very general. Our objective was to determine the occurrence of the fungus in stands damaged by red deer bark peeling in two localities of the Českomoravská vrchovina Highlands where damage occurs very frequently and to describe, as precisely as possible, the spread of rot on the representative selection of sample trees. The obtained data were then compared with studies carried out in Europe by either similar or different methods.

MATERIAL AND METHODS

Experimental plots were selected within two forest regions: Sklené-Světnov and Račín. The size of each plot was 50 × 50 m and their total number was 127. The stand age varied from 15 to 93 years on different plots (according to forestry records).

Both localities are in the management-plan area Přibyslav (Žďárské vrchy Nature Reserve) – Skle-

Supported by the Ministry of Education, Youth and Sports of the Czech Republic, Project No. MSM 6215648902.

Table 1. The proportion of trees damaged by bark peeling and browsing and the proportion of trees with rot

Locality	Total number of trees	No. of trees damaged by bark peeling	% in the total number of trees	No. of trees with wound rot	% in the number of damaged trees
Sklené-Světnov	8,550	4,124	48	2,888	70
Račín	8,150	3,260	40	2,152	66
Total	16,700	7,380	44	5,040	68

né-Světnov at altitudes of 640–780 m, Račín at altitudes of 550–780 m. Monocultures of *Picea abies* predominate with the spruce proportion exceeding 90%. In some younger stands, group-admixed *Fagus sylvatica* occurs. The area is a part of a hunting ground with the regulated spring population of red deer 10 animals/1,000 ha. Sixty-six experimental plots were selected in Sklené-Světnov: 3 in the 1st, 23 in the 2nd, 20 in the 3rd, 18 in the 4th and 2 in the 5th age class. Sixty-one experimental plots were selected in Račín: 5 in the 1st, 21 in the 2nd, 23 in the 3rd, 12 in the 4th age class.

On each of the plots, spruce trees were classified into the following categories: healthy tree, damaged tree, damaged tree affected by rot (gaping wound, oozing wound occlusions, and wounds of large extent). In total, 16,700 trees were examined (8,550 trees in Sklené-Světnov, 8,150 trees in Račín). The monitoring was carried out in 2004 (Sklené-Světnov) and 2006 (Račín).

On selected plots, sample trees (damaged trees affected by rot) with mensurational quantities approaching the values of the mean tree were marked. On each of the plots, 5–10 sample trees (by the stand age and the number of suitable trees) were felled and studied in detail. In total, 200 sample trees were studied – 97 in Sklené-Světnov and 103 in Račín. The sample trees were measured (wound dimensions to the nearest ± 25 cm^2, total length in cm, diameter in cm, wound distance from the stem base in cm) and then cut to one-metre sections up to the point where the decay was no more visible at the upper end of the section. The last section was further cut into 5 cm discs to determine the highest point of the decay in the stem as accurately as possible. With the use of the obtained parameters and Smalian's or Huber's formula, the section volumes were calculated as well as the volumes of healthy and decayed wood. The loss of wood by decay was determined as the proportion of decay volume in the whole sample tree volume. At the wound level, a 5 cm thick disc was cut out of the stem. The block was dendrochronologically evaluated and the year of injury was determined. The rate of rot progress in cm/year was determined as the height of rot ascent divided by the number of years elapsed from the year of the damage occurrence. When determining the rate of *S. sanguinolentum* progress, we did not take into account a possibility that the infection may not have occurred in the year of the stem damage by bark peeling or browsing but in the following years. In fact, it is not possible to determine the year of infection retrospectively.

In both localities, the discs cut from the wound level were photographed with a digital camera and the percentage of decayed wood was marked out. But only in Sklené-Světnov, the cross-section area and the area of decayed wood were precisely determined at length from the photographs with the aid of LUCIA G program.

RESULTS

The monitoring showed that the proportion of trees damaged by bark peeling and browsing in

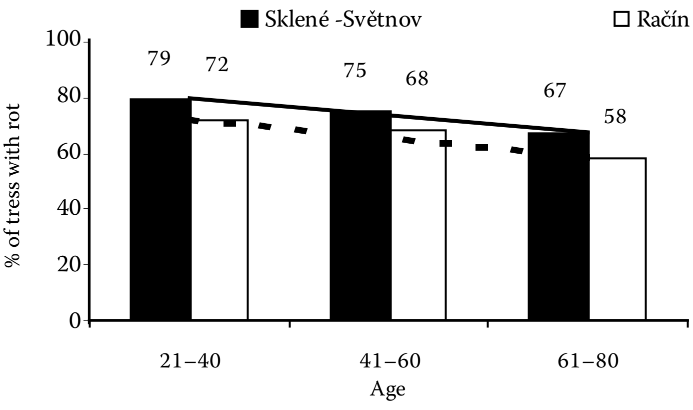

Fig. 1. The percentage of trees attacked by *Stereum sanguinolentum* in the total number of damaged trees in the particular age classes. A linear trend is marked

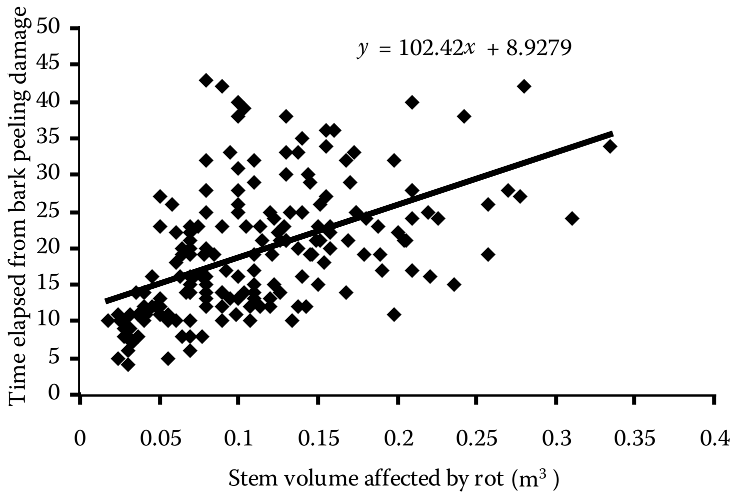

Fig. 2. Relationship between the stem volume affected by *S. sanguinolentum* rot and the time elapsed from bark peeling or browsing damage

Sklené-Světnov locality was slightly higher than in Račín. The same locality had the highest percentage of stems attacked by *S. sanguinolentum* (Table 1). The percentage of rot occurrence in both localities decreases with the age of stands (age class), with linear trends showing a very similar course (Fig. 1).

Some properties of the decay were analysed from 200 sample trees felled on the plots. Bark peeling damage occurred when the age of trees was between 4 and 48 years. The size of open wounds ranged from 50 to 1,650 cm^2 in the sample trees. One to sixty years (16 years on average) in Sklené-Světnov and four to forty-two (18 years on average) in Račín had elapsed from the year of bark peeling or browsing damage to the year of monitoring. The decay column ascended to a height of 0.2–8.0 m and its mean volume was 0.11 m^3 (0.11 m^3 in Sklené-Světnov, 0.12 m^3 in Račín). In relative values, rot affected 22 to 70% of the volume of the sample tree stem (42% on average) – 22–70% in Sklené-Světnov (42% on average), 23–70% in Račín (42% on average). The volume of wood devalued by rot correlates positively with a time period elapsed from bark peeling damage ($r = 0.510$, $P < 0.05$). The relationship is a logical result of the rot spread through the stem (Fig. 2).

The area of decayed wood in cross-section at the wound level varied from 3 to 71% (43% on average) in Sklené-Světnov and from 12 to 83% (47% on average) in Račín. The percentage of cutting face affected by rot correlates positively with the height of the rot ascent in the stem ($r = 0.665$, $P < 0.05$). There is also a correlation between the area of decayed (discoloured) wood at the wound level and the volume of decay in the stem ($r = 0.573$, $P < 0.05$) given by the regularities of rot spreading and stem geometry.

The average annual vertical spread of rot through a stem decreased with the stand age or with its age class (Table 2, Fig. 3). The average annual vertical spread of the *S. sanguinolentum* rot through a stem correlates negatively with the time period elapsed from the stem damage (Fig. 4) both in the aggregate set of sample trees ($r = –0.602$, $P < 0.05$) and in particular localities (Sklené-Světnov $r = –0.767$, $P < 0.05$; Račín $r = –0.630$, $P < 0.05$).

The wounded area did not show a significant effect either on the annual vertical spread of rot ($r = 0.336$, $P < 0.05$) or on the annual horizontal spread of rot ($r = 0.128$, $P < 0.05$). No significant relationships were found between the wound size and the tree age at the time of damage ($r = 0.101$, $P < 0.05$).

DISCUSSION

The average percentage of trees attacked by decay after bark peeling and browsing by red deer is 70% in Sklené-Světnov and 66% in Račín (Table 1).

Table 2. Average volume affected by rot and annual vertical spread of decay in different age classes (only age class II–IV) as the total of two localities

Age class	Number of sample trees	Volume of sample tree (m^3) (average)	Volume of decayed wood (m^3) (average)	% of decayed wood volume	Average age of damage	Years from damage (mean)	Rate of vertical spread (cm/year)
II (21–40 years)	90	0.14	0.06	42	19	14	19.5
III (41–60 years)	84	0.33	0.14	41	32	21	16.6
IV (61–80 years)	26	0.38	0.16	42	33	31	13.3
Total	200	0.26	0.11	42	26	19	17.4

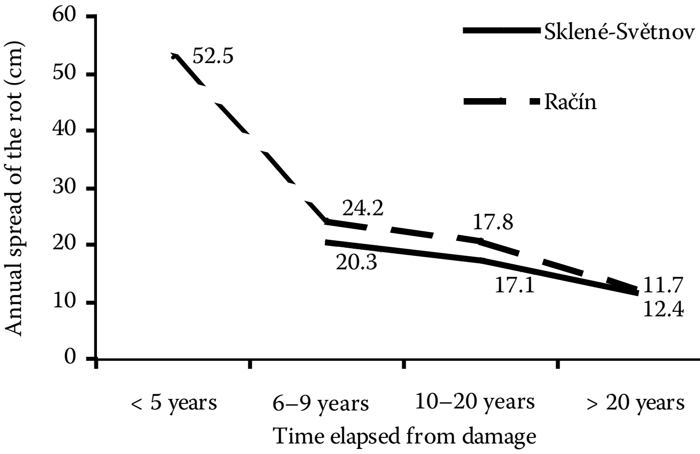

Fig. 3. Annual spread of the rot according to the time elapsed from damage

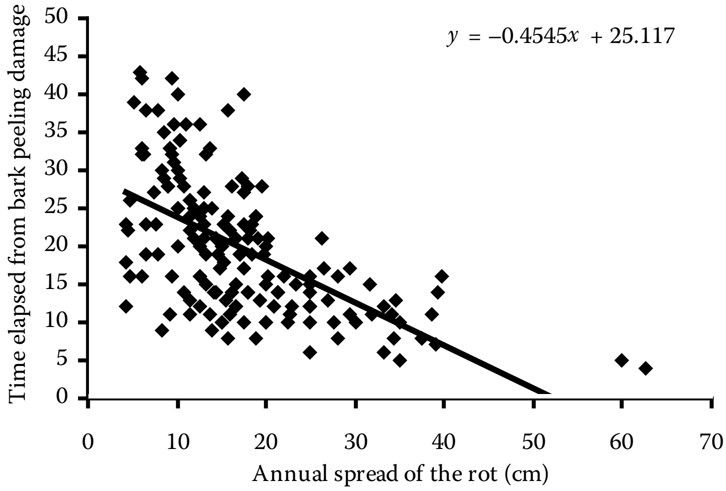

Fig. 4. Relationship between the vertical rate of the *S. sanguinolentum* rot spread and the time elapsed from bark peeling or browsing damage

These findings correspond with a number of similar research studies, for example Pechmann and Aufsess (1971) reported 60% of trees with decay. A lower proportion of attacked trees was noted particularly in the Beskids Mountains (Czech Republic) by Čermák et al. (2004) – 49%. In northern Europe the proportion was below 30% (Vasiliauskas et al. 1996; Vasiliauskas, Stenlid 1998a; Veiberg, Solheim 2000) or in the United Kingdom it was about 50% (El Atta, Hayes 1987). Higher figures of attack were found in the Drahanská vrchovina Uplands (Czech Republic) by Čermák et al. (2004) – 82%, in Russia by Smirnov (1981) – on average 82%, in Poland by Domanski (1966) – 88% and in Germany by Roeder (1971) – 99.7%.

Relationships between the age when trees were damaged by bark peeling or browsing and the percentage of these trees affected by rot could not be verified by our methods. A positive correlation between the frequency of infection and the age when the damage occurred was supported by Vasiliauskas et al. (1996). A decreasing trend of the proportion of trees attacked by rot with the age of monitored stands (Fig. 1) needs to be interpreted particularly as a result of tending felling. The rigorous health selection when most damaged trees with visible rot are preferentially removed (with open dry wounds of a large extent or with moist wounds) results in the elimination of a number of trees in the stand only at the expense of trees with rot. The effects of tending felling on the found percentage of attack are significantly higher than the effects of age when the damage by game occurred. Thus, the assumption that the wounds of smaller size originating due to rough bark on older trees participated in the decreasing trend of the proportion of trees with rot was not proved. The correlation between the size of the wound and its age when it originated is not significant. The prevailing origin of stem damage by game at an age of 10 to 35 years can be interpreted by smooth bark and the absence of lower branches protecting the stem of the youngest trees to a certain extent. The preference of stands aged 10 to 40 years was also found in other European studies: 21–40 years (Eckmüllner 1985), 15–30 years (Koltzenburg 1985), 10–20 years (Girompaire, Ballon 1992), 18–38 years (Gill et al. 2000).

The annual vertical spread of rot through a stem ranging from 4 to 63 cm/year corresponds with other data from the Czech Republic determined by

Table 3. Rate of vertical spread and horizontal spread (growth of the area of decayed wood in cross-section)

Locality	Rate of vertical spread (cm/year)		Rate of horizontal spread (cm^2/year)		Average % of decayed wood in cross-section
	average	range	average	range	
Sklené-Světnov	15.3	4.2–37.5	31	5–78	43
Račín	19.5	4.2–62.5	–	–	47

the same methods; Čermák et al. (2004) reported a range of 1–70 cm/year. The mean rates of rot spread from individual localities correspond to the rates determined in previous studies (Pawsey, Stankovicova 1974; Roll-Hansen, Roll-Hansen 1980; Vasiliauskas, Stenlid 1998b). Data on the lateral spread of rot (31 cm^2/year, on average 43% of decayed wood in cross-section) in Sklené-Světnov are slightly higher than those reported in the study of Vasiliauskas and Stenlid (1998b), in which the average proportion of the rot-affected area in cross-section at the place of the wound was 36.8% and the rot spread at an average rate of about 20 cm^2/year.

The determined negative correlation between the annual vertical spread of rot through a stem and the time elapsed from the stem damage proves the supposed retardation of rot spread with the time elapsed from the stem infection. The same conclusion was also drawn by Čermák et al. (2004). The calculated values of correlation coefficients (see Results) indicate that rot spreads through a stem evenly, both vertically and horizontally (laterally). Vasiliauskas and Stenlid (1998b) arrived at the same conclusion although the relationship determined by the authors was less significant ($r = 0.474$, $P < 0.001$).

No relationships were found between the wounded area and the rate of vertical or lateral spread of rot. Vasiliauskas and Stenlid (1998b) came to the same result. Relationships between the size of wounds and the percentage of stems infected by *S. sanguinolentum* were not determined. A number of authors mentioned a higher probability of stem infection by *S. sanguinolentum* (in *Picea sitchensis* as well as *Picea abies*) in larger wounds (Löffer 1975; Roll-Hansen, Roll-Hansen 1980; El Atta, Hayes 1987; Gill et al. 2000). However, *Picea abies* is attacked by *S. sanguinolentum* relatively intensively even in cases of small gaping wounds as supported by this paper and by other papers (Gregory 1986; Gill 1992; Gill et al. 2000). Roll-Hansen and Roll-Hansen (1980) or Vasiliauskas et al. (1996) reported that wounds larger than 50 cm^2 showed good conditions for infection. Considering the present conditions it is possible to suppose that the noticeable effect of the size of wounds on rot penetration and spread is particularly evident in smaller wounds. In larger wounds, the rate of rot occurrence does not markedly increase any more. Roeder (1971) even stated that in wounds longer than 120 cm it was not possible to find a significant relationship between the time elapsed from damage and the vertical spread of rot in the stem. In addition to the size of the wound on the stem surface a certain role can also be played by its depth. The infection by *S. sanguinolentum* rather occurs, to a greater extent, in stems where wood was damaged as well, compared to stems where only bark was damaged (Pawsey, Stankovicova 1974).

References

BALEK J., 2001. Hniloby dřeva – dlouho přehlížený problém. Zprávy lesnického výzkumu, *46*: 117–118.

ČERMÁK P., JANKOVSKÝ L., GLOGAR J., 2004. Progress of spreading *Stereum sanguinolentum* (Alb. et Schw.: Fr.) Fr. wound rot and its impact on the stability of spruce stands. Journal of Forest Science, *50*: 360–365.

DOMANSKI S., 1966. Próba fytopatologicznej oceny swierkow ospalowanych przez zwierzyne w Karkonoszach. Folia Forestalia Polonica – Serie A Leśnictwo, *12*: 157–174.

ECKMÜLLNER O., 1985. Die Schal- und Ruckeschaden in Wirtschaftswald/Hochwald. Ergebnisse der österreichischen Forstinventur 1971–1980. Zentralblatt für das Gesamte Forstwesen, *102*: 190–214.

EL ATTA H.A., HAYES A.J., 1987. Decay in Norway spruce caused by *Stereum sanguinolentum* Alb. & Sch. Ex. Fr. developing from extraction wounds. Forestry, *60*: 101–111.

GILL R., 1992. A review of damage by mammals in north temperate forests: 3 Impact on trees and forests. Forestry, *65*: 683–686.

GILL R., WEBBER J., PEACE A., 2000. The economic implications of deer damage. [Final Report for The Deer Commission for Scotland.] Wrecclesham, Forest Research Agency.

GIROMPAIRE L., BALLON P., 1992. Conséquences de l'écorçage du cerf elaphe dans le Massif des Vosges Alsaciennes. Revue forestière française, *44*: 501–511.

GREGORY S.C., 1986. The development of stain in wounded Sitka spruce stems. Forestry, *59*: 199–208.

KOLTZENBURG C., 1985. Schutzwirkung durch mechanisch-biologischen Schalschutz in Fichtenbeständen. Forst und Holzwirt, *40*: 471–475.

LÖFFER H., 1975. The spread of wound rot in Norway spruce. Forstwissenschaftliches Centralblatt, *94*: 175–183.

PAWSEY R.G., STANKOVICOVA L., 1974. Studies of extraction damage decay in crops of *Picea abies* in southern England. I. Examination of crops damaged during normal forest operations. European Journal of Forest Pathology, *4*: 129–137.

PECHMANN H., AUFSESS H., 1971. The organisms causing stem rot in spruce stands. Forstwissenschaftliches Centralblatt, *90*: 259–284.

PULPÁN L., 2001. Vliv hospodaření na vznik hnilob. Zprávy lesnického výzkumu, *46*: 135–136.

ROEDER A., 1971. The effect of deer barking on spruce: surprising results. Allgemeine Forstzeitschrift, *26*: 907–909.

ROLL-HANSEN F., ROLL-HANSEN H., 1980. Microorganisms which invade *Picea abies* in seasonal stem wounds. I. General aspects. Hymenomycetes. European Journal of Forest Pathology, *10*: 321–339.

SIMON J., KOLÁŘ C., 2001. Economic evaluation of bark stripping by red deer on the basis of analysis on a time growth series of spruce stands in the Hrubý Jeseník Mts. Journal of Forest Science, *47*: 402–409.

SMIRNOV K.A., 1981. Effect of elk damage to spruce bark on increment and species succession in the southern taiga. Lesovedenie, *4*: 56–65. (In Russian)

VASILIAUSKAS R., STENLID J., 1998a. Fungi inhabiting stems of *Picea abies* in a managed stand in Lithuania. Forest Ecology and Management, *109*: 119–126.

VASILIAUSKAS R., STENLID J., 1998b. Spread of *Stereum sanguinolentum* vegetative compatibility groups within a stand and within stems of *Picea abies*. Silva Fennica, *32*: 301–309.

VASILIAUSKAS R., STENLID J., JOHANSSON M., 1996. Fungi in bark peeling wounds of *Picea abies* in central Sweden. European Journal of Forest Pathology, *26*: 285–296.

VEIBERG V., SOLHEIM H., 2000. Rot after deer damage in spruce in Sunnfjord. Rapport fra Skogforskningen, *18*: 16.

Received for publication July 18, 2007
Accepted after corrections October 9, 2007

Hniloba *Stereum sanguinolentum* po poškození jelení zvěří na Českomoravské vrchovině

ABSTRAKT: Na dvou lokalitách na Českomoravské vrchovině bylo sledováno poškození smrku *Picea abies* loupáním a ohryzem kůry způsobenými jelenem lesním. Celkem bylo monitorováno 127 ploch o velikosti 50 × 50 m v porostech ve stáří 15–93 let. V souhrnu bylo 44 % z 16 700 stromů poškozeno loupáním a ohryzem, 68 % z poškozených stromů bylo zasaženo hnilobou *Stereum sanguinolentum*. Velikost ran po loupání a ohryzu byla od 50 do 1 650 cm^2. Na plochách bylo skáceno celkem 200 vzorníkových stromů s prezencí hniloby. K poškození loupáním u nich došlo ve věku 4–48 let. Hnilobou bylo zasaženo 22–70 % hmoty kmene vzorníku (v průměru 42 %). Hniloba se v kmeni vertikálně šířila průměrnou rychlostí 17,4 cm/rok (v rozsahu od 4 do 63 cm/rok). Objem znehodnocené hmoty koreluje s dobou uplynulou od poškození loupáním, rychlost postupu negativně koreluje s dobou uplynulou od poškození kmene.

Klíčová slova: *Picea abies*; ranová hniloba; hniloba kmene; jelen lesní; loupání; ohryz; *Stereum sanguinolentum*

Corresponding author:

Doc. Ing. Petr Čermák, Ph.D., Mendelova zemědělská a lesnická univerzita v Brně, Fakulta lesnická a dřevařská, Lesnická 37, 613 00 Brno, Česká republika
tel.: + 420 545 134 119, fax: + 420 545 211 422, e-mail: cermacek@mendelu.cz