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Stem cracks of Norway spruce (*Picea abies* (L.) Karst.) provenances in Western Latvia

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Abstract. Stem cracks are damaging for timber quality and can reduce the monetary value of a tree both directly and indirectly: serving as gateway for fungal infections. Aim of the study was to assess the influence of tree dimensions and seed origin on the frequency of stem crack for Norway spruce. The study was carried out in two contiguous provenance trials (material from 12 countries), established in 1972 and 1975 in Western Latvia. Stem cracking was assessed using five-score scale. Most of the affected trees (90%) had very light or light damage. There was no relation of diameter at breast height to incidence of stem cracks. Analysis revealed a significant provenance effect on occurrence of stem cracks. Russian provenances tended to have lower risk of stem cracking and relatively narrow variation within the region, while Baltic and Ukrainian origins had wide range of stem cracking, having best as well as worst provenances in terms of cracking. Overall it is possible to select fast growing provenances with relatively low incidence of stem cracks.

Key words: stem defects, stem scars, provenance transfer.

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Introduction

Norway spruce (*Picea abies* (L.) Karst.) is widespread and economically important tree species in the Baltic Sea region (Schelhaas *et al.*, 2006). It is shade tolerant and therefore can be used not only in clear cutting system, but also in continuous cover forestry (Westin & Haapanen, 2013). The species is not too demanding to weed control and responds well to improved growth conditions (Liepins *et al.*, 2008; Jansons *et al.*, 2016; Klavina *et al.*, 2016). However, it is prone to different risks including wind, browsing and fungi (Modrzynski, 2007; Mullin *et al.*, 2011; Burnevičа *et al.*, 2016).

Intensive breeding of Norway spruce is carried out in most of the Baltic Sea region countries (Jansons *et al.*, 2015). It ensures the possibility to substantially increase the productivity (Jansons *et al.*, 2006; Jansons, 2008; Mullin *et al.*, 2011). For this purpose, as well as to test the possibilities for adaptation to climatic changes and better utilization of the growth conditions (namely – vegetation period) (Neimane *et al.*, 2016) provenances are transferred and tested, and results of such test used in recommendations for practical forestry and further breeding (Giertych, 2007). Usually the evaluation and selection of the best-performing genotypes for seed orchards and further breeding is carried out at the age of ~12–14 years, however, a number of potential risks cannot be assessed at so early age. One of such risks is stem cracks, which tend to appear in 15–35 years old spruce stands (Dietrichson *et al.*, 1985; Persson, 1994). The damage usually appears as longitudinal cracks with length varying from few centimetres to several

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meters and radially leads into the stem, occasionally until the pith (Dietrichson *et al*., 1985). Cracks may also be closed and seen as a scar in the bark with a stained black coverage, under which a crack can be healed if the cambium is able to overgrow the open wound (Persson, 1994).

Cracks can be caused by lightning, wind, drought or frost (Persson, 1994; Cherubini *et al*., 1997). Most probable cause of the cracks for *P. abies* seems to be late summer droughts. During drought periods in hot summers, tension inside tracheid increases with increasing water deficit until cell collapse, when hydrostatic tension in tracheids exceed the fracture limits of the middle lamella (Kramer & Kolowski, 1979, cited by Dietrichson *et al*., 1985; Caspari & Sachsse, 1990; Mattheck & Kubler, 1997; Grabner *et al*., 2006).

Stem cracks are damaging for timber quality both directly and indirectly serving as gateway for fungi. For example, in an analysis of browsing damage in a 30-year-old Norway spruce stand decay was found in 13–50% of the wounded stems (Burneviča *et al*., 2016). Similarly, a large number of fungi (28 taxa) was isolated from browsing damages of *Pinus contorta* Douglas ex Louden (Arhipova *et al*., 2015). Despite the potential importance, few studies have addressed the issue of stem cracks of Norway spruce, especially in the Baltic States. Therefore, the aim of our study was to assess the influence of tree dimensions and seed origin on the frequency of stem cracks for Norway spruce.

Material and Methods

The two Norway spruce provenance trials examined are located in Western Latvia (56°51′ N; 22°31′ E). The trials had been established in 1972 (Saldus 1972) and 1975 (Saldus 1975) and incorporate 70 provenances from 12 regions (Table 1).

Stem damage was assessed in summer 2016 using a five-score scale. Short (a few centimetres) and shallow cracks in the bark, not reaching the wood, were rated with score one. Light damage (score 2) was a shallow crack in the bark (similar but longer than for trees with score 1), up to around 1 m. Moderate damage (score 3) was a crack in the bark and reaching the wood, or from 1 to 2 m long closed scars with stained black coverage. Severe damage (score 4) was a crack reaching deep in the wood and scars with stained black coverage longer than 2 m. Very severe damage (score 5) consisted of one or more open stem cracks several metres long and radially reaching deep into the stem towards the pith.

The trials were established on agricultural land with moderately fertile mineral soil with normal moisture regime (corresponding to *Hylocomiosa* or *Oxalidosa* forest type) using 2-years-old seedlings. Planting distance was 2 × 1 m with initial density 5000 trees ha^{-1}. The experimental design comprised block plots (15 trees) in 8 blocks. Tending was carried out, but data about thinnings before year 2005 are missing. The trials were seriously damaged by a storm in 2005. After the storm and salvage logging only 52.2% (Saldus 1972) and 39.1% (Saldus 1975) of trees remained in comparison to the figures before the storm (year 2004). Therefore, most of the calculations were based on measurements of *DBH* for all the trees from year 2004 to more correctly represent growth potential of different provenances. When comparing dimensions between trees with and without stem cracks, measurements from year 2004 for trees still alive in 2015 were used.

For the *DBH* and *H* means and 95% confidence intervals (*CI*) were calculated. Since mean *DBH* and *H* for both trials did not differ significantly, all data were analysed together. Due to very uneven structure of blocks after storm, it was not possible to incorporate effect of them in calculations.

Table 1. Overview of material used in the trials.

Region	Provenances		*DBH* ± 95% *CI*, cm **	*H* ± 95% *CI*, m **	*No.* of tress in 2004	*No.* of trees in 2015	Incidence of stem cracks (variation within region), % ***
	No	Names*					
Denmark	2	Hazede, Nidebe	15.9±1.43	14.9±0.54	48	22	36.4 (33.3–42.9)
Baltic region	31	Jurbaka, Bērzgale, Katleši, Kalupe, Krāslava, Līgatne, Mazsalaca, Ogre, Raņķi, Aizpute, Irlava, Kuldīga, Remte, Valdemārpils, Ņemencina, Panevežys, Prjanu, Smalininka, Augstroze, Bānūži, Jaunkalsnava, Mazsalaca, Ogre nursery, Raņķi, Sece 1, Sece 2, Taurkalne, Zaļumi, Bēne, Blīdene, Kalvene	16.2±0.28	16.3±0.13	834	383	29.9 (5.6–62.5)
Norway	1	Telemark	16.1±1.41	15.5±0.98	31	12	50.0
Romania	2	Dorna Cinderni, Levisen	17.8±1.49	15.7±0.68	43	17	41.2 (33.3–50.0)
Slovakia	3	Benus, Smolnik, Zakamenne	16.1±0.93	15.2±0.64	74	27	37.0 (25.0–46.7)
Finland	1	Solböle	11.9±1.56	12.7±0.95	21	11	36.4
Ukraine	12	Delatina, Hripileva, Laziscinska, Razlucka, Scepotska, Skole, Turbatska, Vinster, Bogdan, Guklive, Mislivka, Torun	17.1±0.61	16.0±0.26	248	99	37.1 (11.1–63.6)
Hungary	1	Geistervielsen	14.6±2.07	14.2±1.22	24	9	33.3
Germany	12	Babben, Grunhaus, Kobeln, Krauschwitz, Krinitsch, Reinhardsdorf, Rottenkirche, Thuringer Wald, Totenkopf, Triebeschwitz, Weisswasser, Westerhof	16.0±0.50	14.9±0.24	323	132	28.0 (15.8–55.0)
Russia	4	Drtuznoselska 44, Druznoselska 54, Kartasevo, Orlinska	16.1±0.77	16.5±0.41	111	64	21.9 (11.1–33.3)
Sweden	1	Stallarp	15.0±2.31	15.0±1.45	17	9	33.3
Total	70		16.2±0.27	15.3±0.14	1774	785	31.1 (5.6–63.6)

*Names of provenances as stated in the trial establishment documentation; no geographical coordinates were available.
**Measurements from 2004.
***Assessed in 2015.

Generalized linear model was used to evaluate incidence of different cracking severity (cracking scores) choosing *DBH* as a quantitative covariate and provenance as a qualitative covariate, and using Poisson distribution with "log" link function.

Results and Discussion

The average incidence of stem cracks in the trials was 31.1%. However, most of the affected trees (90% from the trees with stem cracks) had only light (score 1 and 2) cracks, usually limited to the bark (Figure 1).

There was found no significant relation between *DBH* and occurrence of stem cracks (p = 0.59) (Figure 1). Notably, but not significantly, more frequent cracking was observed in smallest *DBH* class (Figure 2). However, no severe cracks were in that class. Napola & Napola (2014) found in most of the cases no correlation between *DBH* and frequency of stem cracks. In contrast to our results, Persson (1994) reported, that spruces with larger diameter – growing at the edge of the stand (gap within the stand) or in wider spacing – tend to have stem cracks more frequently. Vasiliauskas *et al.* (2001) based on analysis in seed orchards, found that within a clone trees with larger *DBH* are more likely to have cracked stems. Contradiction between finding of the studies might be result of different stand densities or different methodology, namely – how large damage was considered a stem crack. In our study light stem damage was found in a majority (90%) of the affected trees. In further studies in Latvia it would be advisable to investigate stands with more severe stem cracks to reveal any possible relations.

Provenance was a significant factor (p = 0.01) determining the incidence of stem cracks with different severity. Incidence of stem cracks among provenances varied from 5.6% (Kalvene, Latvia) to 63.6% (Hripileva, Ukraine). Kalvene, Kartasevo, Jaunkalsnava, Babben and Grunhaus were provenances showing significantly lower

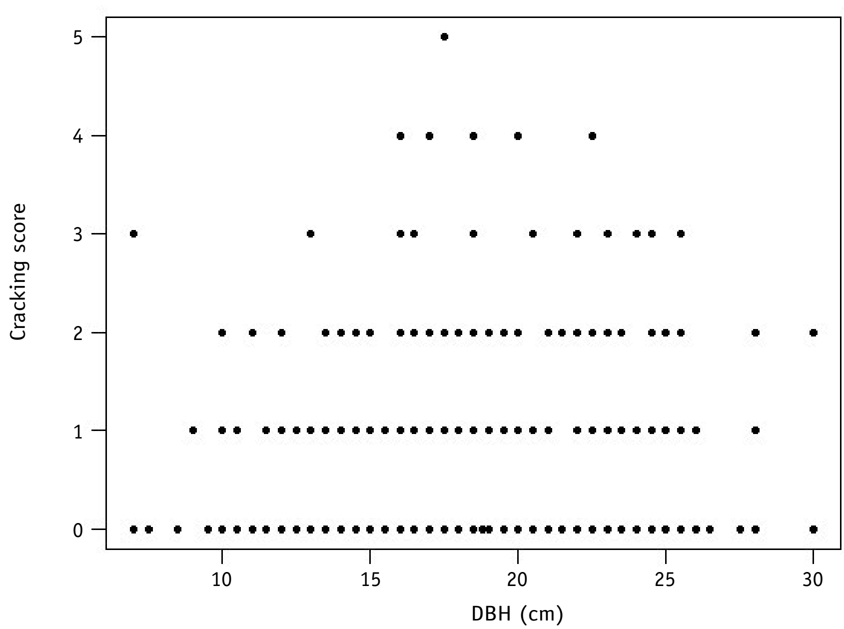

Figure 1. Difference in DBH among trees with different cracking severity.

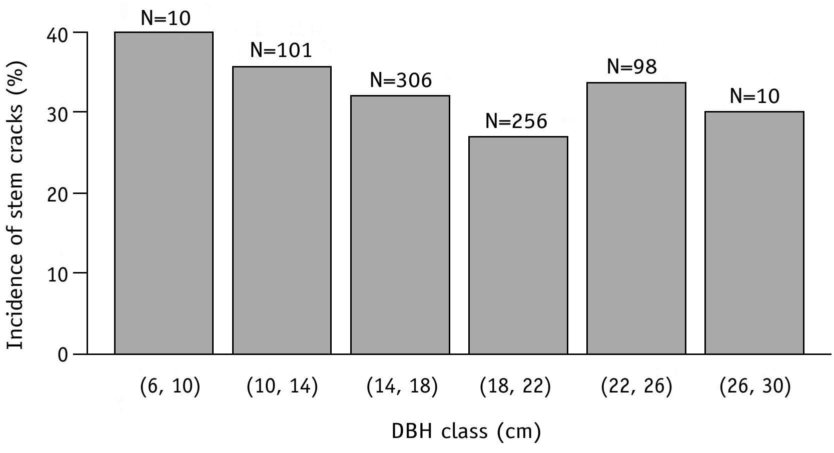

Figure 2. Incidence of stem cracks by DBH classes.

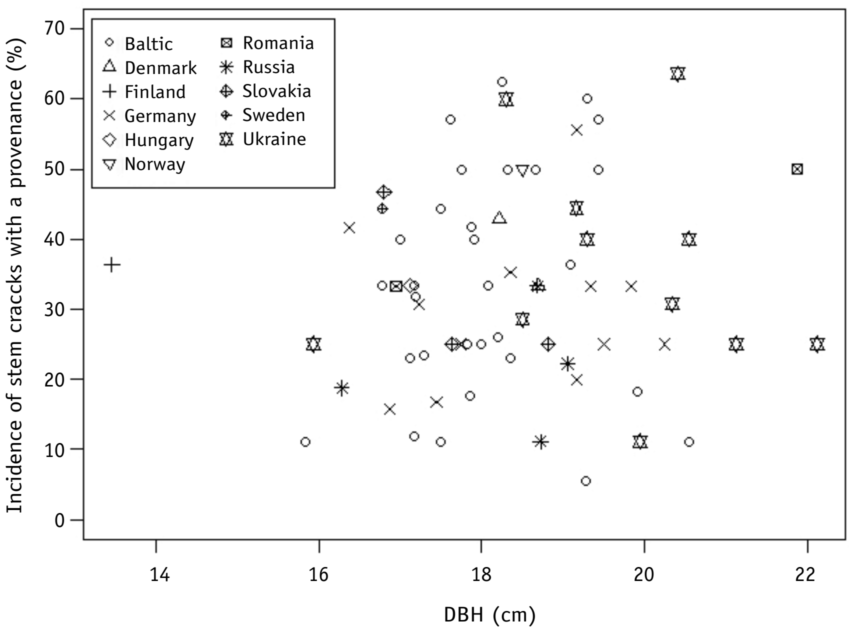

Figure 3. Difference in DBH and incidence of stem cracks among material origin regions.

risk of cracking, while Hripileva, Līgatne, Scepotska, Taurkalne and Bogdan were more prone to the damage than other provenances. The least affected provenances were from Baltic region, Russia and Germany, but most affected represented Ukraine as well as Baltic region. Overall at seed source region level the least frequently damaged were seedlots from Russia (21.9%) and Germany (28.0%), but the most frequently were affected trees of Norwegian (50.0%), Romanian (41.2%) and Ukrainian (37.1%) origin (Table 1). Besides, range of stem cracking frequency for Russian provenances was relatively narrow (11.1–33.3%). Other provenances tend to show wide range of stem cracking frequency within a seed source region (Table 1). From Baltic region come both the least and the most cracking provenances (range of provenance differences was 5.6%–62.5%). Even though some of the most affected provenances were from Ukraine, it is also possible to select seedlots from this region with relatively high mean *DBH* and low frequency of stem cracks (Figure 3). Overall it indicates a potential to select fast-growing material with low frequency of this stem defect. However, it is not adequate to evaluate such regions as Norway, Finland, Sweden and Hungary, since they are represented in this study with only one provenance each.

The least affected provenances in earlier reports seem to resemble so called "north-eastern region" of Norway spruce with greatest wood volume, which includes Northeast Poland, Baltic States, Northern Belarus and Western Russia (Giertych, 2007), which partly correspond to results of the present study. Earlier studies indicate negative effect of material transfer from Central Europe northward to Fennoscandia (Dietrichson *et al*., 1985; Persson, 1994; Napola, 2014). In Southern Sweden high frequency of cracked stems for Romanian and Slovakian provenances, but less damage than expected was observed for Baltic and Belorussian provenances (Persson & Persson, 1992; Persson, 1994). Seedlots from Finland, Northern Poland and Western Russia were among least damaged in Southern Sweden and Norway. Also Norwegian and Swedish provenances had reduced number of cracked stems, but high proportion of trees with stem cracks was observed in provenances from Southern Germany, Denmark and Southern Sweden (Dietrichson *et al*., 1985). Napola & Napola (2014) observed severe cracks and wounds for Norway spruce of German origin in Finland. Contradiction between the earlier reported findings and results of our study might be explained by the location of the experiment (differences in climatic conditions or particular set of meteorological conditions causing the cracks) as well as by particular provenances included in respective trials.

Conclusions

In the trials tree dimensions was not a significant factor affecting the occurrence of stem cracks. Provenance was a significant factor determining the occurrence of stem cracks. No clear tendency in stem cracking for provenances transferred over long distances was observed. Local material from Baltic region varied much in terms of frequency of stem cracks. Russian provenances tended to have lower risk of stem cracking and relatively narrow variation within the region, while careful selection among provenances of Baltic and Ukrainian origin would be necessary.

It is possible to select fast growing provenances with low incidence of stem cracks, since occurrence of stem cracks is not related to *DBH* at provenance level. Therefore evaluation of occurrence of stem cracks at least at the provenance level is advisable before the decision on suitability of the reproductive materials for use in a particular region.

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