The extent of root rot damage in Norway spruce stands established on fertile sites of former agricultural land

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ABSTRACT: The aim of this study was to compare the degree of root rot damage in two large complexes of Norway spruce stands established on former agricultural land at fertile sites. The root rot infection was observed on the stump cutting area on both intended and salvage clear fellings. Stands in Kružberk area in the Nízký Jeseník Mts. established on arable land showed very poor stability and large root rot damage at the age of 40–50 years. In contrast, stands in Lužná area in the Javorníky Mts., founded on former sheep pastures, were markedly much less damaged at the age of 90–110 years and proved to be able to provide quality timber, although they were damaged by the root rot as well.

Keywords: afforestation of agricultural land; Kružberk area; Lužná area; Norway spruce; root rot

Agricultural overproduction in Europe is the main reason for rising interests in the afforestation of agricultural land. The present EU agricultural policy has resulted in a new wave of afforestation, which means that the forestry sector will have to cope with the specificities of this problem. There were several waves of afforestation in history and many high-quality stands were founded on agricultural land. Therefore we should learn from the present state of these forest stands to establish stable and productive stands and especially not to repeat the mistakes of the past.

The quantitative side of timber production is not usually the problem here, because agricultural land is usually more productive than forest land. However, afforestation is different from reforestation in many aspects, which brings some problems concerning particularly the stability of some tree species. Most conifers and especially Norway spruce (*Picea abies* [L.] Karst.) are endangered on former agricultural land by primary parasitic wood-damaging fungi – *Heterobasidion annosum* (Fr.) Bref. and *Armillaria ostoyae* (Romagn.) Herink. It is a well-known fact that Norway spruce stands established on abandoned agricultural land after World War II are today heavily damaged by the red rot of *Heterobasidion annosum* and their stability is rather poor. The danger of upcoming climate change is also expected to increase the damage caused by *Heterobasidion annosum*, especially at water-affected and former agricultural sites (Jankovský 2002).

The site history is a very important factor determining the intensity of *Heterobasidion annosum* infection. In order to understand the behaviour of the fungus at a given site it would be important to know the earlier stand composition, the former use as a pasture or arable land, and the thinning and felling regimes used, as well as other management practices carried out in the stand (Korhonen, Stenlid 1998).

Damage caused by *Heterobasidion annosum* is usually greater on land formerly used for agriculture than on old forest soils. The disease usually starts after the first thinnings. The risk is especially high in fields with high lime content and pH > 6, which is partially due to the low amounts of antagonistic *Trichoderma* and *Penicillinum* species in agricultural

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soils in general and alkaline soils in particular. Another factor favouring the disease is the development of superficial root systems due to subsoil compaction, which increases the number of root contacts and helps the vegetative spread of the fungus from tree to tree (Kornhonen, Stenlid 1998).

Problems with water supply are often mentioned as one of the main reasons for severe root rot damage in Norway spruce stands. The superficial root system on former agricultural land suffers from water deficiency in dry periods and therefore the concentration of fungistatic substances in the phloem decreases, which along with the turgor decrease makes the trees more prone to the fungal infection (Černý 1989).

MATERIAL AND METHODS

The aim of this study was to compare the degree of root rot damage in two large complexes of Norway spruce stands established on former agricultural land at fertile sites in two upland regions of Moravia. The basic idea was to find differences in the health condition between stands of these two areas, which had the same species composition (pure spruce) and the same or comparable typological units (group of forest types), whereas both complexes were proved to be the first generation of forest on former agricultural land.

The first complex (Kružberk area) is situated in the Nízký Jeseník Mts. west of the Kružberk dam on the Moravice River. The stands of today's 3rd to 5th age classes were founded in abandoned fields at an altitude of 460–620 m a.s.l. after the German population of the village of Herzogwald had been expelled after World War II (Mareš 2005).

The second complex (Lužná area) is situated in the Javorníky Mts. northeast of the village of Lužná. These stands were founded on former sheep pastures about a hundred years ago when the need for quality spruce timber had emerged in this region. These stands lie on a steep southern slope at an altitude of 550–730 m a.s.l. Military maps from the 18th and 19th century were used to verify that these stands were really the first generation of forest on former pastures. The first local afforestation activities date back to the last quarter of the 19th century. The oldest stands from the first afforestation period, which started in 1875, have already been mostly cut down and reforested. The present study is aimed at spruce stands from the second wave of afforestation, which was conducted after 1896 (Žaloudík 1984).

The main problem concerning the detection of root rot damage on living trees of younger age is that the symptoms are not always apparent. Symptoms of *Heterobasidion annosum* root rot in living trees are not characteristic and cannot be distinguished from those caused by other root diseases. In spruce, extensive butt rot can develop within the stem of a living tree, without any external symptoms (Greig 1998).

The degree of fungal attack was therefore analyzed on the surface of stumps on clear-cut areas. The clear cuts were both planned final cuts (Lužná area) and salvage cuttings and planned reconstruction clear cuttings (Kružberk area). The particular species of fungi were not identified within this study. The own five-class scale (Table 1) was used to assess the degree of rot damage to each single stump on a clear-cut area. The percentage of these classes was calculated for each plot. The survey was made by one person, so the subjectivity of such an assessment allows to compare single plots among themselves and both complexes of the studied forests with each other.

In Kružberk area seven plots were assessed in total. There were two plots set in the large stand 412C5 (Forest Management Plan as of 1. 1. 2003) to compare different terrain orientation of two separate clear-cuts – plot K3a was on a hill top and plot K3b was on its northern side, but both plots were still in quite a plain terrain.

In some stands almost all trees were damaged by deer barking, but there were some stands (412C5 and 401B5, i.e. plots K3a, K3b and K5) near the village of Dvorce where there was not any kind of such damage. This made it possible to compare the rot damage in stands with and without the influence of deer barking and later the infection by secondary parasitic fungi. The cause of salvage fellings was a windthrow in most cases and also bark beetles in small plots. These spots were usually extended into

Table 1. Classification of stumps according to the degree of root rot damage

Class	Extent of rot damage
1	healthy, no signs of fungal attack on the stump cutting area
2	small area of hard rot up to 10% of stump area, marginal soft rot up to 5%
3	large hard rot, small soft rot area, between classes 2 and 4
4	large soft rot above 30%
5	whole stump area rotten or a large central hollow

a larger reconstruction harvest and the survey was carried out on the whole clear-cut areas.

In Lužná area (Forest Management Plan as of 1. 1. 2000) ten sample plots were assessed, which were all intended final fellings. Two clear-cut areas (in stands 2h9 and 2o10) were divided after a reconnaissance into two sample plots because of two reasons. The clear-cut area in stand 2h9 was divided in the map of forest site types into two parts with different altitudinal vegetation zones (forest types 4B1 and 5B1), so it was decided to set two separate sample plots there according to this border to find out if there is any difference in root rot damage.

The clear cut in stand 2o10 was divided into two sample plots (L6a and L6b), because its large part was situated on a small and rather elevated stony ridge with apparently different site conditions from the rest of the clear-cut area, although this was not differentiated in the type map.

Chi-square statistic (programme Unistat version 5.1) was used to compare the distribution of rot classes and to detect the frequency dependence among individual plots within both areas (Lužná and Kružberk) to see if there is a statistical difference. This was also done to compare the plots in stands with and without the deer barking damage in Kružberk area.

RESULTS AND DISCUSSION

All plots in Kružberk area (Table 2) showed great root rot damage. The most surprising fact is that the plots in stands without any signs of old deer barking damage (K3a, K3b, K5) had worse results compared to stands greatly damaged by game and secondary fungal infection. The difference is, however, only in the degree of rot on the stumps, as nearly all stumps in the whole Kružberk area showed signs of rot infection. Stands without the deer barking damage lie very close to the village of Dvorce, where the intensity of former soil cultivation and fertilizing is expected to have been quite high. This only proves the fact that on fertilized arable land the red rot of *Heterobasidion annosum* is a real threat to Norway spruce disregarding additional damage to stems caused by game. The least rot damage within Kružberk area was found on plot K2 with some healthy stumps. Also the forest type (5S1) is different there from the other stands, which suggests that the stands at less fertile sites are more resistant to rot. No significant difference was found between two plots (K3a, K3b) in stand 412C5 (Table 4).

The fact that the plots in Kružberk area were set on salvage cuttings may have slightly influenced the objectivity of obtained results for the whole area, but there were no indications that the root rot damage to surrounding and still standing trees could have been significantly lower.

Spruce stands established on former sheep pastures in Lužná area about a hundred years ago have a much better health condition from the aspect of root rot damage (Table 3). Summary percentages of classes 1 and 2 exceed 50% in all but one (L6b) sample plot. Plot L6b was situated on a small stony ridge within the main slope. The other part of the clear cut (plot L6b) showed significantly better results. Analogous results were found on plots L5a and L5b, which are two adjacent clear cuts. The visibly drier conditions and more exposed terrain on L5b have apparently resulted in the greater root rot damage.

Table 2. The Kružberk area results. Number of stumps in each class and respective percentages

Plot No.		K1		K2		K3a		K3b		K4		K5		K6	
Stand No.		303E5		303B5		412C5		412C5		402E5		401B5		303A5	
Forest type		5B1		5S1		5B3		5B3		5B1		5B3		5B1	
Age		42		49		47		47		42		47		42	
		n	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
Class	1	0	0.00	12	17.65	4	2.80	2	1.79	2	1.59	4	4.44	2	2.41
	2	3	5.45	10	14.71	10	6.99	10	8.93	14	11.11	4	4.44	12	14.46
	3	15	27.27	16	23.53	15	10.49	17	15.18	30	23.81	15	16.67	26	31.33
	4	17	30.91	15	22.06	43	30.07	36	32.14	39	30.95	31	34.44	25	30.12
	5	20	36.36	15	22.06	71	49.65	47	41.96	41	32.54	36	40.00	18	21.69
Total		55	100	68	100	143	100	112	100	126	100	90	100	83	100

Table 3. The Lužná area results. Number of stumps in each class and respective percentages

Plot No.		L1		L2a		L2b		L3		L4	
Stand No.		2l10		2h9		2h9		2l10		2m10	
Forest type		5B1		4B1		5B1		5A3		5U1,5B1	
Age		99		91		91		98		103	
		n	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
Class	1	47	25.82	36	21.69	23	20.00	31	14.49	37	25.34
	2	67	36.81	49	29.52	35	30.43	84	39.25	50	34.25
	3	35	19.23	33	19.88	22	19.13	44	20.56	28	19.18
	4	18	9.89	20	12.05	17	14.78	33	15.42	16	10.96
	5	15	8.24	28	16.87	18	15.65	22	10.28	15	10.27
Total		182	100	166	100	143	100	112	100	126	100
Plot No.		L5a		L5b		L6a		L6b		L7	
Stand No.		2p11		2r11		2o10		2o10		8a11	
Forest type		4B1		5B1		5B1		5B1		5B2	
Age		107		100		100		100		107	
		n	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
Class	1	21	22.34	14	16.87	37	21.76	14	11.11	63	43.15
	2	42	44.68	32	38.55	65	38.24	32	25.40	46	31.51
	3	23	24.47	19	22.89	36	21.18	34	26.98	14	9.59
	4	8	8.51	8	9.64	22	12.94	31	24.60	14	9.59
	5	0	0.00	10	12.05	10	5.88	15	11.90	9	6.16
Total		94	100	83	100	143	100	112	100	126	100

The results from stand 2h9, where the clear-cut area was divided into two plots (L2a and L2b) according to the border (contour line) of altitudinal vegetation zones, did not show any significant differences (Table 5) as both the lower and the upper half of the clear cut had very similar frequency of rot classes.

The best health condition of spruce was found on plot L7 in the easternmost part of Lužná area. This plot had the highest altitude (730 m) in this study.

Table 4. Statistical comparison of plots in Kužberk area by means of chi-square statistic, with the marking of significance. Calculated values of chi-square

Kružberk	K1	K2	K3a	K3b	K4	K5
K6	6.6	11.10*	26.0**	12.96*	3.8	14**
K5	4.6	18.10**	4.1	2.80	6.6	
K4	4.7	19.20**	13.5**	3.98		
K3b	4.7	22.95**	2.6			
K3a	10.6*	31.30**				
K2	15.4**					

*Statistically significant difference, **Statistically highly significant difference

Table 5. Statistical comparison of plots in Lužná area by means of chi-square statistic, with the marking of significance. Calculated values of chi-square

Lužná	L1	L2a	L2b	L3	L4	L5a	L5b	L6a	L6b
L7	13.40**	24.80**	21.80**	39.2**	13.2*	23.9**	20.3**	19.8**	48.7**
L6b	24.30**	14.40**	8.80	10.3*	18.3**	29.4**	10.4*	18.0**	
L6a	2.20	10.97*	8.30	5.5	3.1	7.5	3.9		
L5b	3.30	3.40	2.97	2.0	2.6	12.5*			
L5a	9.96*	21.10**	20.10**	15.3**	12.6*				
L4	0.60	3.50	3.30	7.4					
L3	9.40	9.10	4.90						
L2b	6.80	0.60							
L2a	7.60								

*Statistically significant difference, **Statistically highly significant difference

It may be the influence of better climate conditions for Norway spruce there, when almost a half of the stumps were healthy even at the age of 107 years.

CONCLUSIONS

The results from Kružberk have proved that Norway spruce stands established there on arable land are totally damaged by the red root rot of *Heterobasidion annosum* at the age of 40–50 years and therefore they cannot provide quality timber even at the half time of their intended period. Almost all trees in this area were infected on a stump cutting area by root rot regardless of previous damage to stems caused by game. The extent of root rot was even greater in two stands without deer barking damage, in the vicinity of the village of Dvorce. The least extent of root rot infection was observed in the stand at a rather less fertile site.

The results from Lužná area show that spruce stands founded there on former sheep pastures are relatively stable even at the end of their intended rotation period and can provide timber assortments of high quality, although they were largely infected by the root rot as well. The root rot damage, however, corresponds to the age of these stands at nutrient rich sites. If the rotation period of these stands were shorter there, the extent of root rot infection would be even smaller. Significantly higher root rot damage in the Lužná area was found at exposed stony places with the signs of old soil erosion.

The target tree species composition is today determined according to the forest type classification of afforested land. But the starting site conditions of agricultural land are usually very different from the (potential) conditions of forest environment. This causes many problems for the cultivation of stable and quality forest stands even if the site classification is made correctly.

The recommendation for today's afforestation of agricultural land is therefore to avoid establishing pure Norway spruce stands on arable land as there is no chance that most of them can survive until their usual rotation age. Spruce can be planted there as an admixture to ensure the fast restoration of forest soil characteristics and to provide high timber volumes from thinnings. On the other hand, Norway spruce as our main commercial tree species can be used at a certain proportion even in unmixed stands on former pastures and other mountain grasslands with suitable soil and climate conditions. The reasonably shortened rotation period at these sites would reduce the root rot damage to a more acceptable level.

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