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EVALUATION OF THE RESPONSE OF NORWAY SPRUCE *PICEA ABIES* (L.) KARST. ON SYNERGETIC EFFECTS OF ABIOTIC AND ANTHROPOGENIC STRESS FACTORS IN TWO LOCALITIES OF THE DRAHANY HIGHLAND

P. Čermák, P. Plašil, R. Petlach

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Abstract

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The paper deals with the evaluation of the response of spruce stands on the effect of climatic and anthropogenic factors in two localities predominantly of the 4th forest vegetation zone (fvz) of the Drahany Highland – Forest Range (FR) Proklest, Training Forest Enterprise (TFE) "Masaryk Forest" Křtiny and Forest Range Senetářov, Forests of the CR, Forest District (FD) Tišnov. The evaluation was carried out on the basis of monitoring according to the ICP Forests Programme completed by the determination of the crown structure transformation (CUDLÍN et al., 2001a). This methodology makes possible to estimate retrospective responses of a stand on the actual combination of stress factors as well as its present adaptation potential. In total, 35 circular research plots were monitored (13 FR Proklest, 22 FR Senetářov) with 700 trees in stands dominated by spruce at an age of 79–122 years. Total defoliation ranged between 29.5 and 37% (as an average of the research plots), defoliation of a primary structure in a broad range of 49–85.5%. The average degree of crown structure transformation was 1.57 and 1.6 in FR Proklest and FR Senetářov, respectively. In stands under monitoring, environmental factors manifest themselves differently. Part of the stands (particularly FR Proklest) was affected mainly by unfavourable climatic conditions in the course of several recent years. As for other stands, it is possible to notice further impacts of synergetic effects of stress factors.

stress response, defoliation, crown structure transformation stage, Norway spruce, Drahany Upland

Forest decline as the result of synergetic effects of abiotic, biotic and anthropogenic factors is a phenomenon which will be obviously encountered with increasing frequency (thanks to persisting negative impacts of man and thanks to changing climatic conditions). Since the 80s of the 20th century, therefore, an effort occurs in forest science to obtain more comprehensive characteristics describing health conditions of a tree and the level of its resistance potential. As indicators making possible to describe or interpret response of spruce to the complex of stress factors those characteristics are most frequently used which monitor the condition of crowns (e.g. defoliation) and needles (damage to needles, colour changes, number of needle year-classes etc.). An extensive monitoring of the condition of crowns occurs in Europe since 1986 in the network of plots "level 1" within the ICP Forests Programme (the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests). A number of authors dealt with elaboration of the methodology and interpretation of ascertained facts, e.g. LORENZ (1995) and LORENZ et al. (2001, 2002). Monitoring the crown structure brings valuable data not only on the health condition of trees but also on production potentials. Relationships between the density of crowns and the growth of trees were repeatedly demonstrated (e.g. SOLBERG, TVEITE, 2000). Gradually, other methods appear increasing interpretation possibilities of the monitoring. At present, it is possible to use a macroscopic marker based on the distribution of developmental stages of buds (ALBRECHTOVÁ et al., 2001) to assess trends in the further development of a tree (spruce).

Methods of the evaluation of crown transformation by means of terrestrial surveys used in the paper elaborate original findings and principles of LESINSKI, LANDMAN (1985) and GRUBER (1994). A stage of the crown structure transformation describes both the rate of the present damage (defoliation) to an assimilatory apparatus and the rate of the substitution of previous damage by the gradual formation of secondary shoots. In this way, it is possible to assess retrospective responses of trees to particular combinations of natural and anthropogenic stress factors. However, it is also possible to estimate the present adaptation potential of a stand (CUDLÍN et al., 2001a).

Studies presented in the paper continue in similar research carried out in the area of the Křtiny TFE during last years using either the same methodology in 2001 (JANKOVSKÝ et al., 2004) or other methods in 2002 (ČERMÁK et al., 2004). The objective of the monitoring was to determine responses of spruce to existing stress load in allochthonous spruce stands of medium altitudes (largely the 4th FVZ) on oligotrophic, oligotrophic-mesotrophic and meso-trophic sites of the Drahany Highland.

MATERIAL AND METHODS

The Forest Range Proklest, TFE "Masaryk Forest" is situated between villages Křtiny, Jedovnice, Bukovina and Bukovinka at an altitude of 460–573 m. The majority of the area belongs to the 4th FVZ (93% of the FR stand area, 11 research plots), the remaining part to the 3rd FVZ (7% of the FR stand area, 2 research plots). The monitored plots rank among communities of *Querci-fageta typica*, *Fageta typica* and *Fageta abietino-quercina*. In monitored stands, Norway spruce (*Picea abies*) predominates (75% or more) being completed by beech (*Fagus sylvatica*), larch (*Larix decidua*), Scots pine (*Pinus sylvestris*), silver fir (*Abies alba*) and Douglas fir (*Pseudotsuga menziesii*).

The Forest Range Senetářov (Forests of the CR, Forest District Tišnov) is situated SW of Lipovec, E of Ostrov near the Macocha Cave and N of Krasová and Kotvrdovice. Its eastern border is created by Mt. Kojál (600 m alt.). The area forms a forest complex in the cadastre of Krasová and Kotvrdovice at an altitude of 510–581 m. All research plots belong to the 4th FVZ. The plots rank among plant communities of *Fageta typica*, *Fageta quercino-abietina* and *Fageta abietino-quercina*. As for species composition, Norway spruce (*Picea abies*) predominates (50% or more) followed by larch (*Larix decidua*), Scots pine (*Pinus sylvestris*) and Douglas fir (*Pseudotsuga menziesii*).

For the purpose of monitoring, evaluation of the crown structure transformation according to Cudlín was used (CUDLÍN et al., 2001a) and other characteristics were assessed according to methodology of the ICP Forests (slightly modified). In selected stands aged 79–122 years, permanents circular research plots have been established. In each of the plots, 20 trees were chosen and following characteristics were evaluated in them by means of a telescope in summer months (July – August): social status, type of branching, occurrence and type of top breakage, % extent of particular parts of a crown (juvenile, production, saturation), shape of the upper part of a crown, type of the crown top, total defoliation in %, primary structure defoliation in %, % of secondary shoots, types of potential damage to crown, degree of the crown structure transformation, presence and extent of colour changes (yellowing, rusting), occurrence of flowering and cones, presence and extent of stem damage (mechanical, fungal etc.). In total, 35 plots were monitored (13 in FR Proklest, 22 in FR Senetářov), i.e. 700 trees.

Transformation of the tree crown is a process when the gradual substitution of original primary (proleptic) shoots by secondary shoots occurs. Secondary shoots are intensively formed particularly in case of the disturbance of balance between the total amount of assimilatory organs and external (supply of PAR) or internal (water and nutrients supply) conditions for photosynthetic assimilation. Thus, transformation of the crown structure is a result of the tree response to changes in the spectrum or intensity of the effect of stress factors. This reaction can be manifested as a short-term physiological response or as long-term physiological, morphological and structural changes. Particular stages of crown structure transformation are given in Tab. I.

I: *Crown structure transformation stages (CUDLÍN et al., 2001a)*

Stage	Characteristics
0	Small defoliation of the stem and/or mosaic type, percentage of secondary shoots less than 20 %.
1	Defoliation of the stem and/or mosaic type, counteracted by scattered secondary shoot formation, percentage of secondary shoots less than 50 %.
2	Incipient peripheral (ends of primary branches) injury, sometime sub-top injury, often in combination with stem and/or mosaic type, percentage of secondary shoots from 51 to 80 %.
3	Peripheral injury prevailing, sometime top injury, often in combination with previous injury types, percentage of secondary shoots from 81 to 99 %.
4	Peripheral injury occurring by all branches of the middle part of the crown, sometime top injury, often in combination with previous injury types, percentage of secondary shoots 100%.

Trees under evaluation can be classified to one of four categories of stress response according to basic parameters (total defoliation, defoliation of the primary structure, percentage of secondary shoots): resistant tree, resilient tree, little transformed damaged tree, markedly transformed damaged tree (Tab. II).

II: *Categories of the stress response of spruce according to main characteristics of the tree crown (CUDLÍN et al., 2003)*

Category of the stress response	Total defoliation [%]	Percentage of secondary shoots [%]
Resistant tree	≤ 35% - slightly damaged tree	≤ 50% - slightly transformed tree
Resilient tree	≤ 35% - slightly damaged tree	> 50% - markedly transformed tree
Little transformed damaged tree	>35% - moderately to heavily damaged tree	≤ 50% - slightly transformed tree
Markedly transformed damaged tree	>35% - moderately to heavily damaged tree	> 50% - markedly transformed tree

Based on values of indicators of particular stages of the tree response to the global effect of stress factors (Tab. III) it is possible to determine: if the inner resistance of trees has been already exceeded, if assimilatory organs have been seriously damaged, approximate time of the regeneration of damaged shoots and if trees with the prevailing trend of degradation or regeneration processes predominate (CUDLÍN et al., 2003).

III: *Indicators of critical stages of the response of Norway spruce to the global effect of stress factors on the level of a tree (CUDLÍN et al., 2003)*

The course of a response to synergetic effects of stress factors	**Indicators on the level of a tree**				**Stress stages**
	Total defoliation	**Defoliation of the primary structure**	**Percentage of secondary shoots**	**Additional characteristics**	
Stress exceeds tree resistance.	-	*> 50%*	-		A, B, C
Significant harmful effect on assimilative apparatus.	-	*≥ 80%*	-	Dry terminals of the majority of branches of the 1st order in the production part of a crown.	C
A period of exceeding the inner resistance of a tree (defoliation processes predominate).	-	*≥ 50% a ≤ 65%*	*≤ 40%*	Stress resistance of a tree exceeded.	A I
	-	*> 65% a < 80%*	*≤ 50%*	Stress resistance of a tree exceeded.	B I
	-	*≥ 80%*	*≤ 60%*	A tree with a significant damage to assimilatory organs.	C I
A shoot turnover period (continual replacing of defoliated shoots by secondary shoots).	- *≥ 40%*	*≤ 65%* *≤ 65%*	*> 40%* *> 50%*	Stress resistance of a tree exceeded.	A II
	- *≥ 40%*	*> 65% a < 80%* *> 65% a < 80%*	*> 50%* *> 65%*	Stress resistance of a tree exceeded.	B II
	- *≥ 40%*	*≥ 80%* *≥ 80%*	*> 60%* *≥ 80%*	A tree with a significant damage to assimilatory organs.	C II
Tree regeneration (predominance of regeneration processes over degradation).	*≤ 35%*	*≤ 65%*	*> 50%*	Stress resistance of a tree exceeded .	A III
	≤ 35%	*> 65% a < 80%*	*> 65%*	Stress resistance of a tree exceeded.	B III
	≤ 35%	*≥ 80%*	*≥ 80%*	A tree with a significant damage to assimilatory organs.	C III_+
Tree exhaustion (loss of ability to replace defoliated shoots).	*≥ 40%*	*100%*	*≥ 95%*	A tree with a zero adaptation potential	C III_-

RESULTS

Average values of basic characteristics (total defoliation, defoliation of the primary structure, % of secondary shoots and a degree of the transformation of crown structure) are given in Tab. IV. Based on the comparison of particular plots differences are evident in the range of values both between particular plots and between particular trees in the region of FR Proklest (considerable fluctuation) and in FR Senetářov (small fluctuation). It is particularly evident in the percentage of secondary shoots. In FR Proklest, it ranged between 49.00 and 85.50%, in between 67.75 and 74.75% (Tab. IV). Marked differences occurred also in the range of the stage of crown structure transformation. While in plots of the FR Proklest, trees were noticed with degrees 0–3, in, only trees with degrees 1 and 2 occurred.

In basic characteristics given in Tab. IV, correlations were determined between the age of a stand, extent of yellowing and rusting and extent of stem damage. However, no relationships were found neither in FR Proklest nor in FR Senetářov.

IV: *Basic characteristic of the condition of Norway spruce crowns in permanent research plots in FR Proklest and FR Senetářov*

Plot			Total defoliation		Defoliation of the primary structure		% of secondary shoots		Stage of transformation	
	No.	Stand	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
FR Proklest, TFE Křtiny	1	200 A9	30,00	7,42	53,25	12,77	33,00	15,12	1,00	0,45
	2	200 D11	32,50	7,66	59,25	10,76	40,00	14,32	1,15	0,36
	3	200 A9	29,50	5,45	49,00	8,46	29,50	11,17	1,00	0,32
	4	181 B12	34,25	7,46	67,00	8,57	52,50	15,69	1,65	0,48
	5	184 A12	32,75	5,80	60,75	9,78	42,25	14,79	1,30	0,46
	6	183 A12a	33,00	9,75	65,50	9,86	49,75	13,37	1,45	0,50
	7	178 A10	29,75	7,33	72,25	11,12	60,25	16,47	1,80	0,68
	8	197 A9	30,00	7,75	51,00	9,82	32,50	9,94	1,00	0,00
	9	184 D11	30,75	9,39	54,75	13,92	37,25	17,14	1,20	0,60
	10	184 C8	34,25	9,65	79,50	10,59	69,75	14,27	2,10	0,62
	11	178 A10	31,50	6,14	77,25	10,06	67,75	12,80	1,95	0,50
	12	183 D8	32,50	4,87	83,25	11,21	75,50	16,87	2,35	0,73
	13	196 C9	33,50	5,27	85,50	8,79	78,50	15,50	2,40	0,66
	Mean		**31,87**	**7,23**	**66,02**	**10,44**	**51,42**	**14,42**	**1,57**	**0,49**
FR Senetářov, FD Tišnov	1	705 B 9	36,75	3,63	74,75	6,98	60,25	11,12	1,85	0,48
	2	706 B 10a	35,00	5,00	71,25	5,67	56,25	8,93	1,60	0,49
	3	706 B 10a	35,00	4,47	73,50	5,02	59,25	6,94	1,80	0,40
	4	706 B 10a	32,50	5,36	69,25	6,94	53,50	12,85	1,50	0,50
	5	706 A 12	32,75	4,60	68,75	5,67	52,25	10,06	1,45	0,50
	6	707 B 10	33,25	4,55	69,25	6,18	53,50	8,38	1,60	0,49
	7	707 B 10	34,25	5,07	67,75	7,15	50,00	12,65	1,40	0,58
	8	707 B 10	33,75	4,15	67,75	8,14	50,25	15,04	1,45	0,67
	9	707 C 11	33,75	4,15	69,25	4,82	53,00	6,96	1,55	0,50
	10	708 B 11	36,25	5,21	73,75	6,30	58,50	10,97	1,80	0,51
	11	708 C 12	34,75	4,32	70,00	4,47	52,75	7,98	1,60	0,49
	12	709 C 12	34,50	3,84	68,25	4,82	51,50	7,60	1,40	0,49
	13	709 B 10	36,00	3,00	70,50	4,72	54,00	7,84	1,60	0,49
	14	709 B 10	34,00	4,06	70,50	3,84	55,25	6,61	1,75	0,43
	15	710 A 9/1	35,75	4,82	70,00	5,24	52,25	9,81	1,50	0,50
	16	710 B 13	34,25	3,96	70,00	3,87	54,50	6,87	1,75	0,43
	17	711 A 10a	36,00	3,39	68,75	5,21	51,00	9,82	1,55	0,50
	18	711 A 10a	35,00	2,74	67,50	7,50	50,25	10,89	1,55	0,59
	19	711 B 12	37,00	4,58	73,75	5,67	58,25	9,52	1,65	0,48
	20	711 A 10	36,25	3,49	70,50	6,10	54,00	9,03	1,65	0,48
	21	712 D 9	33,00	4,00	71,25	6,10	57,00	9,00	1,70	0,46
	22	712 D 9	34,75	3,70	69,50	4,97	52,75	8,44	1,60	0,49
	Mean		**34,75**	**4,19**	**70,26**	**5,70**	**54,10**	**9,42**	**1,60**	**0,50**

From the viewpoint of identification of stress stages, spruce responses show considerable differences in plots of FR Proklest (Tab. V). Trees with not-exceeded stress resistance predominate in 1 plot, trees of the period of exceeding the inner resistance of a tree predominate in 5 plots, trees in the shoot turnover period predominate in 3 plots, the balanced number of trees in the period of exceeding the inner resistance of trees and trees in the shoot turnover period predominate in 1 plot and trees in the stage of regeneration predominate in 3 plots. In Forest Range Senetářov, the situation is much more balanced (Tab. V). In all plots, trees in the shoot turnover period predominate.

V: *Number of trees in particular stages of the stress response of spruce, number of trees with significant damage to the assimilatory apparatus (grey fields = predominating category)*

Plot			**Not-exceeded stress resistance**	**Period of exceeding the inner resistance of a tree**			**Shoot turnover period**			**Regeneration**			**Tree exhaustion**	**Significant damage to assimilatory organs**
	No.	Stand	U	A I	B I	C I	A II	B II	C II	A III	B III	C III$_1$	C III$_2$	Deformation of primary structures > 80%
FR Proklest, TFE Křtiny	1	200 A9	**8**	6	4	-	-	-	-	-	2	-	-	-
	2	200 D11	4	**7**	6	-	-	1	-	-	2	-	-	-
	3	200 A9	8	**10**	-	-	-	-	-	2	-	-	-	-
	4	181 B12	1	5	3	-	-	3	-	-	**8**	-	-	-
	5	184 A12	1	**11**	1	-	2	1	1	1	2	-	-	1
	6	183 A12a	1	**4**	2	-	3	**4**	1	3	2	-	-	1
	7	178 A10	-	4	-	-	3	**6**	3	-	1	3	-	6
	8	197 A9	7	**9**	-	-	4	-	-	-	-	-	-	-
	9	184 D11	7	**6**	-	-	3	2	1	-	-	-	-	1
	10	184 C8	-	-	-	-	3	4	**9**	-	-	4	-	13
	11	178 A10	-	1	-	-	2	4	**10**	-	-	3	-	13
	12	183 D8	-	1	1	-	-	1	5	-	-	**12**	-	17
	13	196 C9	-	1	-	-	1	3	4	-	-	**11**	-	15
FR Senetářov, FD Tišnov	1	705 B 9	-	1	1	-	2	**9**	7	-	-	-	-	2
	2	706 B 10a	-	1	2	-	5	**8**	3	-	1	-	-	-
	3	706 B 10a	-	-	-	-	4	**12**	4	-	-	-	-	-
	4	706 B 10a	-	1	2	-	**7**	6	1	1	1	1	-	1
	5	706 A 12	-	2	1	-	**8**	7	2	-	-	-	-	-
	6	707 B 10	-	3	2	-	3	**10**	1	1	-	-	-	-
	7	707 B 10	-	4	-	-	7	**7**	2	-	-	-	-	-
	8	707 B 10	1	2	1	-	5	**11**	-	-	-	-	-	-
	9	707 C 11	-	2	1	-	6	**10**	1	-	-	-	-	-
	10	708 B 11	-	1	1	-	3	**10**	5	-	-	-	-	1
	11	708 C 12	-	3	1	-	4	**11**	1	-	-	-	-	-
	12	709 C 12	-	1	1	-	**10**	7	1	-	-	-	-	-
	13	709 B 10	-	1	2	-	5	**10**	2	-	-	-	-	-
	14	709 B 10	-	-	1	-	4	**14**	1	-	-	-	-	-
	15	710 A 9/1	-	2	2	-	6	**9**	1	-	-	-	-	-
	16	710 B 13	-	1	-	-	4	**14**	-	1	-	-	-	-
	17	711 A 10a	-	4	-	-	5	**10**	1	-	-	-	-	-
	18	711 A 10a	1	4	1	-	2	**11**	1	-	-	-	-	-
	19	711 B 12	-	1	4	-	2	**7**	6	-	-	-	-	1
	20	711 A 10	-	3	-	-	4	**10**	3	-	-	-	-	-
	21	712 D 9	-	-	1	-	5	**8**	5	1	-	-	-	-
	22	712 D 9	-	3	2	-	3	**11**	1	-	-	-	-	-

In both areas, resistant or resilient trees predominate in research plots (Tab. VI). Only in one plot in FR Senetářov, resilient trees together with damaged and intensely transformed trees predominate. Resistant trees predominate in 6 plots of FR Proklest and in 2 plots of FR Senetářov, resilient trees in 7 plots of FR Proklest and in 19 plots of FR Senetářov.

VI: *Number of trees of particular categories of the stress response of spruce (grey fields = predominating category)*

	Plot		Resistant trees	Resilient trees	Little transformed damaged trees	Intensely transformed damaged trees
	No.	Stand				
FR Proklest, TFE Křtiny	1	200 A9	15	2	3	0
	2	200 D11	15	2	2	1
	3	200 A9	16	2	2	0
	4	181 B12	5	9	4	2
	5	184 A12	12	4	4	0
	6	183 A12a	4	7	7	2
	7	178 A10	6	12	1	1
	8	197 A9	15	0	5	0
	9	184 D11	14	3	2	1
	10	184 C8	3	11	0	6
	11	178 A10	3	14	0	3
	12	183 D8	0	16	2	2
	13	196 C9	1	15	1	3
FR Senetářov, FD Tišnov	1	705 B 9	2	8	2	8
	2	706 B 10a	5	8	3	4
	3	706 B 10a	4	10	0	6
	4	706 B 10a	8	9	2	1
	5	706 A 12	8	9	3	0
	6	707 B 10	6	10	2	2
	7	707 B 10	9	7	2	2
	8	707 B 10	6	11	3	0
	9	707 C 11	7	8	2	3
	10	708 B 11	3	12	2	3
	11	708 C 12	4	11	4	1
	12	709 C 12	10	6	2	2
	13	709 B 10	5	9	3	3
	14	709 B 10	4	13	1	2
	15	710 A 9/1	6	7	4	3
	16	710 B 13	4	14	1	1
	17	711 A 10a	5	9	4	2
	18	711 A 10a	6	11	2	1
	19	711 B 12	2	11	5	2
	20	711 A 10	6	8	1	5
	21	712 D 9	5	13	1	1
	22	712 D 9	4	11	4	1

Yellowing was noticed in 10 plots of FR Proklest and only in 3 plots of FR Senetářov (Tab. VII). However, it referred to several individuals not exceeding 10% of the crown volume. Rusting occurred more markedly being found in 11 plots of FR Proklest (in plots 1–3 affected the majority of trees) and in 12 plots in FR Senetářov (Tab. VII). On average, it ranged slightly above 5% of the crown volume. Maximum volume of the affected crown was 15% in plot 13, FR Proklest.

VII: *The occurrence of yellowing, rusting and stem damage*

Plot			**Yellowing**		**Rusting**		**Stem damage**
	No.	Stand	Number of trees	Mean % of the tree crown with presence	Number of trees	Mean % of the tree crown with presence	Total number of damaged trees /of which with a rot*
FR Proklest, TFE Křtiny	1	200 A9	4	5,00%	14	5,70%	13
	2	200 D11	6	5,00%	14	6,10%	13
	3	200 A9	4	5,00%	18	5,80%	10
	4	181 B12	1	5,00%	1	5,00%	5
	5	184 A12	1	5,00%	0	-	9
	6	183 A12a	0	-	0	-	7
	7	178 A10	1	10,00%	6	5,80%	9
	8	197 A9	0	-	2	5,00%	8
	9	184 D11	0	-	5	6,00%	11
	10	184 C8	2	5,00%	3	5,00%	9
	11	178 A10	3	6,70%	9	5,00%	17
	12	183 D8	1	5,00%	2	5,00%	7
	13	196 C9	9	5,60%	9	7,20%	6
FR Senetářov, FD Tišnov	1	705 B 9	0	-	0	-	18/11
	2	706 B 10a	0	-	0	-	14/11
	3	706 B 10a	0	-	0	-	15/13
	4	706 B 10a	1	0,25%	0	-	12/11
	5	706 A 12	0	-	0	-	13/12
	6	707 B 10	1	0,25%	0	-	12/11
	7	707 B 10	0	-	4	1,00%	15/11
	8	707 B 10	2	0,50%	0	-	13/10
	9	707 C 11	0	-	1	0,25%	17/11
	10	708 B 11	0	-	1	0,25%	16/9
	11	708 C 12	0	-	0	-	14/13
	12	709 C 12	0	-	2	0,50%	16/12
	13	709 B 10	0	-	0	-	14/14
	14	709 B 10	0	-	1	0,25%	17/12
	15	710 A 9/1	0	-	4	1,00%	16/13
	16	710 B 13	0	-	6	1,50%	17/13
	17	711 A 10a	0	-	3	0,75%	15/11
	18	711 A 10a	0	-	1	0,25%	17/11
	19	711 B 12	0	-	0	-	13/11
	20	711 A 10	0	-	3	0,75%	15/11
	21	712 D 9	0	-	6	1,50%	16/13
	22	712 D 9	0	-	8	2,00%	19/11

* evaluated only in FR Senetářov

In all the plots, part of trees was damaged to stems by fungal pathogens, particularly by Armillaria spp. (monitored in FR Senetářov only, see Tab. VII) or mechanically by forest machines or game. In 5 plots of FR Proklest and in all 22 plots of FR Senetářov, damaged trees predominated sound trees. The damage ranged from 5 to 40% of the tree girth with the exception of one tree totally affected by resinosis at its base in plot 20, FR Senetářov.

DISCUSSION AND CONCLUSIONS

In stands under monitoring in FR Proklest, environmental factors occurred differently (Tabs. IV, V, VI.). Part of the stands was affected particularly by unfavourable climatic conditions in recent years. Trees in the plots show high resistance. In the stands, trees of the stress stage A predominate – response to a short-term stress load (CUDLÍN, 2001). Mostly, it refers to resistant trees with slightly transformed crowns. In other stands, it is possible to notice impacts of the synergetic influence of stress factors. From the viewpoint of the further development of health conditions, the situation is hazardous particularly in four stands where, due to long-term stress load, resilient trees with the relatively high stage of crown structure transformation predominate. Their condition can be characterized as a significant harmful effect on assimilative apparatus (Tab. V). In remaining stands, the situation is more complicated considering relatively large differences between particular trees. Next development of the response of trees will be particularly related to the course of climatic characteristics (precipitation in the growing season, maximum temperatures etc.).

Results of measurements in FR Proklest can be compared with a similarly outlined survey carried out in 2001 (JANKOVSKÝ et al., 2004) when 12 ICP plots were monitored in the whole area of the Křtiny TFE. As for average values, the situation was more favourable than conditions found in 2003. Average total defoliation was 23.3% (as against 31.9% in 2003), defoliation of the primary structure was 56.4% (as against 66%), the percentage of secondary shoots was 43.8% (as against 51.4%), the degree of crown transformation 1.3 (as against 1.6). The occurrence of yellowing was also slightly higher (in 2001 ≤ 3%). The reason of higher values in 2003 can consist in climatically unfavourable growing seasons of 2002 and 2003. With respect to the fact that monitoring was not carried out in the same plots, it is not possible to state deterioration of forest conditions. In the standardized evaluation of risks of the impact of a climatic change in FR Proklest in 2002, stands with research plots were included into categories of medium to high risk (ČERMÁK et al., 2004). The present condition of stands corresponds to the typification.

In all monitored stands of FR Senetářov, the situation is very similar. Resilient trees in the stage of the cyclic regeneration of shoots, i.e. in the period of the relatively intensive process of substituting damaged primary branches by secondary ones predominate. In the majority of stands, the course of a stress response corresponds to scenario B which is a response to long-term stress effects exceeding the inner resistance of a tree (CUDLÍN, 2001). Smaller fluctuation of values as compared with FR Proklest can be caused by the higher rate of homogeneity of site and stand conditions in the area under study (a plateau in the 4th FVZ, identical or very similar stand structure). On acid sites, lower values were achieved as against nutrient-rich sites, however, the difference amounts to max. 4%, which is within the 5% interval of evaluation and, thus, the difference is not significant. Basic parameters given in Tab. IV reach slightly higher values than in FR Proklest and thus also of values determined in the evaluation of the Křtiny TFE in 2001 (JANKOVSKÝ et al., 2004). In the course of monitoring in 2001, the presence was detected of Armillaria spp. in more than 40% of trees. In our survey, 57.5% of trees was infected by rot (species not distinguished). Considering the dominance of Armillaria spp. in similar localities, it is possible to suppose the occurrence of honey fungus roughly of the same extent.

The supposed dependence of main characteristics under study on the stand age was not found. Relationships between the crown density (crown density + total defoliation = 100) and the tree age was demonstrated in the Šumava Mts. (CUDLÍN at al., 2001b) or in Scandinavia during extensive monitoring the damage to forests in the 80s and 90s (STRAND, 1995; SOLBERG, 1999). Through the repeated monitoring of identical plots in Norway, decrease was found in crown density with the increasing age of trees, intensity of stress load being manifested in the rate of the crown density decrease. Under higher intensity of stress load crown density decreased more rapidly (SOLBERG, 1999). In small stand units monitored in the Drahany Highland, stand microclimatic conditions, slope orientation climate and effects of silvicultural or felling measures manifest themselves increasingly. These factors evidently markedly affect stress factors (at their average level of influence) and the process of the crown density reduction to such an extent that it is not possible to demonstrate relationships between the process and the tree age. However, it is possible that the dependence could be demonstrated under conditions of long-term monitoring the plots similarly as it was carried out during the Norwegian monitoring.

The condition of monitored stands of the Drahany Highland demonstrates the stress load of forest stands due to anthropogenic and particularly climatic factors. In the predominating 4th FVZ, spruce is exposed to temperature and precipitation conditions out of its ecological optimum. It is reflected in its vitality, health condition and in the level of its adaptation potential.

SOUHRN

Hodnocení reakce smrku ztepilého *Picea abies* (L.) Karst. na synergické působení abiotických a antropogenních stresových faktorů na dvou lokalitách Drahanské vrchoviny

Tato práce se zabývá hodnocením reakce smrkových porostů na působení klimatických i antropogenních faktorů na dvou lokalitách převážně 4. lesního vegetačního stupně (lvs) Drahanské vrchoviny – lesnický úsek (LÚ) Proklest na ŠLP Masarykův les Křtiny a revír Senetářov u Lesů ČR LS Tišnov. Hodnocení bylo prováděno na základě monitoringu dle programu ICP Forests doplněného zjišťováním transformace struktury koruny (CUDLÍN et al., 2001a). Tato metodika umožňuje odhadnout retrospektivní reakci porostu na konkrétní kombinaci stresových faktorů a také jeho současný adaptační potenciál. Celkem bylo monitorováno 35 kruhových výzkumných ploch (13 LÚ Proklest, 22 revír Senetářov) se 700 stromy v porostech s převahou smrku ve věku 79–122 let. Celková defoliace se v průměrech za výzkumné plochy pohybovala mezi 29,5 % a 37 %, defoliace primární struktury v širokém rozpětí 49–85,5 %. Průměrný stupeň transformace koruny byl na LÚ Proklest 1,57 a v revíru Senetářov 1,6. V monitorovaných porostech se faktory prostředí uplatňují v různé míře. Část porostů (zejména na LÚ Proklest) byla ovlivněna především klimaticky nepříznivými podmínkami v posledních několika letech, u ostatních porostů lze na základě popsaného stavu hodnocených parametrů konstatovat delší vliv synergického působení stresových faktorů.

odezva na stres, defoliace, stupeň transformace koruny, smrk ztepilý, Drahanská vrchovina

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REFERENCES

ALBRECHTOVÁ, J., ROCK, B. N., SOUKUPOVÁ, J., ENTCHEVA, P., ŠOLCOVÁ, B.: Biochemical, histochemical, structural and reflectance markers of damage in Norway spruce from the Krušné hory Mts. *Journal of Forest Science*, 2001, 47, 1-2: 26-33.

CUDLÍN, P.: Vliv dlouhodobé acidifikace na stav a strukturu asimilačních orgánů smrku ztepilého. In HRUŠKA, J., CIENCIALA, E. (eds.) *Dlouhodobá acidifikace a nutriční degradace lesních půd – limitující faktor současného lesnictví*. MŽP ČR, Praha, 2001, 121-127.

CUDLÍN, P., NOVOTNÝ, R., MORAVEC, I., CHMELÍKOVÁ, E.: Retrospective evaluation of the response of montane forest ecosystems to multiple stress. *Ekológia (Bratislava)*, 2001a, 20: 108-124.

CUDLÍN, P., MORAVEC, I., CHMELÍKOVÁ, E.: Retrospektivní sledování stavu smrkových ekosystémů v Národním parku Šumava. *Silva Gabreta*, 2001b, 6: 249-258.

CUDLÍN, P., NOVOTNÝ, R., MORAVEC, I., CHMELÍKOVÁ, E.: Vliv klimatu a imisního zatížení na retrospektivní reakci smrku ztepilého (*Picea abies* /L./ Karsten) na působení stresových faktorů v Krušných horách, 2003, *manuscript*.

ČERMÁK, P., JANKOVSKÝ, L., CUDLÍN, P.: Risk evaluation of the climatic change impact on secondary Norway spruce stands as exemplified by the Křtiny Training Forest Enterprise, *Journal of Forest Science*, 2004, 50 (6):256-262.

GRUBER, F.: Morphology of coniferous trees: possible effects of soil acidification on the morphology of Norway spruce and silver fir. In GODBOLD, D.L., HÜTTERMANN, A.: (eds.) *Effects of acid rain on forest processes*. Wiley-Liss, New York, 1994, 265-324.

JANKOVSKÝ, L., CUDLÍN, P., ČERMÁK, P., MORAVEC, I.: The prediction of development of secondary Norway spruce stands under the impact of climatic change in the Drahany Highlands (the Czech Republic). *Ekológia (Bratislava)*, 2004, Vol. 23, Supplement 2/2004, in press.

LESINSKI, J. A., LANDMAN, G.: Crown and branch malformation in conifers related to forest decline. In CAPE, J. N., MATHY, P. (eds.). *Scientific basis of forest decline symptomatology, Air Pollution Research Report 15*. Commission of European Communities, Brussels, 1995, 95-105.

LORENZ, M.: International co-operative programme on assessment and monitoring of air pollution effects on forests – ICP Forests. *Water Air Soil Poll*., 1995, 85, 3: 1221-1226.

LORENZ, M., SEIDLING, W., MUES, V., BECHER, G., FISCHER, R.: Forest condition in Europe: 2001. *Technical report*. *United Nations Economic commission for Europe, European Commission* (eds.), Geneva, Brussels, 2001. 103 p.

LORENZ, M., MUES, V., BECHER, G., SEIDLING, W., FISCHER, R., LANGOUCHE, D., DURRANT, D., BARTELS, U.: The condition of forests in Europe, 2002. *Technical report*. *UNECE and EC*, Geneva and Brussels, 2002. 99 p.

SOLBERG, S.: Crown density changes of Norway spruce and the influence from increased on permanent monitoring plots in Norway during 1988 – 1997. *European Journal of Forest Pathology*, 1999, 29: 219-230.

SOLBERG, S., TVEITE, B.: Crown density and growth relationships between stands of *Picea abies* in Norway. *Scandinavian Journal of Forest Research*, 2000, 15: 87-96.

STRAND, G. H.: Estimation of the difference in crown vigor for 2280 coniferous trees in Norway from 1989 to 1994, adjusted for the effects of ageing. *Environment Monitoring and Assessment*, 1995, 36: 61-74.

Address

Ing. Petr Čermák, Ph.D., Ústav ochrany lesů a myslivosti, Mendelova zemědělská a lesnická univerzita v Brně, Zemědělská 3, Brno 613 00, Česká republika, e-mail: cermacek@mendelu.cz