The effect of stress factors on birch *Betula pendula* Roth

D. Kaňová, E. Kula

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

ABSTRACT: In a controlled pot trial, plants of birch (*Betula pendula* Roth) were treated in six variants: acid watering (pH 3), acid watering with spraying, drought, ammonium sulphate fertilisation, ammonium sulphate fertilisation in combination with drought, and control. The response to the treatment with ammonium sulphate in terms of the increment was discordant as it increased the sensitivity of birch to frost. Drought had a negative effect on increments. A combination of ammonium sulphate and drought; drought; ammonium sulphate and sprayed acid watering delayed the shedding of leaves; this was due to a longer vegetation period, significantly higher nitrogen content in these variants, with the exception of drought.

Keywords: *Betula pendula*; stress; acid rain; sulphur; nitrogen; drought; grow; phenology

Although legislation on air protection and various technical measures contributed to the reduction of air pollution in Central Europe, the import of hydrogen cations, sulphur, nitrogen and other substances into the ecosystem continues (Hadaš 2002; Fadrhonsová et al. 2000). Acid precipitation and soil acidification affect the uptake of nutrients by the plants. Cations of metals are released into the soil solution, which may damage the plant (Al^{3+}, Cd^{2+}, high concentrations of Fe^{2+} and Mn^{2+}) (Kitao et al. 2001; Marschner 1995; Procházka et al. 1998). Acid rain affects plant growth in dependence on the substrate (Raynal et al. 1982; Keane, Manning 1988). Air pollution (acid rain, SO_2, O_3) disturbs the cuticle of assimilation organs of plants and increases nutrient washout (Mg^{2+}, Ca^{2+}, K^+) (Bednářová 2002; Liu, Côté 1993). Plants are capable of taking up sulphur from the soil solution or from the air. A high level of SO_4^{2-} in the plant inhibits the course of secondary photosynthetic processes and decreases biomass growth (Procházka et al. 1998; Marschner 1995; Wright 1987).

In plants with an increased content of nitrogen the aboveground biomass is seen to grow faster than the root biomass and, consequently, disorders due to nutrient and water deficiency appear, the vegetation period is prolonged and the plant is more susceptible to frost killing (Marschner 1995; Magill et al. 2000; Zhu et al. 2001). This reaction was also confirmed in the case of the parallel effect of nitrogen and sulphur (Capon et al. 2000). If the intake of nitrogen is high, it is taken up and assimilated to the detriment of the other nutrients (in particular K, Mg, Ca). The photosynthesis, increment and vitality of the plant are reduced (Kulhavý, Formánek 2002; Ingestad 1977).

Drought suppresses the biological activity of the soil and causes changes in the content of available elements. The response of the plant is the closing of stomata, reduction of transpiration, photosynthesis, elongation growth of cells, and all this retards or even stops growth (Procházka et al. 1998). Fertilisation has a positive effect on water uptake and increases resistance to drought (Viktorov, Bystrjancev 1960; Heinze, Fiedler 1981).

The effect of stress factors in forest ecosystems is too complicated, therefore a pot trial was established where the inputs were controlled in order to throw light on the effects of the respective stress situations on birch *B. pendula*, which was chosen as a model woody species because it is widely distributed in the air-polluted areas.

The objective of the present study is the impact of stress factors (acid input – pH 3, drought, increased nitrogen and sulphur input – $(NH_4)_2SO_4$) on the growth properties and phenology of birch *B. pendula*.

MATERIAL AND METHODS

A two-year experiment was established with container-grown birch (*B. pendula*) plants placed in a foil-covered

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Table 1. Health condition of birch specimens (numbers) in the second year of the experiment and content of nitrogen in the leaves in Aug./Sep. (mg/kg dry mass). KO, control; KYZ, acid watering; KYZP, acid watering with acid spraying; SU, drought; NNS – fertilisation with ammonium sulphate plus drought; NN – fertilisation with ammonium sulphate

		Health condition of the plants (numbers)				Content of nitrogen in leaves (μg/g dry mass)	
		Frost damage					
	Variant	Dead plants	Dead terminal shoots	Other damage	No damage	1st year	2nd year
Experiment 1 (1999–2000)	KO	0	0	16	24	24.00	20.54
	KYZ	0	4	15	21	26.47	20.39
	KYZP	0	9	15	16	29.25	21.84
	SU	0	1	0	39	26.80	18.98
	NNS	9	14	1	16	28.30	26.37
	NN	11	20	0	9	30.21	26.27
Experiment 2 (2000–2001)	KO	0	0	2	38	15.71	14.20
	KYZ	0	0	0	40	18.26	18.90
	KYZP	0	0	0	40	20.60	21.00
	SU	0	0	1	39	19.09	14.40
	NNS	0	0	3	37	25.43	23.80
	NN	0	0	2	38	26.60	26.60
Experiment 3 (2001–2002)	KO	0	5	5	30	23.60	16.20
	KYZ	1	7	10	22	23.80	17.10
	KYZP	0	16	9	15	26.80	17.60
	SU	0	8	6	26	23.70	16.70
	NNS	3	9	13	15	28.10	24.40
	NN	5	13	8	14	27.00	24.00

hothouse in the forest nursery in Řečkovice (Czech Republic, Brno, 220 m alt.). The two-year-old plants were planted out (early April) into 10-litre plastic pots with holes and a layer of sand on the bottom for water drainage. Three weeks after planting they were transferred into a foil-covered hothouse that was used to eliminate uncontrolled precipitation. The experiment involved 240 sample trees divided into 6 variants: KO – control, KYZ – acid watering, KYZP – acid watering with acid spraying, SU – drought, NNS – fertilisation with ammonium sulphate plus drought, NN – fertilisation with ammonium sulphate. The KO, KYZ, KYZP and NN variants were watered with 0.5 litre per plant, variants SU and NNS with 0.25 litre per plant and variant KYZP with foliar acid spray, twice a week in the vegetation period. Water for variants KYZ and KYZP was treated with sulphuric acid to pH 3. In winter the watering with water was conducted repeatedly regardless of the variant, or the plants were covered with a layer of snow that was left to thaw to prevent drying out of the soil in the pots. In variants NN and NNS 2.5 g of ammonium sulphate per plant was applied in early May, June and July. The experiment was established repeatedly in 1999 (experiment 1), 2000 (experiment 2) and 2001 (experiment 3).

Only undamaged plants were included in dendrometric assessments of the height of the plants and diameter of the root collar (Table 1). Spring phenological phases (flushing – RA; onset of foliage 100% – PL; full foliage – PLX) and leaf shedding (experiment 2 and 3) of each individual were monitored on a weekly basis. The health condition of each individual tree was monitored in May and November.

The non-parametric Kruskal-Wallis ANOVA (Statistica 6.0) was used to evaluate the height and diameter increments of the plants and the leaf shedding. Changes in height and diameter were assessed over the duration of the experiments; development of leaf shedding was assessed separately for each year in experiments 2 and 3. The Kruskal-Wallis test and multiple comparisons between the variants were conducted. In the case of leaf shedding, multiple comparisons between the variants were limited to differences against control.

RESULTS AND DISCUSSION

In the first year of the established experiments no plants died nor were the tops damaged due to simulated stress. In the spring of the second year of experiment 1 and 3, dying and damage of the plants caused by winter frost appeared. Dying of birch of variants NN (16 plants), NNS (12 plants) and KYZ (1 plant) was detected. The terminals froze out in variants NN (33 plants), NNS (23 plants) and KYZP (25 plants), to a lesser extent in variants KYZ (11 plants) and SU (9 plants), and least of all in controls (5 plants). No dying of plants or frost killing of the termi-

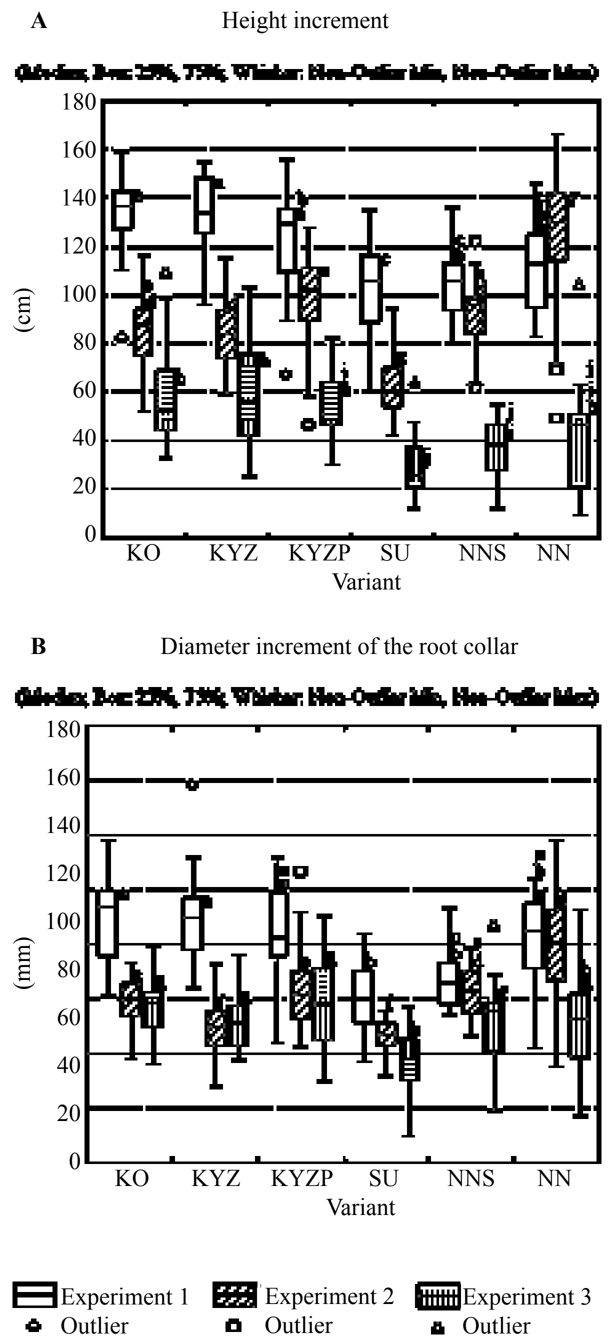

Fig. 1. Height increment of plants and diameter increment of the root collar. Medians indexed by the same letter are not significantly different. Explanations of variants cf. Table 1

nal shoots appeared in experiment 2 (Table 1). Other types of damage included an indistinct terminal shoot, injury of the terminal shoot caused by handling, or, as in the case of experiment 1, insufficient height of the foil hothouse. Frost damage is connected with excessive uptake of nitrogen by the plant (MARSCHNER 1995; MAGILL et al. 2000; ZHU et al. 2001; CAPON et al. 2000) and was confirmed in the experiment (Table 1).

Kruskal-Wallis test proved differences between the variants in terms of the height and diameter increments. The height increment of variant SU was always statistically significantly lower than that of variants KO, KYZ and KYZP, and in experiment 3 also lower than of variants NNS and NN. In experiments 1 and 3 the accretion of the sample trees in variant NNS was lower than in variants KO and KYZ. Increments in variants KO, KYZ, KYZP and NN were on the same level in experiments 1 and 3. In experiment 2 the increments were the highest in variant NN, and in variant KYZP higher than in variant KYZ (Fig. 1A).

The diameter increment of the root collar corresponded to the height increment (Fig. 1B). The differences in diameter increments in variants KO, KYZ, KYZP and NN of experiments 1 and 3 were not significant; the increment of variant SU was lower than that of variants KO, KYZ, KYZP and NNS (experiment 3) and the increment of variant NNS in experiment 1 was lower than in KO and KYZ. Differences were detected in the reaction of the variant to stress between experiment 2 and experiments 1 and 3. In experiment 2 variants KYZP and NNS were on the same level as the control, the diameter increments of variants KYZ and SU were lower and those of variant NN were higher; while no significant difference was detected between the variants SU × KYZ and NN × NNS.

The lower increment in variants NN and NNS of experiments 1 and 3 was caused by frost killing of the fastest growing and, at the same time, the most sensitive plants. Drought stress was the most marked growth inhibitor. In accordance with the findings of HEINZE and FIEDLER (1981) and VIKTOROV and BYSTRJANCEV (1960) an addition of nutrients reduced the effect of drought (variant NNS in experiment 2). Unless frost killing occurred, increments were the highest in birch of variant NN, but the high variability of the values bespeaks of the different reactions of the sample trees to higher levels of nitrogen. MAGILL et al. (2000) confirmed higher biomass increments in broadleaved stands after nitrogen entry, ZHU et al. (2001) in birch (*B. alleghaniensis* Britt.), and combined NO_2 and SO_2 fumigation was seen to effect *Calluna vulgaris* (L.) Hull (CAPON et al. 2000). If, however, nitrogen uptake is excessive, growth is slower (KULHAVÝ, FORMÁNEK 2002; INGESTAD 1977).

In experiment 1 the onset of spring phenophases was retarded in variants NN, NNS and less in KYZP. In the period of flushing, 100% of the sample trees in variants KO, KYZ and SU were flushing, in variant KYZP 75%, in variant NNS 61% and only 28% of the sample trees in variant NN. At the onset of phenophase PL in 70–88% of sample trees of variants KO, KYZ and SU, it was found that variants KYZP, NNS and NN were on the level of 38%, 39% and 10%, respectively. Full foliage of 93–100% of sample trees in variants KO, KYZ and SU corresponded to 60%, 32% and 24% in variants KYZP, NNS and NN, respectively. The onset of phenophases RA and PL in experiment 2 was balanced (93–100% of the sample trees on the date of control). Not until 78–80% of sample trees in variants KO, KYZ, KYZP and NNS were fully foliaged was the onset of this phenophase slightly delayed in vari-

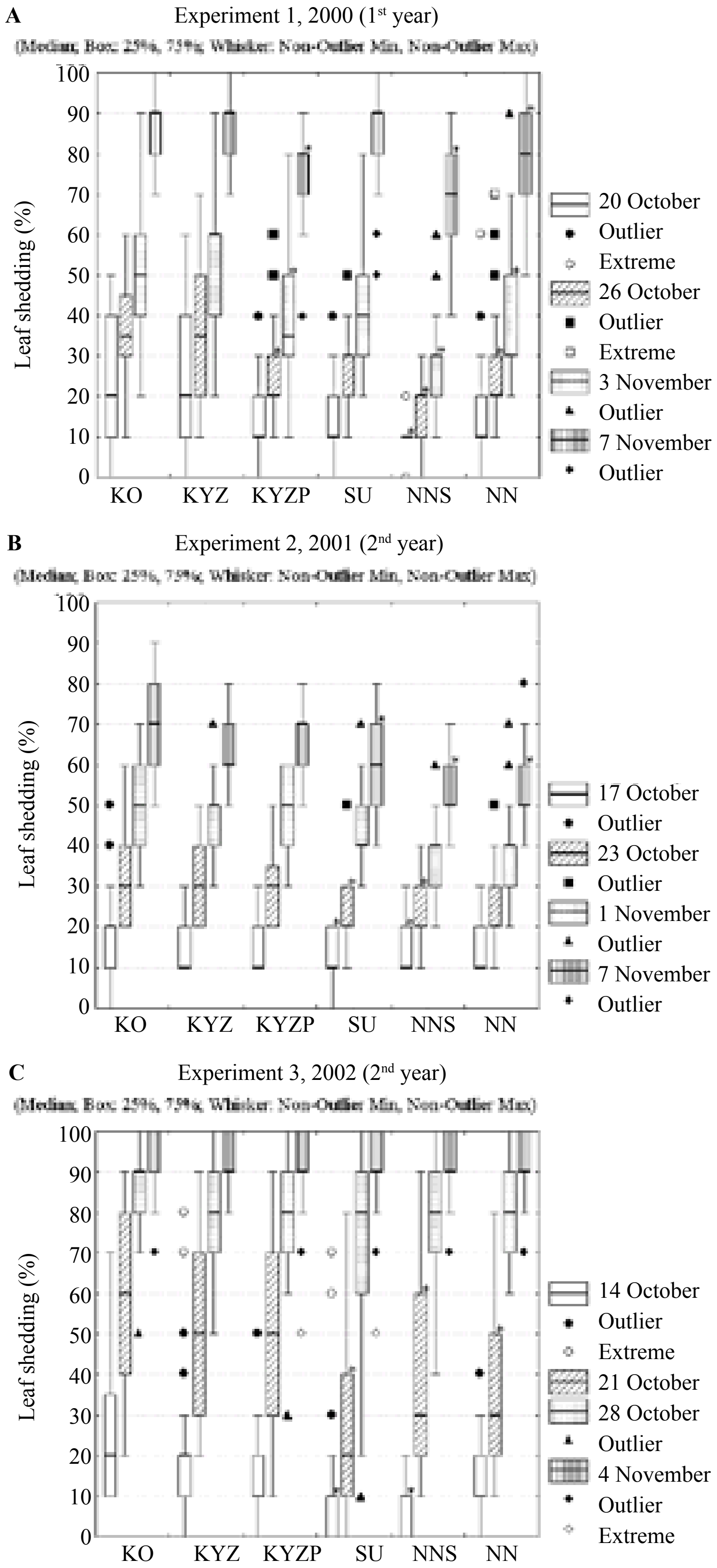

Fig. 2. Leaf shedding. *significantly different from the control. Explanations of variants cf. Table 1

ant NN (65%) and SU (68%). In experiment 3 during flushing of 87–100% of the sample trees in variants KO, KYZ, KYZP and SU, delayed flushing was discovered in variants NNS (76%) and NN (29%). At the onset of phenophase PL in 85 and 93% in variants KYZP and SU the variants NN; and KO, KYZ, NNS were delayed (14%, and 60–69%, respectively). At full foliage of 80 and 93% of sample trees in variants KO and SU this phenophase began in 68%, 72% sample trees in KYZP, KYZ and in 59% and 63% in NNS and NN, respectively (Table 2).

Birch flushing was most delayed in variants NN and NNS and slightly delayed in variants KYZP and KYZ. The delayed onset of spring phenophases is related to frost damage, which causes die-off of branches or parts of the stem and subsequent growth of substitute annual shoots in the spring.

Leaf shedding in the first year of experiment 2 was lower in variant NNS over the whole period (20 October to 7 November 2000) compared to the control, and in variants NN and KYZP from 26 October (Fig. 2A). Leaf shedding in the second year of experiment 2 was lower in variants SU and NNS over the whole period (17 October to 7 November 2001), with the exception of 1 November when the differences in leaf shedding between the variants were statistically insignificant. On 7 November less leaves were shed also in variant NN (Fig. 2B). In the first year of experiment 3 no statistically significant differences between the variants and the control were discovered. At the beginning of the studied period (14 October –4 November 2002) in the second year of experiment 3, leaf shedding was slower in variants SU, NNS (14–21 October) and NN (21 October) (Fig. 2C). From the results it is obvious that leaf shedding is delayed most of all in the variant treated with a combination of fertilisation with ammonium sulphate and drought (NNS), to a small extent in the drought variants (SU), fertilisation with ammonium sulphate (NN) and acid watering with spray (KYZP). The vegetation period was prolonged due to a provable higher level of nitrogen in these variants with the exception of drought.

CONCLUSION

Frost damage appeared particularly in plants of the variants with a higher content

Table 2. Percent of birch trees achieving the phenophase RA, flushing; PL, beginning of foliage in 100%; PLX, full foliage. Explanations of variants cf. Table 1

	Experiment 1 (2000)			Experiment 2 (2001)			Experiment 3 (2002)		
	31. March	11. April	20. April	27. March	4. April	27. April	21. March	4. April	25. April
Variant	RA	PL	PLX	RA	PL	PLX	RA	PL	PLX
KO	100	83	100	93	93	78	100	60	80
KYZ	100	70	93	95	95	80	87	69	72
KYZP	75	38	60	98	98	78	90	85	68
SU	100	88	98	100	100	68	98	93	93
NNS	61	39	32	100	100	80	76	62	59
NN	28	10	24	95	100	65	29	14	63

of nitrogen in the leaves: fertilisation with ammonium sulphate (NN) and also in combination with drought (NNS) and only slightly in the acid watering + spray variant (KYZP). In these variants substitute shoots grew out on the damaged plants in spring and resulted in delayed onset of spring phenophases. If sample trees of none variant were damaged, the onset of spring phenophases was not affected. Ammonium sulphate eliminated the impact of drought, which had the strongest negative effect on increments. Unless killed by frost, birch fertilised with ammonium sulphate showed the highest increments, but the wide range of values bespeaks of a differentiated response of the sample trees to increased supplies of nitrogen. Delayed leaf shedding against the control was most pronounced when fertilisation with ammonium sulphate was combined with drought (NNS), less in the drought variant (SU), ammonium sulphate fertilisation (NN) and acid watering with spraying (KYZP). In the variants with an addition of ammonium sulphate and the variant with acid watering and spraying a slight prolongation of the vegetation period was manifested due to the higher content of nitrogen, as this causes a higher sensitivity to frost.

References

BEDNÁŘOVÁ E., 2002. Stav asimilačního aparátu u lesních dřevin v Krušných horách. Sb. ref. Výsledky lesnického výzkumu v Krušných horách v roce 2001, Teplice 14. 3. 2002. Jíloviště-Strnady, VÚLHM: 77–81.

CAPON S.J.M., ASHENDEN T.W., LEE J.A., 2000. The effect of exposure to NO_2 and SO_2 on frost hardiness in *Calluna vulgaris*. Envir. Exp. Bot., *43*: 111–119.

FADRHONSOVÁ V., ŠRÁMEK V., KROUPOVÁ M., 2000. Vývoj depozic v oblasti Krušných hor. Sb. ref. Výsledky lesnického výzkumu v Krušných horách v roce 2001, Teplice 14. 3. 2002. Jíloviště-Strnady, VÚLHM: 49–54.

HADAŠ P., 2002. Celková potenciální depozice síry, dusíku a vodíkových iontů na území PLO Krušné hory v roce 1999. Sb. ref. Výsledky lesnického výzkumu v Krušných horách v roce 2001, Teplice 14. 3. 2002. Jíloviště-Strnady, VÚLHM: 55–66.

HEINZE M., FIEDLER H.J., 1981. Versuche zur Begrünung von Kalirückstandshalden. 1. Mitteilung: Gefässversuche mit Bäumen und Sträuchern bei unterschiedlichem Wasser- und Nährstoffangebot. In: MELILLO J.M., STEUDLER P., 2000. Long term nitrogen addition and nitrogen saturation in two temperate forests. Ecosystems, *3*: 238–253.

INGESTAD T., 1977. Nitrogen and plant grow; maximum efficiency of nitrogen fertilizers. In: PERALA D.A., ALM A.A., 1990. Reproductive ecology of birch: A Review. For. Ecol. Mgmt, *32*: 1–38.

KEANE K.D., MANNING W.J., 1988. Effect of ozone and simulated acid rain on birch seedling growth and formation of ectomycorrhizae. Envir. Pollut., *52*: 55–65.

KITAO M., LEI T.T., NAKAMURA T., KOIKE T., 2001. Manganese toxicity as indcated by visible foliar symptoms of Japanese white birch (*Betula platyphylla* var. *japonica*). Envir. Pollut., *111*: 89–94.

KULHAVÝ J., FORMÁNEK P., 2002. Dusík v lesních ekosystémech Krušných hor. Sb. ref. Výsledky lesnického výzkumu v Krušných horách v roce 2001, Teplice 14. 3. 2002. Jíloviště--Strnady, VÚLHM: 37–46.

LIU G. E., CÔTÉ B., 1993. Neutralization and buffering capacity of leaves of sugar maple, largetooth aspen, paper birch and balsam fir. Tree Physiol., *12*: 15–21.

MAGILL A.H., ABER J.D., BERNTSON G.M., McDOWELL W.H., NADELHOFFER K.J., MELILLO J.M., STEUDLER P., 2000. Long term nitrogen addition and nitrogen saturation in two temperate forests. Ecosystems, *3*: 238–253.

MARSCHNER H., 1995. Mineral Nutrition of Higher Plants. London, Academic Press: 889.

PROCHÁZKA S. et al., 1998. Fyziologie rostlin. Praha, Academia: 484.

RAYNAL D.J., ROMAN J.R., EICHENLAUB W.M., 1982. Response of tree seedlings to acid precipitation – II. effect of simulated acidified canopy throughfall on sugar maple seedling growth. Envir. Exper. Bot., *22*: 385–392.

VIKTOROV D.P., BYSTRJANCEV N.I., 1960. Increasing of drought resistance of birch and elm seedlings with P fertilizers. In: MELILLO J.M., STEUDLER P., 2000. Long term nitrogen addition and nitrogen saturation in two temperate forests. Ecosystems, *3*: 238–253.

WRIGHT E.A., 1987. Effect of sulphur dioxide and nitrogen dioxide, singly and in mixture, on the macroscopic growth of three birch clones. Envir. Pollut., *46*: 209–221.

ZHU X.B., COX R.M., MENG F.-R., ARP P.A., 2001. Responses of xylem cavitation, freezing injury and shoot dieback to simulated winter thaw in yellow birch seedlings growing in different nursery culture regimes. For. Ecol. Mgmt, *145*: 243–253.

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Vliv stresových faktorů na břízu *Betula pendula* Roth

D. Kaňová, E. Kula

Lesnická a dřevařská fakulta, Mendelova zemědělská a lesnická univerzita, Brno, Česká republika

ABSTRAKT: Sazenice břízy (*Betula pendula* Roth) byly v rámci řízeného nádobového pokusu ošetřovány v šesti variantách: kyselá zálivka (pH 3), kyselá zálivka s postřikem, sucho, hnojení síranem amonným, hnojení síranem amonným v kombinaci se suchem a kontrola. Nejednotná reakce v přírůstu břízy se projevila při vstupu síranu amonného, který zvýšil její citlivost na mráz. Sucho ovlivnilo negativně přírůst. Opožděný opad listů nastal při působení síranu amonného a sucha; sucha; síranu amonného a kyselé zálivky s postřikem v důsledku prodloužení vegetačního období průkazně vyšším obsahem dusíku v těchto variantách s výjimkou sucha.

Klíčová slova: *Betula pendula*; stres; kyselý déšť; síra; dusík; sucho; růst; fenologie

Do ekosystémů imisních oblastí jsou stále vnášeny vodíkové kationty, síra, dusík a další látky, které mění podmínky pro růst a vývoj rostlin. K objasnění vlivů jednotlivých stresových situací (kyselé vstupy, sucho, zvýšené vstupy dusíku a síry) na břízu *B. pendula*, která byla vybrána jako modelová dřevina vzhledem ke svému rozšíření v imisních oblastech, byl založen nádobový pokus s řízenými vstupy, který usnadňuje sledování v lesních ekosystémech velmi komplikovaného působení jednotlivých stresových faktorů. Cílem příspěvku je prezentovat jejich vliv na růstové vlastnosti a fenologii břízy *B. pendula*.

Dvouletý pokus s kontejnerovanými sazenicemi břízy *B. pendula* umístěnými v prostředí fóliovníku v lesní školce Řečkovice (Česká republika, Brno, 220 m n. m.) byl založen opakovaně v letech 1999 (experiment 1), 2000 (experiment 2) a 2001 (experiment 3). Každý experiment zahrnoval 240 vzorníků rozdělených do 6 variant: KO – kontrola, KYZ – kyselá zálivka (přídavek kyseliny sírové, pH 3), KYZP – kyselá zálivka s kyselým postřikem listů, SU – sucho (1/2 normální zálivky vodou), NNS – hnojení síranem amonným a sucho, NN – hnojení síranem amonným. Bylo provedeno dendrometrické stanovení výšky sazenic a tloušťky kořenového krčku. Sledovaly se jarní fenofáze (rašení; začátek olisťování; 100% plné olistění), opad listů a zdravotní stav každého jedince. K vyhodnocení dat byla použita neparametrická Kruskal-Wallisova ANOVA (Statistica 6.0).

Na jaře druhého roku experimentu 1 a 3 bylo zaznamenáno odumření a poškození rostlin vlivem zimních mrazů. Břízy odumřely ve variantách NN, NNS a KYZ. Terminály vymrzaly nejvíce ve variantách NN, NNS a KYZP, méně KYZ, SU a nejméně v kontrole. V experimentu 2 nebylo zaznamenáno odumření rostlin ani vymrzání vrcholů (tab. 1). Poškození mrazem je spojováno s nadbytečným příjmem dusíku rostlinou (Marschner 1995; Magill et al. 2000; Zhu et al. 2001; Capon et al. 2000), což se v experimentu potvrdilo (tab. 1).

Nástup jarních fenofází v experimentech 1 a 3 byl opožděn ve variantách NN, NNS a mírně ve variantě KYZP a KYZ (tab. 2). Opoždění souvisí s poškozením mrazem, které způsobí odumření větví nebo části kmene a následný růst náhradních letorostů v jarním období. Pokud nebyly vzorníky poškozeny, ani nástup jarních fenofází nebyl ovlivněn (experiment 2).

Výškový i tloušťkový přírůst byl nejvýrazněji snížen působením sucha. V souladu s poznatky Heinze a Fiedlera (1981) a Viktorova a Bystrjanceva (1960) byl jeho vliv eliminován přídavkem živin (varianta NNS v experimentu 2). Ve variantách NN a NNS experimentů 1, 3 byl zaznamenán nižší přírůst, který byl způsoben vymrznutím nejrychleji rostoucích a současně nejcitlivějších jedinců. Pokud nedošlo k vymrzání (experiment 2), přirůstaly nejvíce břízy ve variantě NN, i když velký rozptyl hodnot svědčí o různé reakci vzorníků na zvýšený přísun dusíku (obr. 1, 2). Větší přírůst biomasy při vstupech dusíku potvrzují u listnatého porostu Magill et al. (2000), u břízy (*B. alleghaniensis* Britt.) Zhu et al. (2001) a kombinovaná fumigace NO_2 a SO_2 působila na *Calluna vulgaris* (L.) Hull shodně (Capon et al. 2000). Pokud je však příjem dusíku nadměrný, dochází k retardaci růstu (Kulhavý, Formánek 2002; Ingestad 1977).

Opoždění opadu listů vůči kontrole bylo nejvýraznější v kombinaci hnojení síranem amonným a sucha, méně ve variantě se suchem, hnojením síranem amonným a s kyselou zálivkou s postřikem (obr. 3, 4, 5). Ve variantách s přídavkem síranu amonného a variantě kyselé zálivky s postřikem se projevilo mírné prodloužení vegetačního období vlivem vyššího obsahu dusíku, což vyvolává vyšší citlivost k mrazu.

Corresponding author:

Prof. Ing. Emanuel Kula, CSc., Mendelova zemědělská a lesnická univerzita, Lesnická a dřevařská fakulta, Lesnická 37, 613 00 Brno, Česká republika
tel.: + 420 545 134 127, fax: + 420 545 211 422, e-mail: Kula@mendelu.cz