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The Effect of «Acid Rains» and Mineral Fertilization on the Development of Biometrical Features of *Fagus sylvatica* L. Seedlings

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Summary

The purpose of the present experiment was to describe the influence of various methods of mineral fertilization: NK into leaves (Florovit), NPK onto soil (Fruktus 2) and liming (dolomite magnesium) on the development of *Fagus sylvatica* L. seedlings subject to the influence of simulated acid rains of pH 2.5, 3.0, 3.5, 4.0, 4.5.

As a result of the carried out analysis of the correlation coefficient a reciprocal high correlation was found between particular parameters of growth of *Fagus sylvatica* L. seedlings i.e. of the diameter of root nect, root mass, total mass of: seedlings, leaves, main shoots, lateral shoots, ligneous parts, overground parts, as well as of total length of lateral shoots. Whereas no high correlation was observed between the above mentioned parameters and a total heigth of the seedling.

The obtained results of the analysis of changes in biometric characteristics of *Fagus sylvatica* L. seedlings showed, that the best development was achieved at pH 4.5, whereas their weakest development was observed at 2.5. The analysis showed the decrease in values of analysed characteristic together with the increase in acidity of aqueous solutions.

The first and second and third year of the experiment for *Fagus sylvatica* L. showed that kind of fertilization did not effect positively the increase in values of the analyzed biometrical feature – total height of seedling comparing with those of control plots. The significant improvement of total height of seedling was noticed on control plot with pH 3.5 in relation to pH 2.5 on control plot in first year. The best increment of total height of seedling was noticed for pH 3.5 for each year.

The third year of the experiment showed that using fertilization: Ca + Mg onto soil, NK into leaves and NPK onto soil it is possible to restrict the unfavourable influence of «acid rains» on total mass of *Fagus sylvatica* L. seedling. The best significant increment of this biometrical feature was observed on pH 4.0. When one wants to restrict the unfavourable influence of «acid rains» on analyzed total mass of seedlings within pH 2.5–4.5 it is possible to choose optimaly one from three applied fertilizing variants.

Key words: Acid rain, fertilizers, biometrical features, tree seedlings, Fagus sylvatica L.

Abbreviations: pH = pH of simulated acid rains.

Introduction

It is claimed that one of the main causes of the new forest dieback is the changes in soil chemistry provoked by acid rain. «Acid rain» causes marked disturbance in the uptake of nutrients by plants and at the same time limits their growth (Altshuller & Linthurst 1976, Ulrich 1983, Ulrich 1986, Abrahamsen et al. 1987, Krause 1988, Białobok 1989, Greszta at al. 1990, Huettl 1990, Gruszka 1991). This process occurs expecially intensively on barren grounds e.g. on sands for:

Table 1: Chemical characteristics of water used for preparation of aqueous solution of sulphuric acid.

	unit	pH in H_2O	Na	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Cd	Ni	Cr	Cl
Water used	mg/L	7.8	21.48	1.0	31.4	6.2	0.35	6.2	0.175	<0.005	0.03	<0.005	0.07	<0.01	0.97
Added with water	kg/ha/y	7	279.2	13.0	408.2	80.6	4.55	80.6	1.99	–	0.39	–	0.81	–	4.55

Table 2: Chemical characteristics of the soil used for experiment.

	unit	pH in H_2O	pH in KCl	N	C	P	Na	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Cd	Ni	Cr
Soil	µg/g	7.3	7.1	420	6700	–	130	380	910	410	3270	241	22	14	18.2	1.4	6.3	5.5
exchangeable elements	µg/g			–	–	27.1	–	18.5	11.5	–	–	–	–	–	–	–	–	–

Pinus sylvestris L., *Pinus strobus* L., *Larix decidua* Mill., *Abies alba* L., and *Fagus sylvatica* L. (Gruszka 1991). To some extent is counteracted by supplying soil with nutrients and liming (Rugge 1978, Huettl 1988, 1989, Zoettl et al. 1989, Huettl et al. 1990, Huettl & Fink 1991). It is believed that the negative effects of acid rain may be limited by supplying the soil with fertilizers in the form of easily assimilative macroelements i.e. NPK, dolomite (Charitonov 1970, Huettl & Wiśniwski 1987, Huettl 1988, 1989, Huettl et al. 1990, Huettl & Fink 1991).

Mineral fertilization and liming has become one of the main operations to reestabilize the forest ecosystem. In this case fertilization and liming is an important agent of prevention and counteraction negative effects of air pollution and in particular of acid rain on bio-, pedo- and hydrosphere (Huettl 1986, Zoettl & Huettl 1986, Brocksen et al. 1988, Huettl & Wiśniwski 1987).

In our investigation the main aim has been to detect the acid rain effects on the productivity of *Fagus sylvatica* L. seedlings treated also with fertilizers and lime.

Material and Methods

Artificial acid rain was obtained from a water solution of H_2SO_4 to reach the following pH in KCl values: 2.5, 3.0, 3.5, 4.0, 4.5 under a plastic roof. The average yearly rainfall in nearest area is about 600 mm, but in order to compensate for an increased transpiration under the roof the seedlings were exposed to higher rainfall, 1300 mm per year. Concentrated H_2SO_4 was used in preparing the acid solutions. After mixing the solutions were checked and corrected with H_2SO_4 and NaOH to obtain required pH-values. The water was taken from a deep water well, and the water was filtered to absorb eventual particles. The chemical composition of the water is given in Table 1.

The seedlings were prevented from the influence of precipitation by a roof without front and side walls, making other atmospheric factors such as temperature, humidity, fog, dew and others not much different from natural conditions.

One year old seedlings of *Fagus sylvatica* L. were used, identical as far as their quality and health were concerned – I class acc. to estimation used in PGL (BN-76/9212-02). *Fagus sylvatica* L. seeds were from the Brzesko Forestry Inspectorate (habitat type of forestry Lśw, 60–80 years). The seeds were germinated in an open greenhouse.

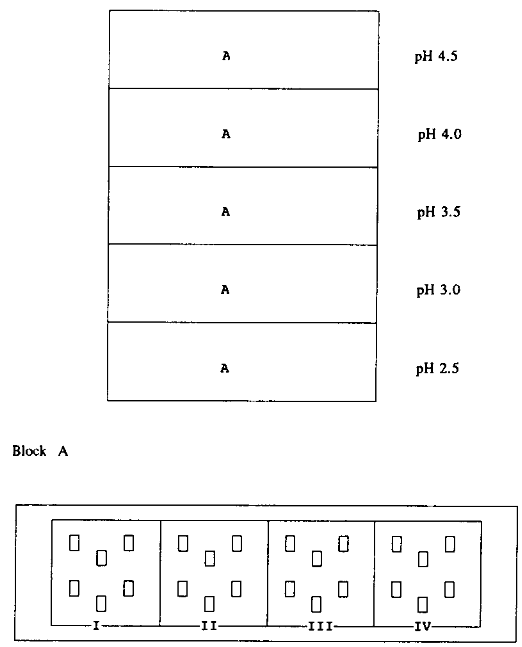

Fig. 1: Diagram of field experiment.
pH 2.5, pH 3.0, pH 3.5, pH 4.0, pH 4.5 – pH of simulated acid rain; A – Block A; I – control (without fertilization); II – fertilizer: Ca+Mg onto soil; III fertilizer: NK into leaves; IV – fertilizer: NPK onto soil; □ – single *Fagus sylvatica* L. seedling.

The seedlings were planted in the open greenhouse but under similar conditions on mixed loamy sand (Table 2) using separated plots measuring 80×80 cm. The plots were separated from one another by a concrete slab 60 cm deep in the ground, in order to avoid the overgrowth of the roots into neighbouring plots and a horizontal dislocation of water solutions of different pH. Each plot contained 6 seedlings. A general plan of the experiment is shown in Fig. 1.

The experiment was established in the spring of 1989. The seedlings were planted in March and watered with original ground water for 2 months to facilitate root stabilizing and to eliminate losses caused by the transplantation stress.

From mid-June on, the seedlings were watered with artificial acid rain each third day. The control plots of the experiment were sprayed only with acid rain of different pH: 2.5, 3.0, 3.5, 4.0, 4.5 each year.

Table 3: Multiple correlation matrix of the analyzed biometric characteristics for *Fagus sylvatica* L.

	RND	RM	NM	LSM	MSM	LPM	APM	SM	SH	LSL
RND	1.000	0.838	0.834	0.767	0.854	0.858	0.860	0.872	0.848	0.842
RM		1.000	0.931	0.853	0.859	0.896	0.928	0.974	0.730	0.869
NM			1.000	0.842	0.864	0.894	0.949	0.958	0.763	0.907
LSM				1.000	0.820	0.932	0.925	0.912	0.628	0.843
MSM					1.000	0.972	0.960	0.936	0.843	0.857
LPM						1.000	0.989	0.967	0.794	0.891
APM							1.000	0.988	0.803	0.917
SM								1.000	0.787	0.914
SH									1.000	0.784
LSL										1.000

Names of Variables: RND – diameter of all roots neck (cm); RM – mass of a root (g); LM – total mass of leaves (g); LSM – total mass of lateral shoots (g); MSM – total mass of main shoots (g); LPM – total mass of ligneous part (g); APM – total mass of aboveground part (g); SM – total mass of seedlings (g); SH – total height of seedlings (cm); LSL – total length of lateral shoots (cm).

A second serie of plots was sprayed with acid rain like the control plots, and was also fertilized from April to September with dolomite on the soil surface (Ca+Mg on soil): 5 % MgO, 70 % CaO each year. Eight g was given on each plot and each month, which means: 37.5 kg MgO $ha^{-1} \cdot y^{-1}$ and 525 kg CaO $ha^{-1} \cdot y^{-1}$.

A third serie of plots was sprayed with acid rain like the control part, and was fertilized from April to September once a month with the mineral fertilizer NK «Florovit» onto the needles (NK onto needles) each year. These plots received fertilizers containing: 3.0 % – N, 2.4 % – K_2O, 0.75 % – Ca, 0.3 % – S, 0.1 % – MgO, 400 mg/dm^3 – Fe, 150 mg/dm^3 – Zn, 150 mg/dm^3 – Mn, 70 mg/dm^3 – Cu, 30 mg/dm^3 – B, 20 mg/dm^3 – Mo. Of the fertilizer material was taken 25 mL per 5 L of water from April to September meaning: 12 kg N, 9.6 kg K_2O, 3.0 kg Ca, 1.2 kg S, 0.4 kg MgO, 0.16 kg Fe, 0.06 kg Zn, 0.028 kg Cu, 0.018 kg B, 0.008 kg Mo per ha, per year.

A fourth serie of plots was sprayed with acid rain like the control part, and was fertilized once a month with a solid mineral fertilizer «Fruktus 2» (NPK onto soil) each year. These plots received fertilizers containing: 13.5 % N, 5 % P_2O_5, 20 % K_2O, 5 % MgO, 0.2 % – Cu, 0.2 % – Zn, 0.2 % – Mn, 0.2 % – Br, 0.01 % – Mo, in the proportion of 38 g per one plot – which means 175.5 kg N, 65 kg P_2O_5, 260 kg K_2O, 65 kg MgO, 2.6 kg Cu, 2.6 kg Zn, 2.6 kg Mn, 2.6 kg Br, 0.13 kg Mo per ha, per year.

The experiment was carried out in the nursery at Jodłówka for three years, close to Brzesko – 60 km eastwards of Kraków, on the permises of the Brzesko Forest Inspectorate belonging to Kraków District Head Office for State Forests.

After three vegetation seasons, Oct. 1991, the total biomass of leaves, shoots and roots was taken for analyses of *Fagus sylvatica* L.. The plant material was separated as follows: main shoots grown in the years 1988, 1989, 1990, 1991, lateral shoots from years: 1988, 1989, 1990, 1991, leaves and roots from the whole seedling; assimilation system for beech (1990, 1991). For determinin a mean mass of 1000 leaves the material was collected from the whole plant.

The following biometric characteristics were analysed for plants:

1. total height of a seedling before beginning and in 1, 2, 3, year of the experiment,
2. diameter of the root neck,
3. total mass of: roots, seedling, lateral shoots, main shoots, lingneous and aboveground parts, after the third year of the experiment,
4. mean total lenght of lateral shoots after the third year of the experiment,
5. mean mass of 1000 leaves in the 2, 3, year of the experiment,
6. mean length of lateral shoots in the 1-st, 2nd and 3rd year of the experiment.

The mass of the analyzed vegetable material was determined by means of the laboratory balance of Medicat Ltd. 1600C type with an accurracy up to ± 0.01 g, and the length and height by the ruler of Skala type with an accurracy of ± 0.1 cm.

Results

Correlation coefficients for the biometric variables between each characteristic were calculated. The results are given in Table 3.

On the basis of analysis of correlation coefficient diameter of the root neck, total dry weight of: leaves, lateral shoots, ligneous and above ground parts of seedlings, seedling at the end of the experiment, total length of lateral shoots – for these variables the correlation coefficient is higher than 0.850, that is to say, the above mentioned characteristics are highly correlated between each other. For further analysis the total dry weight of seedlings was taken as a representative value for this group. The total height of the seedling, which is not highly correlated with remaining variables (the correlation coefficient is lower than 0.850). This variable should be separately analyzed features. Thus two characteristic features were chosen for further analysis: the total height of a seedling and its total mass (Oktaba 1971). The results after three years of the experiment on chosen biometrical features are given in Table 4.

The average of total mass of seedlings, on controlled plots in the 3-rd year of the experiment, changed together with the change of pH of the aqueous solution; ranging from the least 17.62 g value at pH 2.5 it systematically increased up to pH 4.0, reaching the largest mass of 112.04 g. After exceeding pH 4.0, the mass value decreased and at pH 4.5 it was 88.06 g (Table 4).

The average of the total height of seedlings after 3rd year of the experiment on the control plots varied together with the increase of the pH from the least 22.88 cm value at pH 2.5, to the highest one of 86.64 cm at pH 4.0. Above this pH the height decreased to 84.77 cm at pH 4.5 (Table 4). The same tendency to decreasing the increment of the main shoot has been observed in particular years. At pH 2.5 a total

Table 4: Average values of chosen biometric characteristics of *Fagus sylvatica* L. at the end of the experiment of different pH treatments ± standard deviation).

pH	total height of seedling in cm on control plots after						total mass of seedlings on control in g in 1991		total height of seedling in cm on Ca+Mg plots after						total mass of seedlings on Ca+Mg plots in g in 1991	
	1989		1990		1991				1989		1990		1991			
	av.	±	av.	±	av.	±	av.	±	av.	±	av.	±	av.	±	av.	±
2.5	9.35	7.86	15.20	13.51	22.88	22.16	17.62	21.85	16.45	10.23	33.55	19.31	52.77	28.21	62.51	39.51
3.0	15.30	4.78	22.48	5.56	31.27	10.39	21.17	15.60	20.92	6.35	37.15	9.91	60.07	18.30	73.14	54.95
3.5	22.15	9.80	39.28	22.96	59.23	29.69	72.54	76.05	28.05	12.58	51.15	23.35	78.47	36.96	80.51	61.59
4.0	26.55	5.74	49.13	19.15	86.72	16.52	112.04	41.40	23.67	9.27	49.10	15.43	71.15	21.29	98.93	92.67
4.5	33.15	15.42	53.85	10.95	84.77	27.68	88.06	77.45	24.15	4.89	41.47	9.42	65.23	16.64	92.67	42.12
pH	total height of seedling in cm on NK plots after						total mass of seedlings on NK plots in g in 1991		total height of seedling in cm on NPK plots after						total mass of seedlings on NPK plots in g in 1991	
	1989		1990		1991				1989		1990		1991			
	av.	±	av.	±	av.	±	av.	±	av.	±	av.	±	av.	±	av.	±
2.5	30.18	19.41	43.07	27.16	60.15	35.79	81.82	56.65	21.88	5.56	37.93	16.95	56.67	19.20	65.20	28.88
3.0	23.68	8.52	46.35	17.26	66.42	22.45	79.32	39.34	21.95	8.15	39.08	17.57	63.80	24.66	66.14	45.63
3.5	28.05	6.49	46.45	12.64	61.35	15.43	96.34	52.71	22.53	4.59	42.52	16.56	70.02	22.17	106.29	61.46
4.0	25.33	7.74	45.97	15.90	75.30	20.47	112.67	71.08	24.10	8.48	46.67	21.89	81.03	30.17	109.57	66.17
4.5	29.42	9.68	47.43	14.08	70.88	16.98	147.45	127.21	30.98	12.84	47.95	15.15	81.93	21.52	114.35	33.51

height of seedlings in 1990 was 15.20 cm (the least value), then it systematically increased up to 53.85 cm at pH 4.5 achieving the largest value (Table 4). In 1989 the total height of the seedlings was changing from the least value of 9.35 cm at pH 2.5 it increased up to 33.15 cm at pH 4.5 achieving the highest value (Table 4).

The average of total mass of seedlings, on Ca + Mg plots in the 3-rd year of the experiment, changed together with the change of pH of the aqueous solution; from the least amont of 62.51 g value at pH 2.5 it systematically increased up to pH 3.5, reaching the largest mass of 98.93 g. After exceeding pH 4.0, the mass decreased and at pH 4.5 it was 92.67 g (Table 4).

The average of the total height of seedlings on the Ca + Mg plots in the 3-rd year of the experiment growed together with the increase of the pH from the least value 52.77 cm value at pH 2.5, to the greatest one of 78.47 cm at pH 3.5. Above this pH value, the height decreased to 65.23 cm at pH 4.5 (Table 4). The same tendency to decreasing the increment of the main shoot has been observed in individual years year. At pH 2.5 a total height of seedlings in 1990 was 33.55 cm (the least value), while at pH 3.5 it was 51.15 cm (the highest value), above this pH the height of seedlings decreased up to 41.47 cm at pH 4.5 (Table 4). In 1989 the total height of the seedlings was changing from the least value of 16.45 cm at pH 2.5, it increased achieving the largest value of 28.05 cm at pH 3.5, and then this height decreased to 24.15 cm at pH 4.5 (Table 4).

According to pH of acid rain the average of total mass of seedlings, on NK plots in the 3-rd year of the experiment, changed together with the change of pH of the aqueous solution; from the 81.82 g value at pH 2.5 the mass decreased up to pH 3.0, reaching the least value of 79.32 g, and then it incereased achieving the largest value 147.75 g at pH 4.5 (Table 4).

The average of the total height of seedlings on the NK plots in the 3-rd year of the experiment varied together with the change of the pH from the lesst value 60.15 cm at pH 2.5, it increased to 66.42 cm at pH 3.0. Above this pH value followed the height decrease to 61.75 cm at pH 3.5, and then the height increased to the largest value of 75.30 cm at pH 4.0, but at pH 4.5 it again decreased to 70.88 cm (Table 4). The same tendency has been observed for particular years. At pH 2.5 a total height of seedlings in 1990 was 43.07 cm achieving the least value, then this value increased achieving the largest value 46.45 cm at pH 3.5, and above this pH the decrease in the seedlings height ranged 45.97 cm for pH 4.0 and afterwards increased to 47.43 cm at pH 4.5 (Table 4). In 1989 the total height of the seedlings changed in the following way: from 30.18 cm the largest value at pH 2.5, the value decreased up to 23.68 cm at pH 3.0 achieving the least value, and then this height increased to 28.05 cm at pH 3.5, and again it decreased up to 25.33 cm at pH 4.0, and next it increased to 29.42 cm at pH 4.5 (Table 4).

According to pH of acid rain the average of total mass of seedlings, on NPK plots, changed together with the change of pH of the aqueous solution; from the least value of 65.20 g at pH 2.5 the mass increased systematically up to pH 4.5 reaching the largest value 114.35 g (Table 4).

The average of the total height of seedlings on the NPK plots in the 3-rd year of the experiment varied together with the change of the pH from the least value 56.67 cm at pH 2.5, than it increased systematically achieving the largest value 81.93 cm at pH 4.5 (Table 4). The same tendency has been

Table 5: Two way Analysis of variance indicats significant effect (P = 0.05) of: pH of acid rain treatment, kind of fertilization, interaction between pH and fertilization for two biometrical features of *Fagus sylvatica* L. seedlings treated with different pH of artificial acid rain and different kind of fertilization for taken homogeneous scheme.

biometrical feature	total height of seedling												total mass of seedling after 1991		
	in 1988			in 1989			in 1990			in 1991					
scheme: kind of fertilization/significant factor	pH	kind of fertilization	interaction pH-fertilization	pH	kind of fertilization	interaction pH-fertilization	pH	kind of fertilization	interaction pH-fertilization	pH	kind of fertilization	interaction pH-fertilization	pH	kind of fertilization	interaction pH-fertilization
homogenous scheme for pH	2.5, 3.0, 3.5, 4.0, 4.5			2.5, 3.5, 4.5			2.5, 3.5, 4.5			2.5, 3.5, 4.5			2.5, 3.0, 3.5, 4.0, 4.5		
Ca+Mg onto soil-control				*			*			*			*	*	
NK into leaves-control										*			*	*	
NPK onto soil-control				*		*	*			*			*	*	
homogenous scheme for pH	2.5, 3.0, 3.5, 4.0, 4.5			2.5, 3.5, 4.5			2.5, 3.5, 4.5			2.5, 3.5, 4.5			2.5, 3.0, 3.5, 4.0, 4.5		
Ca+Mg onto soil – NK into leaves															
Ca+Mg onto soil – NPK onto soil															
NK into leaves – NPK onto soil															

observed for particular years. At pH 2.5 a total height of seedlings in 1990 was 37.93 cm (the least value), then this value increased achieving the largest value of 47.93 cm at pH 4.5 (Table 4). In 1989 the tottal height of the seedlings changed in the following way: fron the least value 21.88 cm at pH 2.5, the value increased to the largest one of 30.98 cm at pH 4.5 (Table 4).

Significant factor effect

The plan of the experiment described in material and methods considered two different opposing principles:

1. using of fertilization or not:
   Ca + Mg on soil-control, NK on leaves-control, NPK on soil-control
2. fertilizer application:
   Ca + Mg on soil – NK on leaves, Ca + Mg on soil – NPK on soil, NK on leaves – NPK on soil.

Inhomogenously of data for a certain treatment indicate that other factors might influence on results. Being a factorial experiment the results were confirmed by analyses of variance (two way Anova factor analysis – Oktaba 1971). With pH as one factor and fertilizers as the other.

Statistical analyse showed that the total height of seedlings before experiment (1988) was equal and we can draw a conclusion that the experiment was established in a correct way (Table 5).

Statistical analyse for total height of seedling (homogenous for pH: 2.5, 3.5, 4.5) after first year indicate significant differences for pH in: «Ca + Mg onto soil-control» and «NPK onto soil-control», and interaction between pH and fertilization in: «NPK onto soil-control» on biometrical feature changing the value in first case: between pH: 2.5 and 3.5 about 12.20 cm, 2.5 and 4.5 about 15.75 cm – the best increment was noticed for pH 4.5 the worst for pH 2.5, in a second case: changing the value between pH: 2.5–3.5 about 12.98 cm. Interaction between pH and fertilization caused significant effect on biometrical feature on control and NPK plots – for control plot with pH 2.5 in relation to different pH of control plots an average increased as follow: to pH 3.5 about 23.80 cm. The worst development was noticed on control plot with pH 2.5, the best on control plot with pH 3.5.

Statistical analyse for total height of seedling (homogenous for pH: 2.5, 3.5, 4.5) after second year indicate significant differences for pH in: «Ca + Mg onto soil-control» and «NPK onto soil-control» (Table 5) on biometrical feature changing the value in first case: between pH: 2.5 and 3.5 about 20.84 cm, 2.5 and 4.5 about 20.93 cm – the best increment was noticed for pH 4.5 the worst for pH 2.5, for second case: between pH: 2.5–3.5 about 21.33 cm. The worst development was noticed for pH 2.5, the best for pH 3.5.

Statistical analyse for total height of seedling (homogenous for pH: 2.5, 3.5, 4.5) after third year indicate significant differences for pH in: «Ca + Mg onto soil-control», «NK into leaves-control» and «NPK onto soil-control» (Table 5) on biometrical feature changing the value in first case: between pH: 2.5 and 3.5 about 31.09 cm, 2.5 and 4.5 about 37.26 cm, for second scheme: 2.5 and 3.5 about 36.31 cm, for third scheme: 2.5 and 3.5 about 43.13 cm. The best increment was noticed for pH 3.5 the worst for pH 2.5.

Statistical analyse for total mass of seedling (homogenous for pH: 2.5, 3.0, 3.5, 4.0, 4.5) after third year indicate significant differences for fertilization and pH for: «Ca + Mg onto soil-control», «NK into leaves-control» and «NPK onto soil-control» (Table 5) – on biometrical feature changing the value using fertilization-increasing the value in first scheme: about 19.20 g, in second scheme about 41.24 g and in third scheme about 30.00 g in relation to control plots. Significant effect of pH on biometrical feature changed the value between pH for first scheme: 2.5 and 4.0 about 65.52 g, 2.5 and 4.5 about 50.70 g, 4.0 and 4.0 about 58.58 g, for second scheme: 2.5 and 4.0 about 62.64 g, 2.5 and 4.5 about 68.34 g, 3.0 and 4.0 about 62.36 g, for third scheme: 2.5 and 4.0 about 69.40, 2.5 and 4.5 about 60.09 g, 3.0 and 4.0 about 67.40 g, 3.0 and 4.5 about 58.10 g. The best increment was noticed for pH 4.0 the worst for pH 2.5.

Discussion

The obtained results of the analysis of changes of biometric characteristic of *Fagus sylvatica* L. seedlings, growing on plots: control, fertilized with: Ca + Mg onto soil, NK into leaves (Florovit), NPK onto soil (Fruktus 2) showed at pH: 2.5, 3.0, 3.5, 4.0, 4.5 of simulated acid rains that seedlings achieved the best development at pH 4.5, whereas the weakest one at pH 2.5. This confirms the hypothesis presented at the Conference of United Nations (1971) and also Dahl and Skre (1971) that the low reaction is not suitable to beech (Baule and Fricker 1971, Gruszka 1991) and that the optimum growth of *Fagus sylvatica* L. is achieved at pH of soils within the range of pH in H_2O: 5.5–6.5, and maximum 7.1 (Ivanov 1970, Fielder et al. 1973 – referred to Kowalkowski 1982).

It was found that the coefficient a reciprocal high correlation was found between particular parameters of growth of *Fagus sylvatica* L., seedlings i.e. of the diameter of root nect, root mass, total mass of: seedlings, leaves, main shoots, lateral shoots, ligneous parts, overground parts and lenght of lateral shoots. Whereas no high correlation was observed between the above mentioned parameters and a total heigth of the seedling.

In the event of introduction of higher acidification into soil, the beech reacted by decrease in all values of growth parameters. This confirms the results obtained by Gruszka (1991).

Fagus sylvatica L. with *Quercus alba* L., *Carya ovata* Mill., *Fagus grandifolia* Ehnh. belong to a group of trees hardy to air pollution. The limitation of growth and damades of the assimilation system were found only at pH 2.5 of acid rains. But, in general at pH 2.5 overcolouring and necrosis as well as weaker growth of seedlings may be observed (Foy 1974, Jensen and Dochinger 1989).

The first and second and third year of the experiment for *Fagus sylvatica* L. showed that kind of fertilization did not effect positively the increase in values of the analyzed biometrical feature – total height of seedling comparing with those of control plots. The significant improvement of total height of seedling was noticed on control plot with pH 3.5 in relation to pH 2.5 on control plot in first year. The best increment of total height of seedling was noticed for pH 3.5 for each year.

The third year of the experiment showed that used fertilization: Ca + Mg onto soil, NK into leaves and NPK onto soil it is possible to restrict the unfavourable influence of «acid rains» on total mass of *Fagus sylvatica* L. seedling. The best significant increment of this biometrical feature was observed on pH 4.0. When one wants to restrict the unfavourable influence of «acid rains» on analyzed total mass of seedlings within pH 2.5–4.5 it is possible to choose optimaly one from three applied fertilizing variants.

The obtained results confirm that *Fagus sylvatica* L. develops best on limestone soils without strong acidification (Peninningsfeld 1964, Charitonov 1970, Baule and Fricker 1971, Kowalkowaki 1982). The satisfactory results after liming may be expected at an sufficient supply with remaining nutrients. The fertilization experiments carried out in nurseries and on stand areas at simultaneous supplying with various combinations of: N, P, K, Ca show a diversified influence of fertilization the increment of the cross-section sufrace and of the height of a tree. The favourable influence was observed by: Trillmich (1969), Kern and Moll (1971), Pasternak et al. (1978). No reaction was observed by Hausser (1971), whereas the negative results were found by: Mitscherlich and Wittich (1963), Kenel and Wehrmann (1967), Moller et al. (1969). In comparision with other species the beech settles more fertile sites, well supplied with nutrients. Therefore satisfactory results after fertilization of stands are are obtained on exceptionally poor site (Fober 1990).

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