EFFECTS OF ACIDS ON FOREST TREES AS MEASURED BY TITRATION IN VITRO, INHERITANCE OF BUFFER CAPACITY IN PICEA ABIES

F. SCHOLZ and S. RECK, Institut für Forstgenetik und Forstpflanzenzüchtung der Bundesforschungsanstalt für Forst- und Holzwirtschaft, D 207 Schmalenbeck, Germany.

ABSTRACT

The effect of acidic precipitation on vegetation is the result of an interaction between the acid and the plant. The metabolism of plants is dependent on optimal pH-values, which are maintained by regulation. There are differences in the effectiveness of regulation under such exogenous influences as acidic precipitation. These differences can be related to the resistance of plants to acidic precipitation or to certain pathogenic fungi. Such differences were measured as buffering capacity of homogenized leaves during titration with acid. There are significant differences in buffering capacity between clones in *Pinus* spp. and *Picea abies*. A highly significant variance in buffering capacity also was found among families of *P. abies*. Calculations of genetical parameters show that the phenotypical variance of buffering capacity is governed mainly by genetical factors.

Metabolic processes in plant cells are very sensitive to pH-changes. An optimal hydrogen ion concentration is maintained by regulation (Rypáček 1939, 1940), which acts against internal and external disturbances. The regulation processes involved can be explained by a cybernetic model (fig. 1) which shows regulation activity of a plant cell, disturbed by acid precipitation after having entered the cytoplasm.

Effects of pH-regulation can be tested by titration with H^+ or OH^-. As measurements in the plant cell are difficult, homogenized needles were titrated by which the actual buffering capacity can be measured. Buffering capacity, which is regarded as an indicator of vitality in plants (Rypáček 1939), should cause resistance of the plant to acidic precipitation. In addition to buffering capacity the regulating activity of the intact plant cell has to be taken in account.

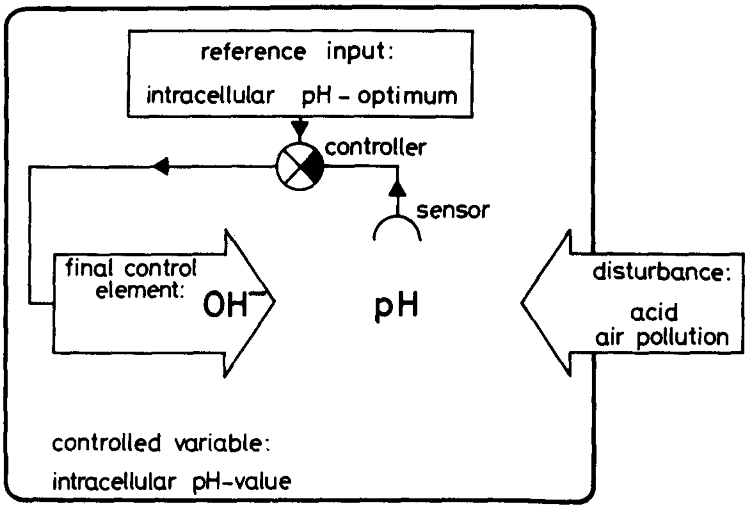

FIGURE 1. Cybernetic model of pH-regulation by a plant cell under influence of acid air pollution.

Relations between buffering capacity of needle homogenate and resistance to SO_2 were found by Grill and Härtel (1972), between buffering capacity and resistance to pH-changing fungi by Scholz and Stephan (1974).

First investigations with an automatic micro-titration method (Scholz 1975) showed significant differences in buffer capacity between *Pinus sylvestris* L., *P. strobus* L. and *P. nigra* Arn.. In this case titration was carried out with NaOH and the consumption of titrand in ml for a pH-change of one unit was taken as an index of the buffering capacity (fig. 2). *P. nigra*, which is known to be more resistant to air pollution than *P. sylvestris*, showed greater buffering capacity (the curves show averages for several clones). *P. strobus* was intermediate in both traits.

As buffering capacity could be an interesting trait for selecting trees resistant to air pollution, investigations on the genetic background of buffering capacity were carried on with *Picea abies* L. In Germany, this is an interesting species for both wood production and mechanical filtration of polluted air in industrial regions.

First the variation of buffering capacity between clones was tested. Tab I shows that almost 70% of the variation can be attributed to differences between clones and only about 8% to variation among isogenetical individuals. This points to genetic differences in buffering capacity.

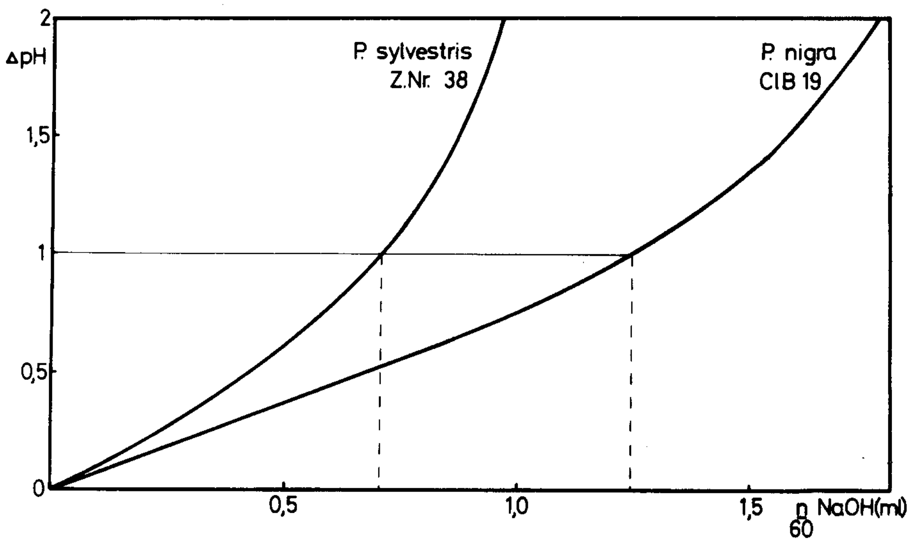

Figure 2. Titration curves of P. sylvestris and P. nigra, clones Z. Nr. 38 and Clb 19 represent the average of all investigated clones (from Scholz 1975).

TABLE I

Analysis of Variance of Buffer Capacity in Clones of Picea abies

Source of variance	d f	F-value	variance component	relative variance component
between clones	3	14.45894^{+++}	0.00697	68.81%
between ramets	12	2.62025^{+}	0.00079	7.80%
between samples	32	-	0.00237	23.40%

$^{+++}$significant at $p<0.001$
$^{+}$significant at $p<0.05$

To estimate genetic parameters for buffering capacity, controlled crossings of *P. abies* were investigated. Buffering capacity was measured as consumption of HCl in µl for a pH-change of one unit. Needle homogenates from 23 families of 7 parent trees, each family consisting of 24 trees, planted in a trial with 3 replications were titrated. An analysis of variance of buffer capacity shows that variance is mostly caused by differences between familes (Tab II). Variation between replications was relatively low. This means that genetical effects appear to be the main factors controlling variation in buffering capacity,

TABLE II

Analysis of Variance of Buffer Capacity in Families of Picea abies

Source of variance	d f	F-value	variance component	relative variance component
between families	18	32^{+++}	3.97	33%
between replications	2	<1	0	0
between families x replications	36	1.63^{+}	0.89	7.5%
between trees	171	3.69^{+++}	4.13	34%
between samples	228	-	3.05	25.5%

$^{+++}$significant at $p<0.001$

$^{+}$significant at $p<0.05$

whereas environmental effects which are estimated by the term "replications" appear to be of no practical importance.

To obtain information about the inheritance of buffering capacity a parent-offspring regression was calculated (fig. 3) which shows that there is a correlation between buffering capacity of parents and offsprings ($r = 0.39$; $0.28 < \rho < 0.48$; $p < 0.05$).

From the theoretical considerations (for further explanations see Kempthorne 1957), the additive genotypic variance σ_A^2 which is the decisive measure for any breeding program, can be estimated by using the covariance between parent and offspring (P and O)

$$\mathrm{cov}(P,O) = 1/2\ \sigma_A^2$$

The equation for calculating the coefficients of regression of offspring on parent and correlation between them is:

$$b_{OP} = \frac{\mathrm{cov}(P,O)}{\sigma_P^2}$$

and

$$r_{OP} = \frac{\mathrm{cov}(P,O)}{\sigma_P \cdot \sigma_O}, \quad \text{respectively.}$$

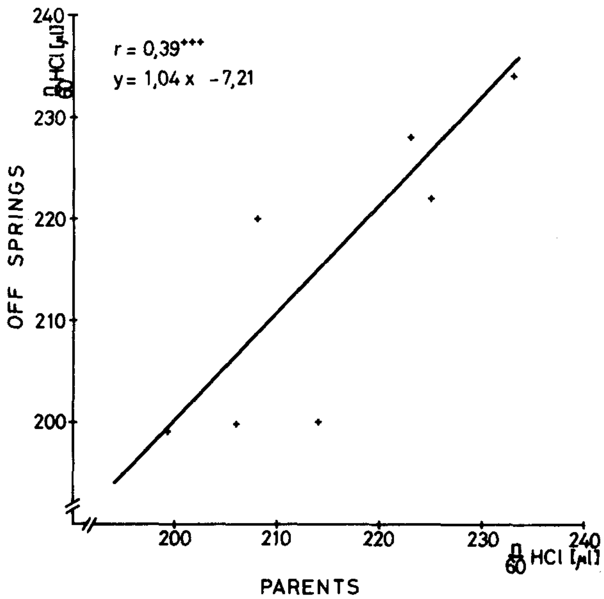

Figure 3. Regression of buffer capacity of offsprings on buffer capacity of parents of Picea abies (only means are plotted). ***$p < 0.001$

For we shall have
$$r_{OP} = b_{OP} \cdot \frac{\sigma_P}{\sigma_O} = \frac{h^2_{n.s.}}{2} \cdot \frac{\sigma_P}{\sigma_O}$$

in which $h^2_{n.s.}$ denotes the heritability in the narrow sense ($h^2_{n.s.} = \sigma_A^2 / \sigma_G^2$); the heritability can be estimated according to

$$h^2_{n.s.} = 2 \cdot r_{OP} \cdot \frac{\sigma_O}{\sigma_P}$$

The standard deviation for the parents should be not smaller than the standard deviation for the offsprings belonging to the same family

$$\sigma_P \geq \sigma_O \quad \text{and} \quad \frac{\sigma_O}{\sigma_P} \leq 1$$

Further investigations are required to calculate exactly the ratio σ_O / σ_P. On the basis of results obtained in this study, we shall assume $\sigma_O / \sigma_P \approx 1$, so that heritability can be estimated roughly by

$$h^2_{n.s.} = 2 \cdot r_{OP} = 2 \cdot 0.39 = 0.78$$

This value, which is definitely an over-estimate, indicates that about 78% of the phenotypical variance in buffering capacity is governed by genetical factors.

These investigations will be continued.

REFERENCES

Grill, D., O. Härtel. 1972. Zellphysiologische und biochemische Untersuchungen an SO_2-begasten Fichtennadeln. MITT. FORST. BUNDESVERSUCHSANST. WIEN 97 II, 367 - 386.

Kempthorne, O. 1957. AN INTRODUCTION TO GENETIC STATISTICS. New York, John Wiley & Sons, Inc.

Rypácek, V. 1939. Die pH-Regulation des Mediums als Vitalitätsindikator der Pflanzengewebe. Ein Beitrag zur experimentellen Ökologie der Pflanzengewebe. STUD. BOT. CECH. II FASC. I, 6 - 22.

Rypácek, V. 1940. Studien über die pH-Regulation durch Pflanzengewebe. STUD. BOT. CECH. III FASC. 2, 81 - 112.

SCHOLZ, F., B. R. STEPHAN. 1974. Physiologische Untersuchungen über die unterschiedliche Resistenz von Pinus sylvestris gegen Lophodermium pinastri. I. Die Pufferkapazität in Nadeln. EUR. J. FOR. PATH. 4: 118 - 126.

Scholz, F. 1975. BIOCHEMISCHE UNTERSUCHUNGEN ZUR RESISTENZ VON WALDBÄUMEN GEGEN FLUOR-IMMISSIONEN, IX. International Conference on Air Pollution and Forestry, Marianzke Lazne, CSSR, Proceedings in Press.

ACKNOWLEDGEMENTS

We want to thank Mrs. R. Schmidt for her accurate technical assistance and Mr. D. Krusche for writing and performing computer programs.