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Variation in Mineral Nutrient content between young plants of Norway spruce provenances and clones*)

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Summary

A part of the results of a program to evaluate the possibilities of clonal identification in Norway spruce are presented. The material analysed are 3 years old clonal plants of 10 provenances with 50 clones each. The needle mineral nutrient content is discussed. There is a strict genetic control for the nutrient uptake, explaining roughly 80% of the total variation. About 75% of the genetic variation appear on clonal level and only about 25% on provenance level. There is no obvious correlation between height growth and anyone of the needle nutrient contents on clonal level. The great genetic variation within provenances can be explained as a reaction to a heterogeneous environment.

The necessity to maintain genetic variation in breeding material to reduce risks is stressed.

Key words: Norway spruce, genetic variation, mineral nutrient content, cutting propagation.

Zusammenfassung

Aus einem Programm, das zum Ziel hatte, die Möglichkeiten der Klonidentifikation bei Fichte *(Picea abies)* abzuklären, wird hier ein Teilmaterial, das den Nadelnährstoffgehalt behandelt, vorgestellt. Es wurden 3 Jahre alte Fichtenstecklinge von 10 Herkünften mit jeweils 50 Klonen analysiert. Von jedem Klon lagen 3 Wiederholungen vor.

Die Nährstoffaufnahme scheint starker genetischer Kontrolle zu unterliegen, die genetische Variation erklärt ungefähr 80% der insgesamt auftretenden Variation.

Von der genetischen Variation treten etwa 75% auf dem Klonniveau und 25% auf dem Herkunftsniveau auf. Es besteht keine Abhängigkeit zwischen Höhenwachstum und irgendeinem einzelnen Nadelnährstoffgehalt auf dem Klonniveau. Die erhebliche genetische Variation innerhalb von Herkünften kann als Reaktion der Population auf heterogene Umweltbedingungen erklärt werden. Hieraus wird in der Diskussion abgeleitet, daß es auch für forstliches Züchtungsmaterial notwendig ist, genetische Variation zu erhalten, um Risiken zu verringern.

1. Introduction

Within the frame of a research program which had the aim to test the possibilities for clonal identification in Norway spruce, we included mineral nutrient content of branches too.

In this program we included 10 provenances with 50 clones each and we measured morphological, physiological, chemical and biochemical traits. In this paper the results of the evaluation of the mineral needle nutrient content of the clones will be discussed.

2. Material and methods

All 1.500 plants were 3 years old nursery stock. Three plants of each of the 500 clones (10 provenances × 50 clones each) were analysed. The experimental material grew in a nursery in Escherode. Analyses were carried out at the

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Five needle nutrients were analysed: N, P, K, Ca and Mg. The nutrient contents were evaluated from branches 15 cm long, removed from the two upper whorls.

For P, K, Ca. and Mg needles were ashed at 500—600° C, and dissolved in HCL; analyses for K, Ca and Mg were carried out, using a Perkin Elmer Spectrometer; P analyses were done by the molybdenum-blue method, and N by selenium-sulphuric-acid combustion. All mineral nutrient contents are given as percent of organic matter.

For all characteristics included in the program we run one and two step hierarchical analyses of variance for the estimation of the genetic components (repeatability) and calculated the phenotypic and the genetic correlation coefficients (Le Roy 1966).

All calculations were done on the UNIVAC 1108 computer of the Gesellschaft für wissenschaftliche Datenverarbeitung in Göttingen by Josef Svolba and Bernd Seelmann.

***) We thank Prof. Dr. Ullrich from this Institute for the assistance.

3. Results

The total variation of the 5 characteristics on individual, clonal-means and provenance-means level is given in *Figure 1.* The components of variance for needle nutrient contents on these levels are summarized in *Figure 2.*

From this figure it is obvious, that mineral nutrient uptake is under strong genetic control. In our material genetic influences explain 77% to 88% of the total variation. Since the nursery bed was comparatively homogeneous, these results must not be overemphazised. However they affirm the findings of Evers (1973), who used a much more restricted clonal material of Norway spruce. Therefore it may be of interest to look into some more details.

3.1 *Nitrogen*

For nitrogen needle content 14% of the total variation can be explained by provenance differences, 63% by clonal differences, both significant on the 0,1% level. 23% are residual variance. This may be partly due to local nutritional differences in the transplant bed.

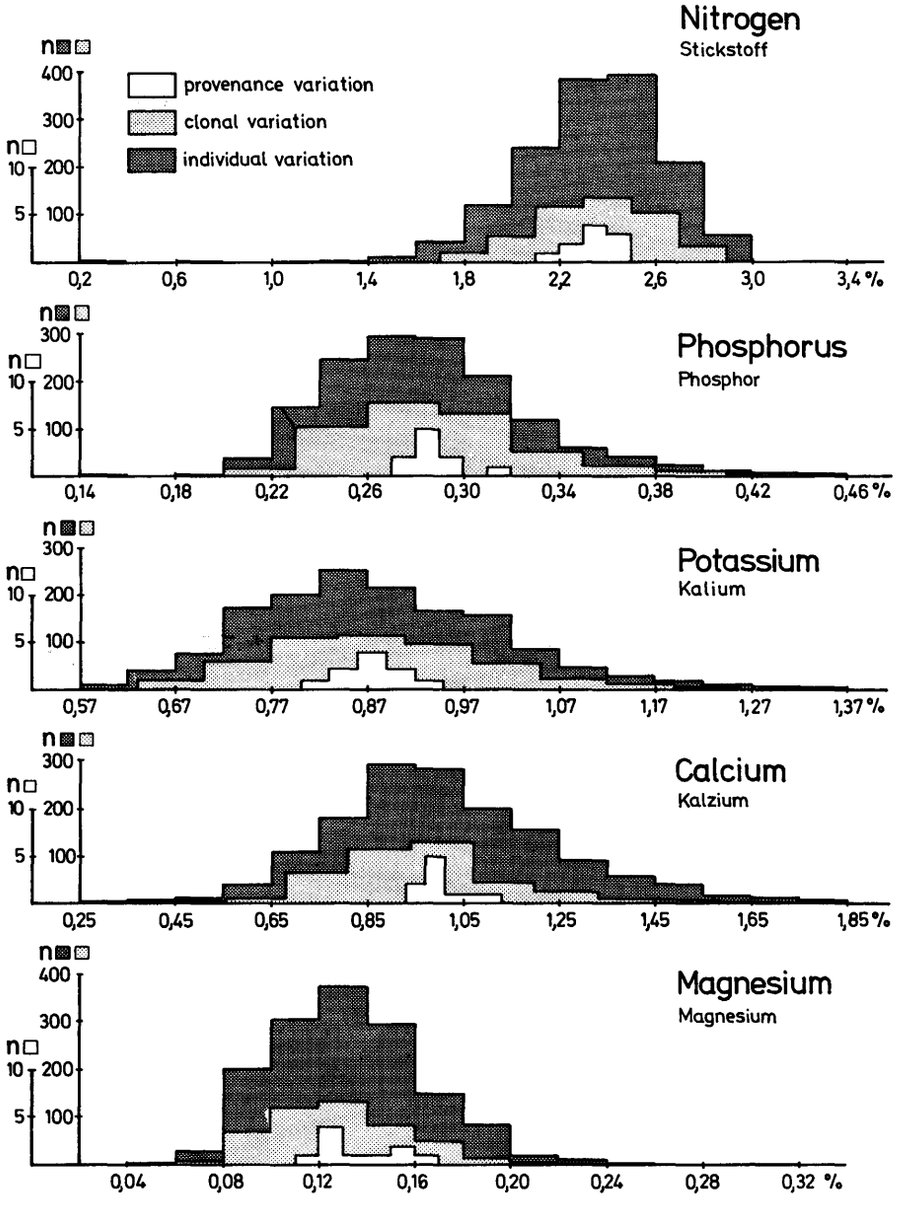

Fig. 1. — Frequency Distribution of Needle Content for N, P, K, Ca and Mg
Häufigkeitsverteilung des Nadelgehaltes an N, P, K, Ca und Mg

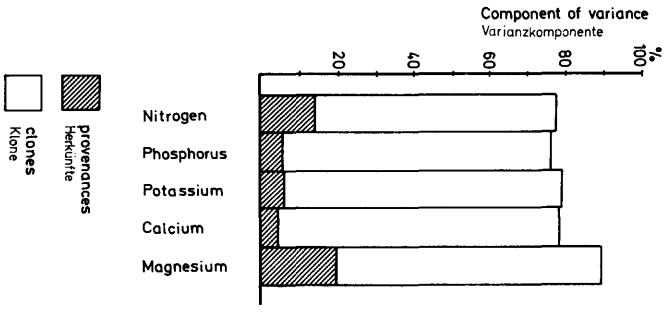

Fig. 2. — Proportion of Genetic Variance from Total Variance (10 provenances with 50 clones each) due to Clones and Provenances
Anteile genetischer Varianz an der Gesamtvarianz in 10 Herkünften mit je 50 Klonen (3 Wdhlgn. je Klon)

The relative proportion of the different influences is given in *Figure 2*. Looking to the total variation, it is obvious, that clonal variation is prevailing compared to provenance variation.

There is a low negative correlation with N-content of the respective clone and height growth r = −0,24****).

Here only one provenance is given as an example (r = 0,001). The deviation of the single plants from the clonal means is demonstrated in *figure 3* for a random sample of 6 clones of the same provenance. There seems to be a slight tendency for increasing N needle content with increasing height on individual level.

On provenance level the correlation between N needle content and growth is low but negative too (r = −0,39).

****) On provenance level the situation may be quite different *(Tab. 1)*.

3.2 *Phosphorus*

Only 6% of the total variation are on provenance level, 73% are on clonal and 21% residual.

As well provenance variation as clonal variation are highly significant. Provenance variation is considerably less than in nitrogen *(Figure 2)*. There is low negative correlation between phosphorus content and height growth on provenance level (r = −0,23). On clonal level there is no correlation at all between height and P content. *Tab. 1* gives the correlation with total clonal means and the clonal means for one provenance. Considerable variation between the plants of the same clone was found, which explains the residual variance similar to nitrogen. But there is no clear trend between growth and phosphorus needle content on the single plant level. The phenotypic correlation is r = −0,05.

3.3 *Potassium*

Similar to phosphorus, only 6% of the total variation can be explained by provenance effects. 72% are clonal effects and 22% are residual. Provenance and clonal effects are highly significant. The components are demonstrated in *Figure 2*.

There is no obvious correlation between height growth and needle potassium content on provenance level (r = 0,04).

There is no clear correlation between potassium content and height growth on clonal level either. There is no definite trend on single plant level too. The phenotypic correlation between potassium content and height growth is very low (r = 0,06).

3.4 *Calcium*

Calcium has the lowest provenance variation (4%) and the highest clonal variation (75%) of all needle nutrients.

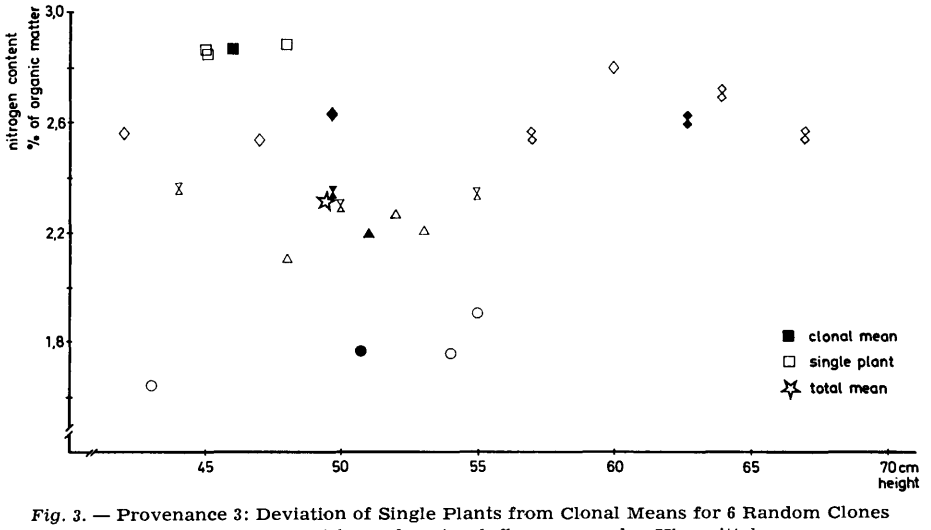

Fig. 3. — Provenance 3: Deviation of Single Plants from Clonal Means for 6 Random Clones
Herkunft 3: Abweichung der Einzelpflanzen von den Klonmitteln

Tab. 1. — Needle nutrient content and height growth

	Clonal means n = 500 (height $\bar{x}$ = 42.9 cm ± 3,9)			Clonal means n = 50 of one provenance (heigth $\bar{x}$ = 49.6 cm ± 8.5)		
Nutrient	mean	stand. dev.	correlation with height	mean	stand. dev.	correlation with height
nitrogen	2.3461	0.2648	-0.244***	2.3150	0.2367	0.0001
magnesium	0.1329	0.0305	+0.076 n.s	0.1548	0.0277	-0.2371
calcium	1.0101	0.2098	0.004 n.s	1.1263	0.2252	-0.3787
phosphorus	0.2849	0.0381	-0.071 n.s	0.2771	0.0329	0.0646
potassium	0.8809	0.1174	+0.095*	0.8569	0.1061	0.3652

Nevertheless both sources of variation are highly significant.

The great influence of the clone can be seen from *(Figure 1)*. In spite of the low contribution of provenances to total variation in calcium content there is a comparatively high positive correlation between calcium content and height growth on provenance level (r = 0,56*).

In contrast to this, there is no correlation between calcium content and height growth on clonal level as expressed by a correlation coefficient of r = 0,00. Within one provenance the situation may be quite different (r = 0,38; *Tab. 1)*. No clear trend can be seen for the deviation of the single plants from the clonal means. The phenotypic correlation for all the material is r = 0,01.

3.5 *Magnesium*

For magnesium we found the highest variation on provenance level of all needle nutrients with 22% of the total variation. Clones explain 66% of the variation and the residual variance is quite low (12%). As well provenance as clonal influences are highly significant. The comparative strong provenance influence can be seen from *figure 1*. Here again we have a positive correlation between magnesium content and height growth (r = 0,75*) on provenance level.

Similar to calcium on clonal level for all the material this correlation is near to zero (r = 0,07). Again it may be quite different for one provenance in tab. 1. For single plants there is no clear trend too. Phenotypic correlation of height with magnesium content on this level is r = 0,04.

4. Discussion

Base of this study is a broad genetic material but only a very specific and comparatively homogenous site. This implicates, that all environmental variation components are underestimated and all genetic components overestimated.

The correlated response for provenance selection *(Figure 4)* and clonal selection *(Figure 5)* shows, that there is significant influence of provenance selection on some of the needle nutrient contents. On clonal level the selection however has no significant influence on any needle nutrient content. Since the main source of variation appears on

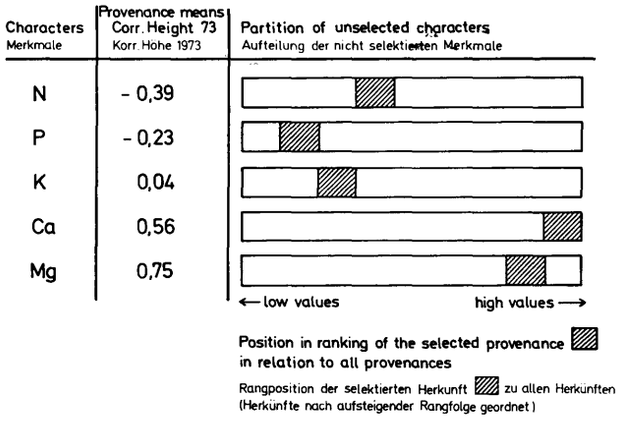

Fig. 4. — Selection for Height of the best Provenance
Auslese der besten Herkunft (10%)

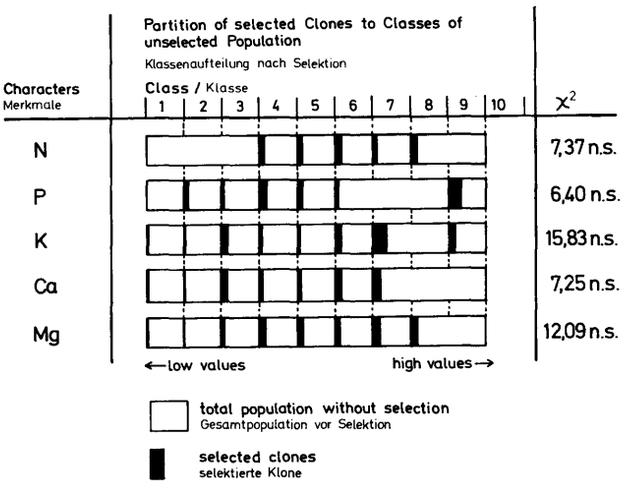

Fig. 5. — Selection for Height of 10% best Clones
Auslese der 10% besten Klone

clonal level, the significant influence of selection on provenance level cannot have severe implications. The possible negative effects are balanced by the high genetic variation within provenances which surpasses by far the variation between provenance means. So every provenance can adjust itself to the conditions of the habitat by natural selection.

An interesting result from an evolutionary point of view is the significant correlation between height growth and calcium and magnesium content on provenance level which could reflect an adaptation to certain site conditions (Teich und Holst, 1974). Very general the findings demonstrate the high genetic variation within populations for all analyzed characteristics. This can be regarded as a security strategy of populations to survive in heterogeneous environment and to conserves a high potential for adaptation. Since forests grow in very heterogeneous environment in space and time this variation reflects the environmental situation. From this study we suggest for breeding programs to maintain considerable genetic variation to prevent risks.

Looking to sampling procedures the study gives some explanation for the wellknown fact, that you have to take a considerable number of trees to analyse needle nutrient content of a stand. This is due as well to genetic variation between individuals as to environmental variation. The results are biased by clonal influences and by provenance influences.

6. Literature

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