Some Experimental Results concerning Age Dependency of Different Components of Variance in Testing Norway Spruce (Picea abies (L.) Karst.) Clones

By M. Huehn(*), J. Kleinschmit(**) and J. Svoboda**

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Summary

A Norway spruce clonal test, established with 5 clones on 5 extremely contrasting sites in 1967 and remeasured for plant-height 10 times until 1981 has been used to estimate the relative importance of the components of variance for "locations", "clones", "locations × clones", "blocks", and "experimental error" dependent on the time. The results show, that in this study "blocks" and "interaction" are of minor importance, accounting to less than 5% of the total variation. Clones account for roughly 10%. These three sources of influence remain more or less constant over time. Considerable changes however occur in the component for "locations" and "experimental error". The first one increases quickly until it reaches a plateau at about 70%, the last one decreases correspondingly and ends up after few years at 15%. All values are quite stable at the end of the time of measurement. These results are discussed on a more general background.

Key words: Norway spruce, clonal test, components of variance, early testing.

Zusammenfassung


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*) Institut für Pflanzenbau und Pflanzenzüchtung der Universität Kiel, Oilschauenstraße 40-60, D-2820 Kiel
**) Niedersächsische Forstliche Versuchsanstalt, Abteilung Forst- pflanzenzüchtung, D-3313 Staufenberg 6

3. Which numerical values do the different components of variance (clones, locations, interactions, experimental error) finally reach?

These three questions shall be followed in this study using data of a Norway spruce clonal test of the Lower Saxony Forest Research Institute.

**Material and Methods**

The data analyzed originate from a set of 5 Norway spruce clones grown under extreme variable site and climatic conditions.

Climatic and site conditions for the 5 plantation sites are summarized in Table 1. These show, that elevation above sea level ranges from 10 m to 800 m, annual precipitation from 759 mm to 1,500 mm, mean annual temperature between 8.2°C to 4.4°C. This covers as much variation as available in northern Germany excluding very few extremes.

Soil nutrition varies from very poor to rich and the physical soil conditions from light sands to heavy, clay soils with high water table.

These facts explain, that the plantation sites cover a broad range, reaching from marginal sites to optimal sites for growing Norway spruce. On these sites 5 Norway spruce clones have been planted in 1967, representing some of the clones of the early propagations in Escherode. All clones originate from one population and have been selected for growth vigour and rootability. The variation of the clones is very much restricted as compared to the sites. The ortets had an age of 30 years when the cuttings have been taken. Therefore a higher within clonal variation has to be expected due to topophysis effects as compared to more juvenile clonal material.

The field tests have been established with 7 years old “bailed” transplants, spacing 2 x 2 m with 7 x 7 plants per plot. The experiment has been laid out as randomized Block experiment with two replications, only on the field test Escherode one clone is only represented in one block, three others are three times replicated. The very variable climatic and site conditions are especially good for the study of the stabilization of the variance components. The comparatively narrow genetic base of the clones results in an underestimation of the variance components of clones.

Height measurements are available for the years 1967, 1968, 1969, 1971, 1972, 1973, 1974, 1975, 1976 and 1981, except the 1967 measurement for Escherode. All replications and all plants of which the complete set of measurements was not available have been excluded from the evaluation to prevent additional experimental error.

We have the following situation:

\[ Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \epsilon_{ijkl} \]

For each ijk-combination, which means for every plot, there exists \( n_{ijk} \) single plants (replications). \( n_{ijk} \) can maximally reach 48. These numbers can vary however considerably due to losses, therefore non-orthogonal evaluation was necessary.

The data have been processed according to the following structure:

factor A (sites) and B (clones) crossclassification, factor C (blocks) hierarchical within A x B combinations. All three factors are regarded as random. A detailed biometrical treatment of this structure is given by RASCH (1971).

The model has the following form:

\[ Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \epsilon_{ijkl} \]

(i = 1, 2, ..., a; j = 1, 2, ..., b; k = 1, 2, ..., c; l = 1, 2, ..., \( n_{ijk} \))
\( \mu = \) overall mean  
\( a_i = \) effect of location \( i \)  
\( b_j = \) effect of clone \( j \)  
\( w_{ij} = \) interaction between site \( i \) and clone \( j \)  
\( n_{ijk} = \) effect of block \( k \) for site \( i \) and clone \( j \)  
\( e_{ijk} = \) experimental error.

Since at the site Escharende one clone has only one replication and the 1967 measurement is missing the following two data sets have been processed separately:

I. Without site Escharende; this results in
\( a = 4; b = 5; c = 2; d = 10 \)

II. Without the clone, only once represented in Escharende and without the 1967 measurement.

This results in:
\( a = 5; b = 4; c = 2; d = 9 \)

Both sets have been evaluated non-orthogonal because of the different \( n_{ijk} \) values. In addition there has been carried out an orthogonal evaluation according to the following procedure:

The minimal \( n_{ijk} = n \) has been located. All the other \( n_{ijk} \) have been fixed to the same constant \( n \) by selection of the first \( n \) values in each \( ijk \)-combination. This resulted in \( n = 23 \). The comparison of the two evaluations is discussed later on.

The variance components \( \sigma^2_e \) (experimental error), \( \sigma^2_{AB} \) (interaction location \( \times \) clones), \( \sigma^2_A \) (locations), \( \sigma^2_B \) (clones) and \( \sigma^2_C \) in \( AB \) (blocks) are estimated by equating the different mean squares with their theoretical expectations (Raschin 1971).

**Results**

The results of the analyses of variance are not presented here since for the discussion of the questions to be answered only the components of variance are of interest.

In three cases there occur negative components of variance. For \( \sigma^2_{AB} \) in evaluation I for the first measurement and for \( \sigma^2_{AB} \) in evaluation II for the 9th and 10th measurement. This is not unusual in estimating variance components; in addition these estimates have very low numerical values, so it is justified to take these for zero.

To transform the variance components into proportions of variability, the single variance component is divided by the sum of all variance components of the respective time of measurement. The results are presented in Figures 1a and 1b.

In both cases the components of variance of \( \sigma^2_{AB} \) and \( \sigma^2_C \) in \( AB \) are minor and without practical importance. Their proportions of variability remain more or less constant during the whole time with relative values less than 5% \( \sigma^2_C \) too has no outstanding importance, remaining nearly constant at about 10%. A significant dependency of age however show \( \sigma^2_A \) and \( \sigma^2_e \). As shown in Figures 1a and 1b the total variability of the material is dominated by these two sources of variation “locations” and “experimental error”. Site influence increases steadily and experimental error decreases continuously. Already after few years about 60% of the total variation can be allocated to site influences. After this time the relative change is minor, indicating that the proportion of variability stabilize quite early. Finally in this study the values for locations reach about 70%, for experimental error about 15%.

This prevailing site influence is not surprising with respect to the quite heterogeneous sites included in this study and the comparative small genetic variation of the clones.

Looking to the first two years of measurement (1967 and 1968) in evaluation I there are obvious irregularities (Figure 1a), which are not to be seen in evaluation II (Figure 1b) where the year 1967 is missing. These irregularities are probably caused by the planting shock.

**Discussion and Conclusions**

The material, used in this study, is by far too limited to draw general conclusions concerning proportions of variability. 4 respectively 5 sites and 5 respectively 4 clones cannot be regarded as a representative sample of all sites and clones possible. This is especially true for the clones. Having this in mind, the clear trend of the results is even more surprising:

For all components of variance under discussion there is a very evident time-dependent trend (Fig. 1a, 1b) with a stabilization of proportions of variability already after few years. The sources of variation AB (interaction) and C in AB (blocks) account together for less than 5% and B (clones) for 10% only; they remain more or less constant in addition. In contrary to these “location” and “experimental error” show an extreme increase respectively decrease until they stabilize after few years on a level of 70% (locations) and 18% (experimental error).

How far the last measurements (1981) really represent constant plateaus can be only judged after further measurements. However, considering the minor changes during the
recent years, this question may be more of academic interest.

A comparison with the study of Huhnh (1974) the numerical values of the plateaus reached are quite different. This underlines the importance of the material used in the study (restricted genetic variation between the clones) as well as the influence of the actual plantation sites.

A good agreement of both studies however is the fact, that for all sources of variation after few years certain plateau values are reached which do not change considerably further on.

The results obtained for the non-orthogonal evaluations I and II do not show any significant differences (Figures 1a and 1b). Therefore, the addition or deletion of single locations or single clones is of no considerable influence on the variability proportions of the material.

The corresponding orthogonal evaluations, which have been carried out with strongly reduced plant numbers, show the same results (Figures 2a and 2b).

This allows the conclusion, that already much more limited numbers of plants (in this case 23 per plot) are sufficient to get a good estimate for the proportions of variability and the final numerical values of the plateaus. This result is important for future planning of experiments.

The results can be well explained by biological reasons: The plants of all field tests have been grown initially in the same nursery. The differences in growth at the time of plantation establishment can be explained by clonal influences and experimental error mainly. This corresponds to the first measurement of the field tests (1967). From this time onwards the influences of the location (climate and soil conditions) on the further growth of the clones can act. These are initially only disturbed by the planting shock. The clones now start to collect the site information, which is variable in time as well, over the years and reflect this information in health and growth. The annual influences can act annually quite different on the different clones, as to be seen e.g. from the variance components for annual ring width, estimated by Lewark (1981) for these experiments, ranging from 7% to 53% for clones depending of the year. During further growth development the annual variation however levels out to the location mean. Since the volume (height and diameter) of the trees increases steadily, the relative contribution of the annual environmental variation to the growth is finally so small, that this has nearly no implications on the proportion of variability.

The main result of the present study: the fast stabilization of the components of variance in the material, also has implications on the problem of juvenile-mature-correlations. This has been discussed elsewhere (Huhnh and Kleinschmidt 1986).

Literatur