Plot sizes in field trials

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(Received for publication January 11, 1955)

1. Preface

In order to study the problem of optimum plot size in field trials, it is necessary to have analyses of various stands. It is difficult to make any progress through theoretical considerations alone. The Norwegian Forest Research Institute has made such materials from stand analyses available to me. These materials consisted of several mapped yield plots of Norway spruce, together with the associated data on diameters, etc. The necessary computations for this study were made possible by grants from the Norwegian Agricultural Research Council.

2. Introduction

Several factors are important in the decision regarding the plot sizes to use in field trials. Factors favouring small plots include the following: (1) it is as a rule difficult to find more extensive homogeneous areas; (2) variation in site tends to decrease with decreasing area; (3) small plots enable more replications in a single location and permit the comparison of many treatments without involving the use of excessively complicated designs; and (4) the recording of data for the individual plot takes somewhat less time for a small plot than for a large one.

However, the use of small plots also involves some drawbacks. These include the following: (1) results on one plot may be greatly dependent upon the conditions in the adjacent plots (especially if guard rows or isolation strips are not used); and (2) in extreme cases there is danger of having empty plots.

Factors of particular importance in determining the magnitude of the errors involved in the use of different plot sizes are as follows:

(1) The distribution of the trees.
(2) Competition among the trees.
(3) Edge effects.

There is not much literature concerning these questions. **Fritsche** (1927) considers the problem in a general way, discussing the specifications for a desirable plot with a special view to yield studies. His conclusion is that plots should have a size of at least 0,3 hectares to give a sufficient accuracy.

Andersson, Gustafsson and **Johnsson** (1951) have carried out computations to determine the variation in the standard error of the mean (ε) with changes in plot size. They take **Hagberg's** yield tables (Hagberg 1938) as their starting point. Using two different assumptions on the standard deviation in volume for individual trees (s), the standard error of the mean volume for plots with n trees is computed according the formula

$$\varepsilon = s/\sqrt{n}$$

The results of these computations show that plots established with 150 plants will rarely give a standard error of plot volumes greater than 2%, even for ages of 70—80 years at which ages the number of trees will have declined to 25—30 trees per plot. Thus, with the use of additional replications the standard error of the mean should be very low. However, the procedure employed in this analysis may lead to fallacious conclusions. First, the systematic variation in site has been neglected. Second, the neighbour effect has not been taken into account.

In most cases the main purpose of the field trials is to investigate the yield resulting under different treatments. This yield may be measured in different ways, but generally the interest center on volume and increment. For example, when plant heights are measured, it is because there is usually a marked correlation between height and volume. In these comments I have had in mind primarily trials testing different strains and provenances, but much of what has been said will apply to other kinds of trials as well.

Strictly speaking, the objective should be to determine the plot sizes that would be most efficient in terms of the data obtained as related to costs. However, it appears to be impracticable to attempt to solve such a problem at the present time. It is, therefore, necessary to consider other criteria of efficiency. The criterion which I have chosen is the optimum utilization of the area. The method of measuring the efficiency of the use of the area is discussed later in this paper. The use of this criterion seems justified in forestry, since it will almost always be difficult to find suitable areas.

Height measurements were not made on all trees in the yield plots which are used in the following analysis. As a result it would be difficult to make the analysis in terms of volume and volume increment. Instead, we may use basal area and basal area increment. It is probable that the results obtained in this way will apply roughly for volume measurements as well. Within a single stand there is a very close relationship between the basal area increment and the volume increment of individual trees. (See, for example, **Prodan** 1951.)

3. Different sorts of trials

Before continuing the discussion of plot size, the method of analysing the results should be considered.

31. Trials without replications (treatment by regression analysis)

In trials which are treated by means of regression analysis or similar methods (graphic smoothing, etc.) the recorded size for each plot will, as a rule, receive direct treatment. This is the procedure which has been generally followed in the preparation of yield tables, etc. The number of plots in any one location has usually been very low.

When small plots are used the results obtained are likely to be fallacious if applied to large stands or large areas. Various stand analyses have shown that a strong linear correlation exists between the diameter and the diameter increment of a tree (or between the basal area and the basal area increment). In the same way, a linear regression will be found if the stand is divided into plots 5 m. by 5m. and the basal area increments for the individual areas are analysed as a function of total basal area. The increment increases linearly with increasing basal area. For example, on the 8 yield plots included in Table 1 the correlation coefficient between basal area increment and basal area on plots 5 m. by 5 m. ranges from 0,59 to 0,92. Taking the arithmetic mean of these correlation coefficients gives a value of 0,81.

Such an increasing *linear* correlation on small plots is in contrast with other investigations on larger areas which have shown that increment remains approximately constant within a fairly wide range of basal areas (Eide and Langsaeter 1941). The reason for this difference in results on small and on large areas appears to be due to the importance of outside influences on small plots.

If it is conceivable that the results obtained for individual plots in a trial have been influenced by outside conditions, this outside effect should be eliminated. This is especially important if the influence is different for the different treatments. These outside effects can be eliminated or reduced by the use of isolation strips or guard rows.

In trials treated by regression analysis, however, the edge effect cannot be eliminated altogether, even by use of isolation strips. The fact is that, due to accidental causes, the basal area per unit area will at times be higher on the plot than on the isolation strips. This means that the edge trees in the plot actually occupy a larger growing space than is taken into account. Periodic remeasurements under these conditions will give records showing greater-than-actual increment in basal area per hectare occurring on greater-than-actual basal area per hectare. In solving for the relationship of basal area increment to total basal area per hectare and other variables, the effect of this is to give too high value for the coefficient of basal area per hectare. Similarly, when due to edge effects the plot actually occupies a smaller growing space than is recorded the results show less-than-actual increment occurring on less-than-actual basal area per hectare, and again the effect is to overestimate the effect of total basal area.

The effect of such expansions or contractions of area due to edge effects can be quite far-reaching. If the number of trees at the edge is somewhat too high, the actual growing space may, for example, extend 0,5 m. outside the plot on all sides. Even with plots as large as 30 m. by 30 m. the actual growing space of 961 square meters will then be 7% greater than the recorded area of 900 square meters. There is, therefore, every reason to be careful in using small plots for trials in which the results are to be treated by regression analysis. Moreover, there is less need to use small plots in such trials than in the case of comparative trials.

32. Comparative trials

In these trials the main emphasis is laid on the *differences* between the treatments. For this reason the trials are laid out in such a way that the different treatments are near each other, in order that site differences and other sources of error may be eliminated as far as possible. In contrast to the preceding group, there will usually be a fairly large number of plots in the same location.

The individual plots are subjected to certain treatments, and it is then the differences between the means for the various treatments which will form the basis for the conclusions. The variation from plot to plot for the same treatment is used for the estimation of error. Under this procedure there is no risk of getting a bias even when the plots are very small (provided the isolation strips are sufficiently wide). Thus, the lower limit for the plot size will be determined by other considerations, including the following:

(1) To enable a good utilization of the available area for the trials it is necessary that the area included in the plots bears a reasonable proportion to the area used for isolation strips.

(2) The lay-out of many small plots is more expensive than the lay-out of larger plots with the same total area.

(3) A determinate plot size, relatively large, will give the most efficient use of the area.

By definition, the efficiency of the use of the total area increases as the error per unit area decreases. It can be shown that the error per unit area is proportional to $s_A \sqrt{A}$ when s_A is the standard deviation per plot when using plots of size A. Similarly, it is proportional to the coefficient of variation times the square root of plot size.

This relationship can also be studied by use of the intraclass correlation coefficient. The following rules apply:

(1) If the correlation between adjacent plots is negative, the use of large plots obtained by combining the smaller plots will increase the efficiency of the use of the area.

(2) If the correlation is positive, the use of the small plots will be more efficient than combining them into larger plots.

(3) If there is no correlation between the adjacent plots, small plots will be just as efficient as large plots, covering the same area.

4. The coefficient of variation of the basal area increment for different plot sizes

The coefficients of variation of the basal area increment for different plot sizes is presented in Table 1. For this analysis the 8 field plots were divided into smaller plots of 5 m. by 5 m., 10 m. by 10 m., and 10 m. by 20 m. The plots of 10 m. by 10 m. were formed by the combination of 4 adjacent plots of 5 m. by 5 m. The plots of 10 m. by 20 m. were formed by combining two plots of 10 m. by 10 m.

Although the analysis is presented here in terms of basal area increment, the results would be practically the same for basal area due to the close relationship between these two factors. An example will show this tendency. For field plot no. 24 the coefficients of variation in basal area increment were 55% and 36% during the first period for plots of 5 m. by 5 m. and 10 m. by 10 m. respectively, showing a decrease of 35% with the increase in plot size. The corresponding figures for basal area were 46% and 30%, showing a decrease of 35%. For the next period the quadruplication of plot size showed a decrease of 28% for basal area increment and of 31% for basal area. Considering the wide variation from plot to plot, it is evident that there would be little, if any, difference in the results if an analysis of basal area had been added to that for basal area increment.

It will be seen from Table 1 that there is usually a negative correlation between the increments for the 4 adjacent plots which together form a plot of 10 m. by 10 m. For pairs of adjacent plots of 10 m. by 10 m., however, the situation is different, with the correlation being positive in some cases and negative in other cases. Such a negative "neighbour correlation" must be due partly to the competition among the trees (the larger ones having a retarding effect on the smaller neighbouring trees) and partly to the distribution of the trees. When the trees are distributed fairly regularly, a plot which by chance con-

Table 1. Coefficient of variation of the basal area increment (per cent)

Plot No.	Site	Age	Number of subplots	Basal area sq.m./ha	Coefficient of variation			Intraclass correlation			
					5 m. by 5 m.	10 m. by 10 m.	10 m. by 20 m.	4 subplots 5 m. by 5 m.	8 subplots 5 m. by 5 m.	2 subplots 10 m. by 10 m.	
24	*A*	53—56	36 (32)[1]	39,5	55 (54)[2]	36 (31)	10	0,23	— 0,11	— 0,88	
		56—59		38,5	61 (55)	44 (38)	9	0,35	— 0,11	— 0,81	
		59—63		30,0	58 (60)	33 (33)	9	0,10	— 0,12	— 0,83	
		63—67		28,7	66 (70)	33 (35)	12	0,01	— 0,11	— 0,74	
		67—72		18,0	116 (118)	36 (38)	18	— 0,21	— 0,11	— 0,50	
25	*A*	57—60	32	33,0	49	15	11	— 0,21	— 0,08	0,09	
		60—64		32,2	50	17	12	— 0,15	— 0,07	0,02	
		64—68		33,2	49	17	11	— 0,16	— 0,08	— 0,14	
		68—73		30,0	54	18	9	— 0,17	— 0,11	— 0,52	
28	*C*	81—86	40	26,1	53	15	11	— 0,23	— 0,09	— 0,11	
		86—91		24,5	52	16	10	— 0,21	— 0,10	— 0,18	
		91—96		21,7	83	44	36	0,03	0,26	0,32	
29	*C*	86—91	36 (32)	34,4	54 (56)	21 (16)	9	— 0,12	— 0,11	— 0,35	
		91—96		26,0	65 (57)	27 (29)	20	— 0,10	— 0,03	0,00	
		96—101		16,3	83 (83)	56 (58)	48	0,26	0,23	0,32	
41[3]	*A*	50—55	36 (32)	46,0	60 (60)	25 (27)	10	— 0,10	— 0,11	— 0,71	
		55—60		28,4	79 (76)	38 (34)	19	— 0,03	— 0,07	— 0,37	
		60—64		24,9	104 (102)	67 (66)	31	0,21	— 0,03	— 0,52	
		64—68		21,6	108 (106)	62 (65)	15	0,11	— 0,12	— 0,89	
		68—72		12,8	170 (170)	71 (74)	51	— 0,10	— 0,04	— 0,05	
42 II	*B*	56—61	72 (64)	36,7	50 (48)	15 (14)	10	— 0,22	— 0,09	0,02	Plantation
		61—65		27,8	63 (61)	26 (26)	21	— 0,11	— 0,01	0,33	
		65—69		27,5	67 (63)	30 (30)	22	— 0,06	— 0,00	0,10	
		69—73		20,1	85 (79)	38 (39)	29	— 0,07	0,01	0,15	
		73—77		22,0	95 (89)	44 (43)	38	— 0,05	0,06	0,45	
		77—81		23,5	96 (89)	46 (43)	38	— 0,02	0,06	0,51	
43 I	*B*	56—61	64	33,7	44	16	13	— 0,14	— 0,04	0,32	Plantation
		61—65		22,2	66	23	15	— 0,17	— 0,08	— 0,15	
		65—69		16,4	94	33	29	— 0,17	— 0,03	0,52	
43 II	*C*	56—61	72	27,2	33	14	11	— 0,09	— 0,01	0,26	Plantation
		61—65		28,6	39	17	15	— 0,07	0,02	0,46	
		65—69		28,6	41	19	13	— 0,06	— 0,03	— 0,04	
		69—73		23,9	52	26	18	0,00	0,00	0,00	
		73—77		25,6	55	30	22	0,05	0,03	0,10	
		77—81		25,9	64	29	24	— 0,06	0,02	0,39	

[1] Figures in parentheses indicate the number of those subplots used to form the 10 m. by 20 m. plots.

[2] Figures in parentheses indicate the coefficient of variation for the subplots used to form the 10 m. by 20 m. plots.

[3] Plot No. 41 is originally a plantation, but as the trees are as unregularly distributed as in a natural regeneration, the plot has been transferred to this group.

tains many trees will in general have neighbouring plots with less than the average number of trees.

If adjacent plots of 10 m. by 20 m. or larger are combined, it is to be expected that in the majority of cases the neighbour correlation will be positive. This is due to the fact that systematic variation in site will have a stronger influence than neighbour correlation in such large plots.

The total basal area per hectare appears to have a strong influence on the coefficient of variation. For plots of 200 square meters with basal areas exceeding 25 sq. m. per ha., the coefficient of variation ranges from 10% to 25%. It increases with decreasing basal area. One reason for this appears to be that the number of trees is lower at low basal areas for stands at the same stage of development. The distribution of the trees will have more influence on the coefficient of variation when the number of trees is low than when it is high. Similarly, the coefficient of variation for any specified basal area is likely to be lower in young stand than it was in the stands analysed here, all of which were rather old.

The error for the total basal area produced during the life of the stand has not been specifically examined. We may take into consideration, however, that some compensating effects will occur, so that the figures would be somewhat lower than those given in Table 1. However, such compensation will not be very effective, because the increments for the separate periods for any one plot are not statistically independent.

The figures in Table 1 seem to indicate that a difference exists between stands developed from natural regeneration and those originating as plantations. For plots of 5 m. by 5 m. the correlation coefficient is about the same, but for plots of 10 m. by 10 m. it averages — 0,34 for stands from natural regeneration against 0,23 for those from plantations. The explanation seems to be that the trees are more uniformly distributed in plantations than in natural stands. Thus in laying out new trials the plots should be made somewhat smaller in plantations than in other stands.

5. Discussion

Plot size in trials treated by regression analysis or similar procedures will necessarily differ widely from plot size in comparative trials. The following discussion is limited to the last mentioned case.

51. *Trials without isolation strips*

Consideration of the various factors presented so far leads to the following conclusions regarding plot size in trials without isolation strips: In plantations plots of 10 m. by 10 m. seem to give a more efficient use of the area (i. e., to have a lower variance per unit area) than to those of 5 m. by 5 m. or those of 10 m. by 20 m. In trials in stands originating from natural regeneration, however, plots of

10 m. by 20 m. seem superior to those of 10 m. by 10 m. This is also seen from Figure 1.

In practice the choice of plot size will be controlled by various considerations. Nevertheless, it is important to know the size which seems to give the most efficient utilization of the area.. It can be seen that this plot size is comparatively small. However, the cases in which there are no edge effects which must be taken into account are relatively few. More commonly it will be necessary to use isolation strips.

52. Trials with isolation strips

The use of isolation strips between plots results in some separation of the plots. The variance will be somewhat larger than if no isolation strips were used, since the trial will cover a somewhat larger area, which in turn involves a greater variation in site. This is of no consequence, however, for the present discussion of plot size or for the use of Table 1. The important consideration is the neighbour correlation between plots with a common border line, because these may eventually be combined to form larger units.

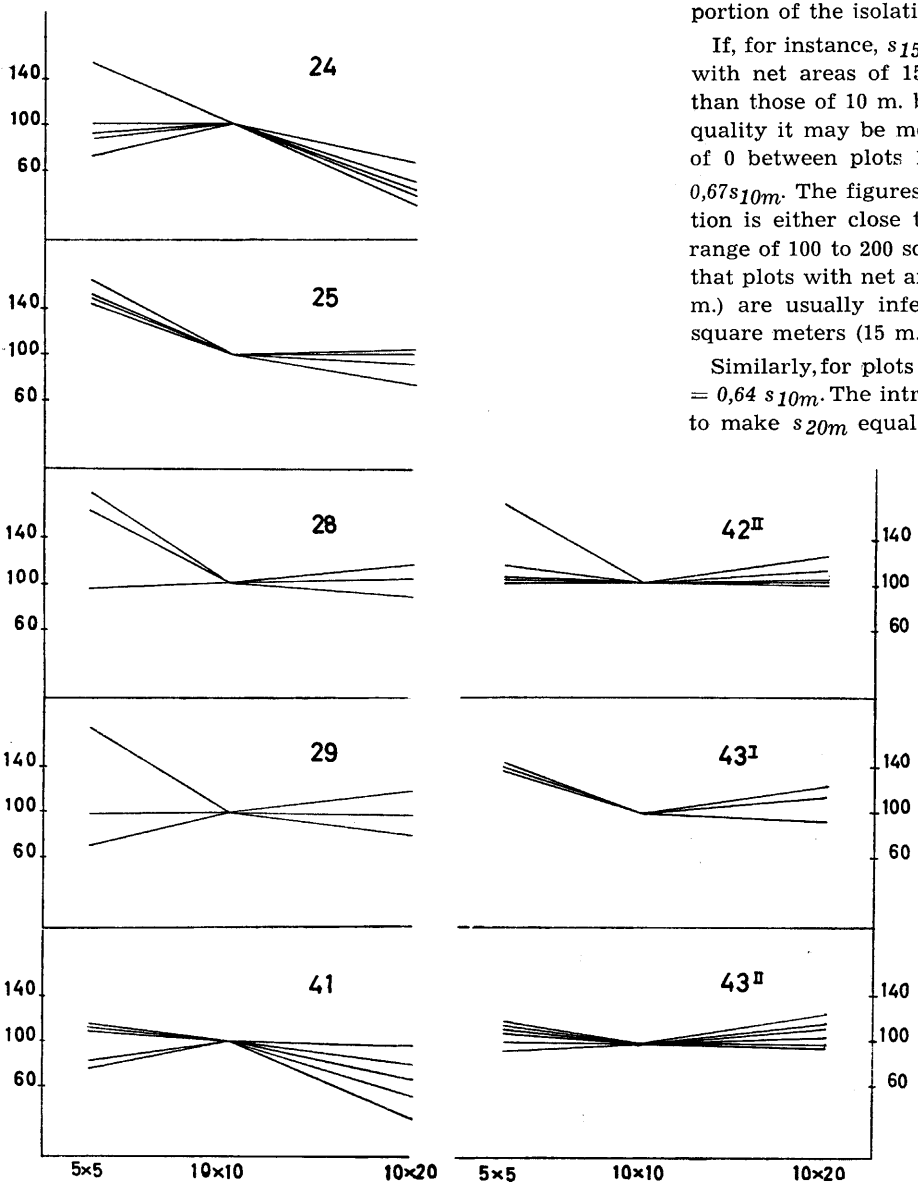

Fig. 1. The factor $s_A\sqrt{A}$ for the different field plots. For subplots of sizes 5m. by 5m. and 10m. by 20m., the values are expressed in percent of those for plot size 10m. by 10m.

In the following discussion the portion of the plot lying inside the isolation strip is termed the net area of the plot. The total area also includes one-half the width of the isolation strips on all sides. In square plots with a side length *S*, the net area will equal $100(1-B/S)^2\%$ of the total area, when *B* represents the width of the isolation strips. If the width of the isolation strips is 1/3 of the side length, the net area is 44% of the total area, while if the width is 1/4 of the side length, the net area is 56%. The percentage increases slowly with increasing side length for a constant width of isolation strip, whereas the plot area increases very rapidly. If we intend to make the most effective use of the experimental area, it is, therefore, very important to keep the width of the isolation strip as low as possible.

Using square plots and isolation strips, for example, 8 meters wide, we can compare the various sizes in the following way: The coefficient of variation for square plots with a size length of *l* inside the isolation strips can be termed s_l. Given the total area, the standard error of the mean for one treatment will be proportional to $s_l\sqrt{L}$, where *L* is the side length of the entire plot including its portion of the isolation strips.

If, for instance, $s_{15m} < 18/23\ s_{10m} = 0{,}78\ s_{10m}$, then plots with net areas of 15 m. by 15 m. will be more efficient than those of 10 m. by 10m. As an illustration of this inequality it may be mentioned that a neighbour correlation of 0 between plots 10 m. by 10 m. means that $s_{15m} = 0{,}67 s_{10m}$. The figures in Table 1 indicate that the correlation is either close to 0 or negative for plot sizes in the range of 100 to 200 square meters. Therefore it is probable that plots with net areas of 100 square meters (10 m. by 10 m.) are usually inferior to those with net areas of 225 square meters (15 m. by 15 m.).

Similarly, for plots of 20 m. by 20 m., $s_{20m} < 18/28\ s_{10m} = 0{,}64\ s_{10m}$. The intraclass correlation coefficient required to make s_{20m} equal to $0{,}64\ s_{10m}$ can be determined by solving the equation

$$0{,}64 = \sqrt{\frac{1+3r}{4}}$$

This gives $r = 0{,}21$ Table 1 indicates that the correlation coefficient between two plots, each 100 square meters or larger, rarely exceeds 0,21 in stands originating from natural regeneration. Such high correlation coefficients for 4 adjacent plots combined into one 20 m. by 20 m. plot are, therefore likely to occur even less frequently. It is probable that in such stands plots with net areas of 400 square meters will be superior to those with net areas of 100 square meters.

The situation is somewhat different for plantations. Here the error is approximately the same for plots of both 10 m. by 10 m. and 20 m. by 20 m. Thus for comparative trials, the plot sizes should be smaller than is usually stated (see, for example, Lindquist 1946). It is worth mentioning that *thinning experiments* exist which seem to have given satisfactory results with plot sizes of 0,1 acre (Hummel 1947).

It is often stated that considerations of accuracy make the use of large plots essential. It is argued that the smaller plot, the greater the magnification of any error when the figures are converted to a per hectare basis. Moreover, it is claimed that there is less possibility for the cancelling out of errors with small plots (see, for example, Fritsche 1927). However, this view is correct only under the condition that the number of plots is fixed. With a fixed sum of money for the trials or a fixed total area, the situation may be quite different. In these cases many small plots (for example, 0,05 ha.) are better than a few large ones (for example, 2,0 ha.).

Another point which is often overlooked is the problem under study. Usually the question to be answered concerns the effect of different treatments within a given geographical area. With the problem put in this way, a very accurate record for the individual plot is not necessary, because the conditions at the special location may deviate from the average conditions of the area. A good representation of the area in question is more probable when we use many small plots than when we use a few large ones.

It would have been desirable to analyse plots somewhat larger than those used in Table 1. This, however, could not be done with the yield plots available as basic data, because they are too small to permit subdivision into an adequate number of units with areas exceeding the 10 m. by 20 m. size.

Strictly speaking, allowance should have been made in this analysis for the fact that the number of degrees of freedom will vary with plot size, if it is assumed that the total study area is fixed. However, the effect of this is that for any given experimental design the number of degrees of freedom will increase when the plot size is decreased.

53. Edge effects

Van Soest (1950) has carried out some interesting measurements on a plot of Japanese larch. The average diameter of the edge trees was much greater than the average for all the trees in the plot, but for the trees in row number 2 the average diameter was no larger than the average for all the trees, excluding the edge trees. Thus, the edge effect was absorbed by the first row.

These results have been confirmed by some measurements conducted at the Institute of Silviculture. About 1910 the Norwegian Railway System planted some small stands of Siberian larch along its lines. For several of these stands it can be established beyond doubt that the present edge trees were also the edge trees when the plantations were established. This is also true of a stand of Siberian fir that has been measured. The average diameters in centimeters for the individual rows are shown in the table below:

	Row 1	Row 2	Row 3	Row 4	Row 5	Row 6	Row 7
Siberian fir	25,5	17,4	17,7	15,9	18,5	16,4	17,0
Siberian larch							
Fåberg	25,1	19,4	19,5				
Vinstra	25,4	16,2	15,9	14,8			

It appears that in these stands, also, the major part of the edge effect on diameter is absorbed by the first row. There is, however, a slight drop between Row 1 and Row 4 at Vinstra. Whether or not this is due to random chance is difficult to decide. The variation within the individual rows is very wide.

In the examples cited here, the edge effect has been extreme since the trees have been growing next to an open field. In contrast, with experimental trials the differences between neighbouring plots will rarely reach such a level. However, in these cases there is another kind of edge effect, viz. that caused by the competition among the trees. If the differences between the treatments become very pronounced, this effect is likely to assert itself over many rows. In practice, these cases will be exceedingly rare.

Isolation strips which include 2 to 3 rows between the plots should be adequate unless the spacing is so close that many trees will disappear before the conclusion of the trial. The situation is quite different for the isolation strip surrounding the area. These strips may border more extensive open fields. Here we must consider an entirely different edge effect. Under such extreme conditions the tree height may be somewhat reduced for a fairly large distance from the edge, as has been shown by Fritsche (1929) among others.

Summary

1. There is a pronounced linear regression between basal area increment and basal area on small plots (5 m. by 5 m.) which is not found on larger areas.
2. Analysis of data from yield plots for Norway spruce has shown that there is a negative intraclass correlation between basal area increment on adjacent plots of the size 5 m. by 5 m., and in many cases also for the size 10 m. by 10 m.
3. In comparative trials in which isolation strips are not needed, the most efficient use of the area (i. e., the lowest variance per unit area) is obtained by the use of plot sizes of approximately 200 square meters in natural stands. For plantations the plot sizes should be somewhat less.
4. In comparative trials in which isolation strips are used, the net area of the plots must be somewhat increased if the utilization of the total area is to be as effective as possible. As the width of the isolation strip is increased, the net area of the plots should also be increased.

Zusammenfassung

Titel der Arbeit: *Teilstückgrößen in Feldversuchen.* —

1. Es besteht eine ausgesprochene lineare Regression zwischen Grundflächenzuwachs und Grundfläche auf kleinen Teilstücken (5 × 5 m), die nicht für größere Areale gilt.
2. Die Analyse von Messungen auf Ertragsprobeflächen der Fichte hat gezeigt, daß die Intra-Klasse-Korrelation zwischen den Grundflächenzuwächsen auf Nachbarteilstücken der Größe 5 × 5 m negativ war. Dies gilt in vielen Fällen auch für diejenigen der Größe 10 × 10 m.
3. In vergleichenden Versuchen, bei denen Isolierstreifen nicht vorhanden sind, wird die beste Ausnutzung der Fläche (bei geringster Varianz je Flächeneinheit) durch Teilstückgrößen von annähernd 200 m^2 erreicht, wenn die Bestände aus natürlicher Verjüngung hervorgegangen sind. Für gepflanzte Bestände kann die Teilstückgröße etwas geringer gewählt werden.
4. In vergleichenden Versuchen mit Isolierstreifen muß die reine Versuchsfläche etwas vergrößert werden, wenn die Ausnutzung der Gesamtfläche so effektiv wie möglich sein soll. Mit Verbreiterung des Isolierstreifens muß auch die reine Versuchsfläche größer gewählt werden.

Résumé

Titre de l'article: *Grandeur des parcelles dans les expériences comparatives.* —

1. On peut mettre en évidence une régression linéaire entre l'accroissement de la surface terrière et la surface terrière elle-même, dans de petites parcelles (5 × 5 m), alors qu'on ne peut le faire sur des parcelles plus étendues.

2. L'analyse des données concernant la production des places d'exérience d'épicéa a montré qu'il existe une corrélation intra-classe négative entre l'accroissement de la surface terrière sur des parcelles voisines de 5 m × 5 m, et fréquemment aussi pour des parcelles de 10 m × 10 m.

3. Dans les expériences comparatives sans bandes d'isolement la meilleure utilisation du terrain (c'est à dire la variance la plus basse par unité de surface), est réalisée avec des parcelles d'une surface d'environ 200 m², en peuplements naturels; pour des plantations on peut employer des parcelles un peu plus petites.

4. Dans les expériences comparatives avec bandes d'isolement, la surface nette de la parcelle doit être quelque peu augmentée, pour avoir une utilisation du terrain aussi rationnelle que possible. Si on augmente la largeur des bandes d'isolement, il faut de même agrandir la surface nette des parcelles.

Literatur

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Künstliche Polyploidie-Erzeugung bei Picea abies und Betula verrucosa

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(Eingegangen am 7. 2. 1955)

In der Forstpflanzenzüchtung wurde der Erkenntnis von der Wirkung des Colchicins als Mitosegift zunächst wenig Beachtung geschenkt. Erst als Nilsson-Ehle (1936) in Ringsjön das Auftreten eines besonders wüchsigen Aspenbestandes feststellte, den Müntzing (1936) durch zytologische Untersuchungen als autotriploiden Klon erkannte, und als auch Johnsson (1940) autotriploide Aspen mit überragender Leistung auffand, gewann die Polyploidiezüchtung für die Forstpflanzenzüchtung wesentlich an Bedeutung. Es setzten Bestrebungen ein, auch an Waldbäumen mit Hilfe von Colchicin künstlich Polyploidie zu erzeugen, wie es an landwirtschaftlichen Nutzpflanzen schon seit einiger Zeit durchgeführt wurde. Soweit bekannt, gelang es Mirow und Stockwell (1939) erstmalig durch Colchicinbehandlung an Kiefernsaatgut und Kiefernknospen bei Waldbäumen künstliche Chromosomenverdoppelung hervorzurufen. Dieser Arbeit folgten eine Reihe anderer, in denen berichtet wird, daß bei Pappel (Johnsson und Eklundh, 1940, Johnsson 1940, 1942 und 1953, Bergström 1940), bei Birke und Eiche (Johnsson und Eklundh 1940), bei *Sequoia gigantea* (Jensen und Levan 1941), bei Erle (Johnsson 1950), bei Fichte (Kiellander 1950, Illies 1952) und bei Lärche (Illies 1952) durch Colchicinbehandlung künstlich Polyploidieerscheinungen hervorgebracht werden konnten.

Aus den oben angeführten Arbeiten geht hervor, daß bei Waldbäumen tetraploide Individuen den diploiden in den meisten Fällen leistungsmäßig unterlegen sind. Diese Tatsache unterstreicht auch besonders Johnsson in seiner Veröffentlichung von 1953, in der er triploide und diploide Aspen in ihrer Jugendentwicklung einander gegenüberstellt. Johnsson hat tetraploides Material aus Kreuzungen zwischen diploiden und triploiden Aspen gewonnen. Von diesen Tetraploiden berichtet er über ihre offensichtlich langsame Entwicklung und reduzierte Vitalität im Vergleich zu den Triploiden. Benutzte er diese Tetraploiden jedoch als Ausgangsmaterial für Kreuzungen mit Diploiden, so erhielt er triploide Nachkommen, deren Leistungen bezüglich der Höhe und Stärke weit über denen der Diploiden lagen.

Im Hinblick auf derartige Ergebnisse führten wir in unserer Zweigstelle u.a. Colchicinbehandlungen an Fichte und Birke durch, um auf diesem Wege tetraploides Material zu erhalten, das als Kreuzungspartner der Ausgangspunkt für besonders wüchsige triploide Nachkommen werden soll.

Die verschiedenen Möglichkeiten der Colchicinbehandlung zur Polyploidieerzeugung bei Forstpflanzen sind von Mirow und Stockwell (1939), Blakeslee und Avery (1937) und besonders ausführlich von Sin Kyu Hyun (1954) beschrieben worden. Am gebräuchlichsten sind Samen- und Sproßpolbehandlungen. Während die Sproßpolbehandlung den großen Vorteil bietet, daß dadurch Teile bereits fruktifizierender Pflanzen polyploidisiert werden können, so hat sie andererseits wieder den Nachteil, daß die auf diese Weise erzeugten polyploiden Gewebe äußerst instabil sind, denn sie kehren oft ganz oder teilweise zum diploiden Zustand zurück. Die durch Samenbehandlung hervorgerufenen Polyploiden sind stabiler.

Versuchsanstellung bei Fichten

Im Januar, Februar und April 1951 behandelten wir in unserer Zweigstelle Samen von *Picea abies* mit Colchicin. Das Saatgut stammte von Fichtenauslesebäumen aus Tharandt. Der Versuch vom Januar erhielt die Nummer 16A/51, der vom Februar die Nummer 16B/51 und der vom April die Nummer 26/51.

Einprozentige Agar-Agarlösung, die 0,25% Colchicin enthielt, wurde in Petrischalen ausgegossen, um nach dem Erkalten darauf die Fichtensamen zum Keimen zu bringen. Gleichzeitig erfolgte das Ankeimen von Kontrollen.