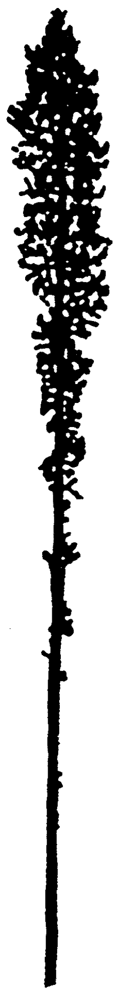

STOCKING CONTROL AND ITS EFFECT ON YIELD

DR. PEDER BRAATHE'

Forest Industry Lecturer

Forestry Program
The University of Alberta
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FOREST INDUSTRY LECTURE SERIES NO. 10

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THE FOREST INDUSTRY LECTURES

Forest industry in northwestern Canada is cooperating with Alberta Energy and Natural Resources to provide funds to enrich the Forestry Program of the Faculty of Agriculture and Forestry at the University of Alberta through sponsorship of noteworthy speakers.

The Forest Industry Lecture Series was started during the 1976-77 term as a seminar course. Desmond I. Crossley and Maxwell T. MacLaggan presented the first series of lectures. The contribution of these two noted Canadian foresters is greatly appreciated.

Subsequent speakers in the series have visited for periods of up to a week, with all visits highlighted by a major public address. It has indeed been a pleasure to host such individuals as C. Ross Silversides, W. Gerald Burch, Gustaf Siren, Kenneth F.S. King, F.L.C. Reed, Gene Namkoong, Roger Simmons, Kenneth A. Armson, and John J. (Jack) Munro. The subjects of their talks are listed on the last page.

This paper, by Peder Braathe, represents his major public talk given on 4 November, 1982.

We would like to take this opportunity to express our thanks again to the sponsors of this program. We appreciate very much their willing and sustained support:

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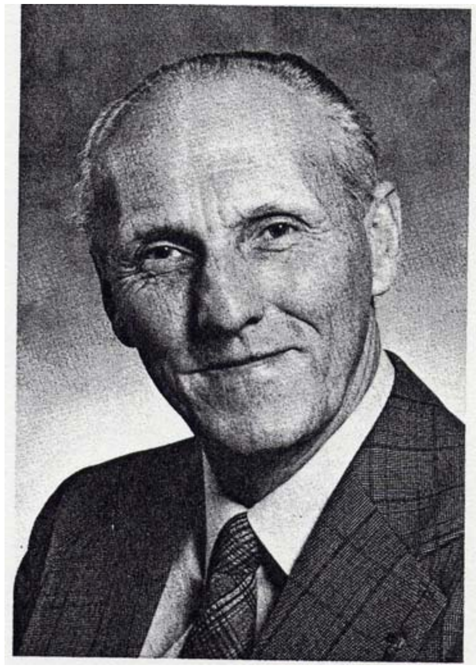
DR. PEDER BRAATHE



Dr. Peder Braathe has been Professor and Director of the Department of Forest Regeneration at the Norwegian Institute of Forest Research (NISK) at Aas since 1957 when he was also named Professor. In addition, he served as Director of NISK between 1962 and 1973.

After obtaining his doctorate of Agriculture from the Agricultural University of Norway in 1954, he spent the subsequent year at the University of New Brunswick as an NRC Postdoctoral Fellow, working on a review of European literature on thinnings.

Dr. Braathe has published extensively in the areas of stocking control, thinnings, weight scaling, regeneration surveys and ecological reserves. He is a participant in the Group for Forest Regeneration at High Latitudes working out of Fairbanks, Alaska; a member of the Norwegian Academy of Sciences and Letters in Oslo; and serves as an examiner for the Agricultural University of Norway in the forestry program.

STOCKING CONTROL AND ITS EFFECT ON YIELD INTRODUCTION

Forest management implies long-term use of one of the most important natural resources. The forester and the forest owner therefore have the great responsibility of maintaining the forests in an optimal way for the benefit of the owner, the wood consuming industries and the nation as a whole. Forests, as a renewable resource, can be utilized at different intensities, but never totally consumed and seldom fully wasted. With proper management, the growing potential of an area can be optimally utilized and a correspondingly high yield of timber can be harvested. In a world with limited resources, proper management and yield should be a responsible goal.

In Scandinavia, sawlogs are expected to be the main element of the future economy of forestry, as they are today. Consequently, an optimal output of good quality sawlogs should be the goal set when establishing a new stand. Pulpwood has to be considered mainly as a by-product of sawlog production, although pulpwood usually contributes positively to the total economy of the forest enterprise.

The basis for a high yield in volume and quality is laid during a few years in the regeneration period. This is the determination period for the composition of the future stand, in regard to mixture of tree species and density. Density determines the quality of the wood produced, especially regarding taper and size of knots. Very often the regeneration is established within only five years, after which it is difficult or even impossible to change the tree species or improve on inadequate regeneration. In a shelterwood system this period may be somewhat longer, but still short in relation to the rotation period of 60 to 90 years. The type of regeneration established today creates the conditions for harvest in the middle of the next century. Inadequate regeneration today, therefore, will give a lower harvest level in the next century.

The level of forest resource utilization cannot be changed rapidly. It depends on the basis laid down when the rotation starts.

METHODS FOR STOCKING ASSESSMENT

Stocking assessment at an early stage should be an important part of forest management. This is the case in Scandinavia, to some extent, although only scattered samples are taken. Stocking assessment can be carried out mainly by two methods.

The simplest method of merely counting trees is suitable in plantations where fairly regular spacing allows most plants to develop into crop trees. In natural regeneration, however, counting trees will overestimate the density, because although some parts are crowded, others are open. To give a proper picture of the potential of development, the number of trees has to be reduced either by personal estimate or in a more methodical way. Both approaches are used. In Sweden, for instance, only the trees which can reach commercial value are counted on circles or quarter circles by the operator. All others are ignored. In Norway, it is proposed never to count more than three trees on an area of 12.5 m^2, which means an average spacing of at least 2 m. This is about the lowest spacing commonly used in Norway for Norway spruce plantations.

The other method is to count stocked quadrats instead of the total number of trees. This stocked quadrat method, based on milliacres, has long been used in Canada and the USA, [KER (1953) and HOSIE (1953)]. The stocked quadrat method is the best measure of density in natural regeneration and is also a good measure in plantations, especially if natural regeneration has also taken place on the same area.

During investigations in the early 1950's concerning the development of Norway spruce regeneration that was irregularly spaced and of varying density, a similar method was useful (BRAATHE 1953). A square 2 by 2 m (4 m^2), which corresponds to a milliacre, was chosen. Instead of counting stocked quadrats, the empty ones were counted and the measure called, the zero-square percentage, calculated. This equals 100 minus the percentage of stocked quadrats.

This zero-square percentage is used in Norway both by the National Survey of Norway and in surveys carried out by foresters and companies.

DENSITY AND YIELD

In the studies mentioned, middle-aged Norway spruce stands that had not been thinned were analyzed. The investigation showed that there was a correlation between the zero-square percentage and the yield of the stand when expressed as a percentage of the corresponding number in the Norwegian yield tables. Figure 1 shows the total yield at 55% of the rotation age. (The rotation age is defined as the year in which the mean annual increment culminates.) The zero-square percentage is counted at a stage of regeneration when the average height of the trees has reached 1.3 m. The correlation between this zero-square percentage and the total yield at 55% of rotation age has a multiple correlation coefficient of 0.98.

In Figure 2, an estimate of total yield for the whole rotation period is made for some plots. Two alternatives, supposed to be the maximum and minimum, are calculated and the best estimate should be between these two curves in the shaded area of the figure. The figure shows that a total yield corresponding to the yield tables is reached at a zero-square percentage of 20 or less. At a zero-square percentage of 50 the total yield will still be at least 80%.

The zero-square percentage system is widely used to estimate future yield. It demonstrates the need to establish regeneration of sufficient density in order to utilize fully the growing potential in the coming rotation. A zero-square percentage of 20 to 30 gives approximately the table values. There is no need to strive for denser regeneration. A zero-square percentage of 30 corresponds to about 1750 counted trees per hectare (700 per acre) in a plantation, and somewhat more in natural regeneration because of the grouping, even after reduction by estimate or calculation.

The investigation and the equation is worked out for Norway spruce. The general trend, however, should be similar for other species as long as the tree heights at the end of rotation are about the same, between 24 and 30 m.

TIME OF ASSESSMENT

Time of the assessment, in the investigations and in the equation, is fixed to the stage of development when the height of the highest tree within each stocked quadrat averages 1.3 m. After this stage, few new seedlings come in, and the zero-square percentage is rather stable at least for a couple of decades. Even a beginning of self-thinning from competition does not alter the zero-square percentage, because the self-thinning takes place in the dense clumps and seldom causes new empty squares. The zero-square method therefore, can, be used up to the stage of the first normal commercial thinning, usually at a stand height of 14 to 15 m.

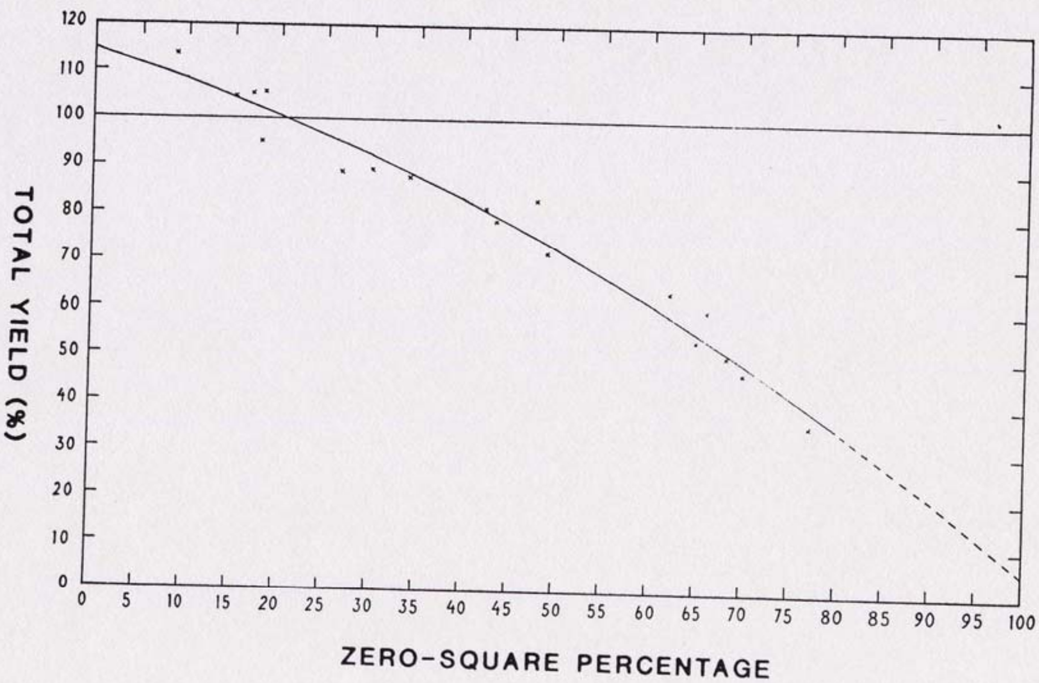


Figure 1 Correlation between zero-square percentage and total yield (%) at 55% of rotation age.

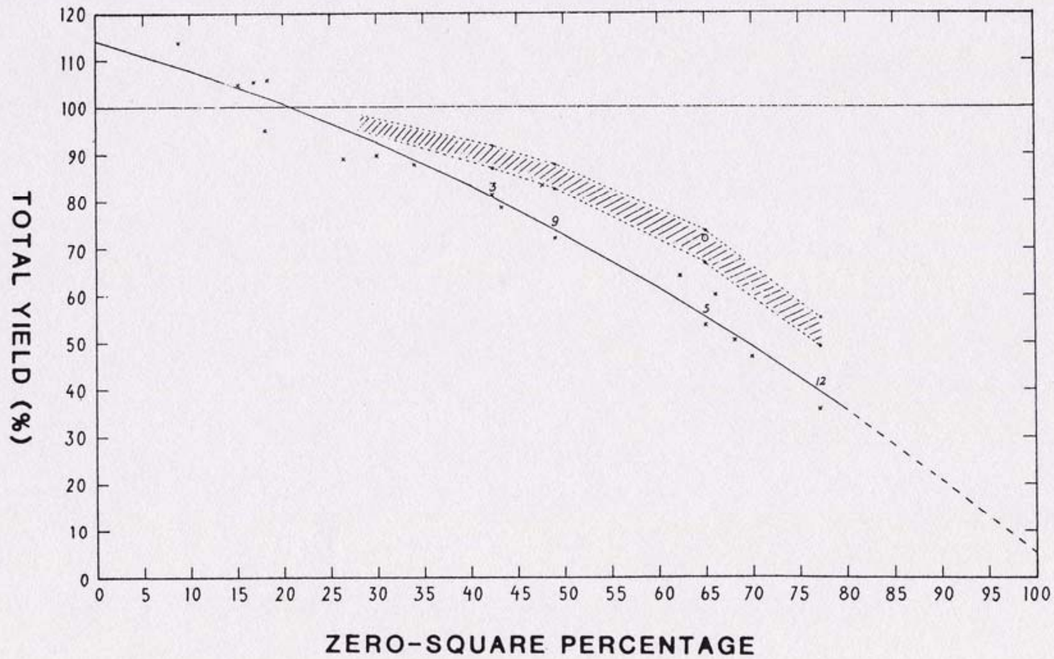


Figure 2 Correlation between zero-square percentage and total yield (%) at full rotation (shaded area).

In a plantation with no possibilities of natural seeding, the assessment can be carried out as soon as the plants are fully established, usually two or three years after planting. If seed sources are available and soil conditions are suitable for germination, however, the regeneration may gradually become denser. The forecast of the future yield for an understocked block in such an area will be more uncertain the earlier the assessment is made.

RESULTS FROM REGENERATION ASSESSMENT

The National Forest Survey of Norway (LANDSSKOGTAKSERINGEN 1980) makes assessment of the regeneration and young stands up to the thinning age. An example of the results is given in Table 1 from Akershus County, which surrounds and includes the City of Oslo. The survey was conducted between 1964 and 1976. The areas of regeneration and young stands not yet thinned amounted to 925 km', which is 30% of the total forest area of the county.

The categories used in the survey and in Table 1 are natural regeneration and plantings; satisfactory and less than satisfactory; and lower than 1.3 m and higher than 1.3 m.

The table shows that natural stands taller than 1.3 m occupy 54% of this area, while planted stands occupy 11.8%. Planted stands less than 1.3 m tall make up 13.5% of the area, while naturally regenerated stands of the same height make up 20.7%. This trend towards more planting relative to natural regeneration has increased since 1976 and today nearly two-thirds of the area which is regenerated is planted. Planting, however, has become very expensive, because of the high labour cost, so a slight decrease in the relative planting area may be expected.

The judgement "satisfactory" or "less than satisfactory" made by the surveyor on the spot. On a zero-square percentage of 50, "satisfactory" is down to about 40 on higher sites and "less than satifactory" upwards to 60 on lower

Categories in percent of regenerated area in Akershus county and zero-square percentage (Z-S P)

Method of 'generation	Classified	Height of regeneration: Lower than 1,3m		Z-S P		Higher than		Z-S P		All heights		Z-S P	
	Satisfactory		13,5		37		**43,8**		33		57,3		**34**
Natural		20,7		**46**		54,0		38		74,7		40	
	Less -,.-		7,2		62		10,2		61		17,4		62
	Satisfactory		12,0		33		11,4		31		23,4		32
Planting		13,5		**36**		11,8		32		**25,3**		**34**	
	Less -..-		1,5		57		0,4		72		1,9		60
	Satisfactory		25,5		**35**		55,1		32		80,7		**33**
Sum		**34,2**		42		65,7		37		100,0		39	
	Less -„-		8,7		61		10,6		**62**		19,3		61

Table 1 Categories in percent of regenerated area in Akershus county and zero-square percentage (Z-S P).

sites.

The main results, however, are the zero-square percentage values within the different categories. For satisfactory regeneration higher than 1.3 m, the zero-square percentage is 33 for natural stands and 31 for plantations. This density gives about 95 percent of the yield table values throughout the rotation.

For regeneration lower than 1.3 m, the zero-square percentages in the same categories are 37 and 33, respectively. These figures may be slightly decreased because new seeding-in is possible at this stage. Although the figures are averages with a variation from under 20 to 50 or more, the total picture is satisfactory for these categories. Although most of the forests in Akershus County lie at lower altitudes with good conditions for forestry, 19.3% of the regenerated area is classified as less than satisfactory with a zero-square percentage in the low sixties. About 10% of the area is stocked with plants higher than 1.3 m, and nothing can be done to improve potential yield. The yield of this area will not reach more than 70 to 75% of the yield table values, and lower quality timber will be produced. However, 8.7% of the total regenerated area has less than satisfactory regeneration below 1.3 m. On this area, additional seeding is possible in the years to come.

SUPPLEMENTARY PLANTING

The question of supplementary planting has two aspects: What is possible biologically, and what can be done within realistic economic constraints?

The Norwegian Forest Research Institute has investigated the first aspect of this question during the last 20 years. Experiments were carried out on high to medium spruce sites in open natural regeneration. Supplementary planting of three species: Norway spruce, Scots pine and Siberian larch, was conducted in open regeneration with heights of the tallest tree within each stocked square ranging from 40 cm to 1.5 m.

Even at 40 cm, seedlings are well established and their height is rapidly increasing. For this reason, supplementary transplants need to start growing quickly to follow the height growth of the initial plants. Larch and pine were used because they are able to cope with the slower growing spruce seedlings.

The larch may not have been of appropriate provenance. Many trees were damaged by wild animals, primarily by roe-deer, or by the elements. Trees growing without other damage often were broken by snow at temperatures around 0°C. The remaining trees, however, grew equally well in height with the Norway spruce regeneration, when the spruce had an initial height of 1.5 m. Until a more suitable provenance is found, Siberian larch cannot be recommended as a supplementary tree in spruce regeneration in Norway.

Scots pine seedlings also grew well together with Norway spruce in stands up to 1 to 1.5 m tall, or even taller. In areas where spruce was the dominant species, however, moose seriously damaged the pine trees. In the last 10 years the moose population in Norway has greatly increased. Scots pine, therefore, can not be recommended as a supplementary tree as long as the moose population remains at the current high level.

Norway spruce is the only species that was not damaged, but it has relatively slow initial growth. Consequently, the supplementary planting should come before the height of the regeneration is 1 m. The openings supplemented should be at least 7 to 8 m in diameter, and only three or four seedlings should be planted in an opening of this size. Seedling growth must start quickly, and the best planting spots must be chosen. Wet patches should be avoided.

The results after more than 20 years of research demonstrate that in very open regeneration with a zero-square percentage of 50 or more, it is possible when supplementing early to improve the stand density. At least some supplemented trees will compete favourably in the future stand.

In spite of these biological possibilities, the economic aspects are not favourable for supplementary planting with spruce unless carried out very early (for instance in the second spring after the cutting of the overstorey trees). If there is any advanced regeneration, these trees will be highly visible as green spots against brown brush that has lost most of the leaves and needles. Areas without regeneration are then easy to recognize and supplementary planting can be carried out. The seedlings also will have a good chance for a quick start before the lesser vegetation becomes too vigorous.

CONTROL OF COMPETING VEGETATION AND BROAD-LEAVED TREES

Besides having a good density, it is important to ensure the development of the regeneration without too much competition from vigorous lesser vegetation, especially from broad-leaved trees. **In** Scandinavia, birch will invade regenerated areas rather quickly after cutting either as stump sprouts or vigorous seedlings.

Birch must be controlled in spruce plantations all over Norwary, and in aspen and oak plantations in southern Norway. This control once was done manually using different types of brush saws. Cutting occurred when the birch was 2 to 6 m tall, at which time the spruce was only 0.5 to 1.5 m in height. With increasing costs, this type of control has become very expensive.

The herbicide Roundup (Glyphosate) now is widely used in Norway. It is highly selective, killing herbs and broad-leaved trees, but leaving the conifers undisturbed when sprayed in late summer after the coniferous leaders have completed their elongation. Spraying is carried out by tractor-mounted sprayers, from helicopters, or by man-carried sprayers.

The herbicide was released for common use in forestry by the medical authorities 7 years ago. Recreational people have put up some resistance to its use because they fear that not enough is known about its long-term effects. In addition, scenery after spraying is not aesthetically pleasing. Sizable dead trees may stand for years; therefore, spraying should be carried out early, preferably when the broad-leaved plants are between 1 and 1.5 m tall. Dead vegetation left after this early spraying will rapidly deteriorate and the visual impact is less dramatic and short-lived. In addition, the development of the spruce seedlings is not hampered and consequently the length of the rotation will be minimized. Density will also remain high since losses to competition are minimized.

Areas with luxuriant and vigorous lesser vegetation, such as high herbs and ferns, should be sprayed before planting of spruce.

The control of broad-leaved trees in coniferous regeneration is an important part of stocking control. In Scandinavia many old plantations, especially of spruce, have been seriously overgrown by broad-leaved trees for long periods, hampering development and reducing density. In Norway, the situation improved after the release of Roundup, but the situation in Sweden is still difficult. There, spraying is generally forbidden; however, the authorities can give permission for this use upon application, and some of the big forest owners and forest companies are spraying to some extent.

BROAD-LEAVED TREES AS FILL-IN TREES

In open regeneration with a high zero-square percentage after plantation or natural regeneration, natural broad-leaved trees could be left as fill-in trees to improve the yield. This is possible by manual cutting or selective spraying by a man-carried sprayer. Leaving broad-leaved trees as fill-in trees will, however, lead to a rather sophisticated stand structure needing repeated tending. Investigations on this subject started six years ago at the Norwegian Forest Research Institute. The aspects under study are the rate of development of both spruce and birch trees left in different mixtures and in different sizes of openings. Final conclusions are not yet possible, but mixed stands of spruce and birch need detailed tending more often than pure stands, so the mixture has no place in large-scale forestry. On small farmers' woodlots, however, it may be possible to utilize the area better than a pure, but open, regeneration of spruce. Nevertheless, the open regeneration with fill-in trees of birch will always be a poor substitute for normally dense and high quality regeneration, which must be the goal set when starting a new rotation.

REGULATION OF SPACING (PRE-COMMERCIAL THINNINGS)

Regeneration may be too dense, for example in pine on dry sandy soils where regeneration conditions are excellent. Spruce may also be too dense where natural regeneration occurs or where a plantation has filled-in naturally. In areas of dense regeneration, an early regulation of spacing (pre-commercial thinning) is carried out, usually at a stand height of 2 to 3 m. The object is to reduce the number of trees so the remaining trees will be of commercial size at the first ordinary thinning. With very high labour costs, thinnings are hardly profitable. The most economical way to manage dense stands is to reduce the number of trees at an early stage, leaving an improved stand of sound and well-shaped trees. VESTJORDET (1977) has conducted large-scale research on this topic. A small reduction in height growth occurs in the first 2 or 3 years after regulation, but this reduction is more than compensated for by stimulated growth in the following 5 to 7 years. Diameter growth is greatly stimulated by the regulation. The total volume increment will be reduced little, in spite of the greatly reduced number of trees. The greatest benefits of early spacing regulation are the improved stability against snow and the postponement of the first thinning to a stage where dimensions are great enough to give a commercial thinning.

The spacing and number of trees per hectare for plantations recommended by the Director of Forestry in the Department of Agriculture, can also be used as guidelines for regulation of spacing. For Norway spruce these figures are given in Table 2, showing spacing between 1.9 and 2.7 m varying with site class and accessibility.

THINNINGS

Earlier, when wood was very valuable and labour inexpensive, four or five thinnings were commonly carried out during the rotation period. Each thinning gave profit to the forest owner. As low quality trees were gradually removed, the stand gained in quality and stability. Extraction was then done by horses, causing little damage to the remaining trees. Today, labour costs have increased and the number of thinnings reduced to a minimum. The question now is, how few thinnings can keep the stand development under fair control throughout the rotation period and reduce the hazard of catastrophic losses, especially from snow?

Different considerations regarding stability have been made and the conclusions indicate that two thinnings are adequate when initial spacing follows the recommendations in Table 2 (BRAATHE 1968, 1971). BRAASTAD (1975) has presented yield tables with two and also with only one thinning, based on thinnings and yield studies.

With two thinnings the bulk of the wood produced is utilized, and deterioration from self thinning is very small, probably 3 to 5%. With no thinnings at all, the self-thinning may be about 20% of the total production. Based on these results, BRAASTAD (1977) recommends two thinnings, as shown in Figure 3. The number of trees in relation to the height of dominant trees should be kept within the shaded area to avoid hazard or instability.

Within the shaded area there are several alternatives. The figure shows the first thinning at a height of nearly 14 m. Under Scandinavian conditions today such a thinning is difficult to carry out profitably and will probably be delayed until the trees attain a height of 16 m or more.

Spacing and number of trees per hectare, Norway Spruce

	Site c	
Conditions for forestry	1+2	3
Good	1,9 - 2,3m 2800 - 1900	2,1- **2,5m** 2300- 1600
Less good	2,1 - **2,5m** 2300 - 1600	**2,3-** 2,7m 1900- 1400

Table 2 Spacing and number of trees per hectare, Norway Spruce.

Number of trees per hectare

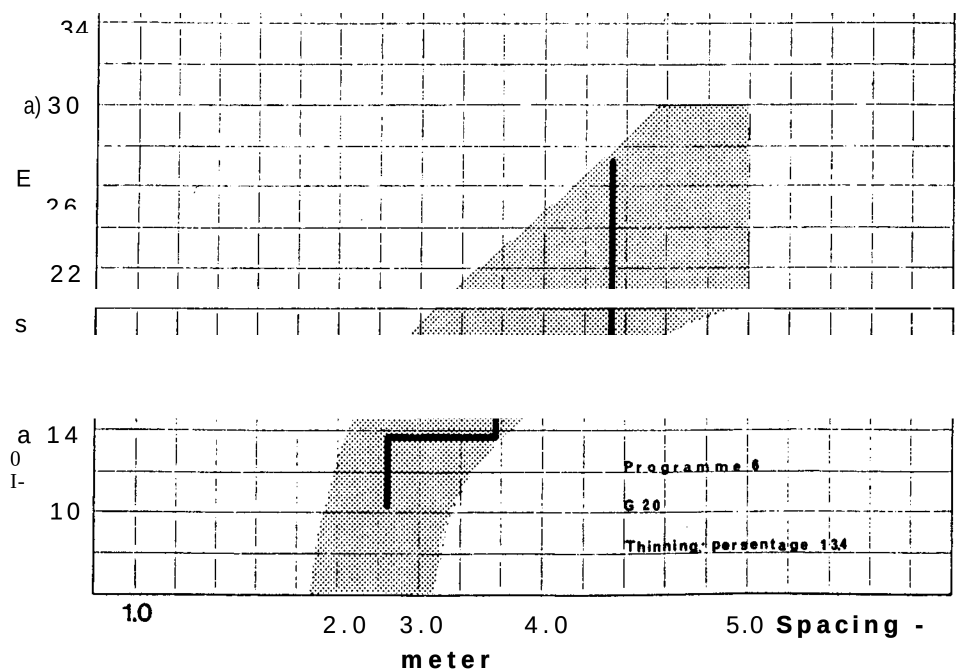


Figure 3 The **relationship** between **spacing and tree height for** Norway spruce (shaded area) with two proposed thinnings.

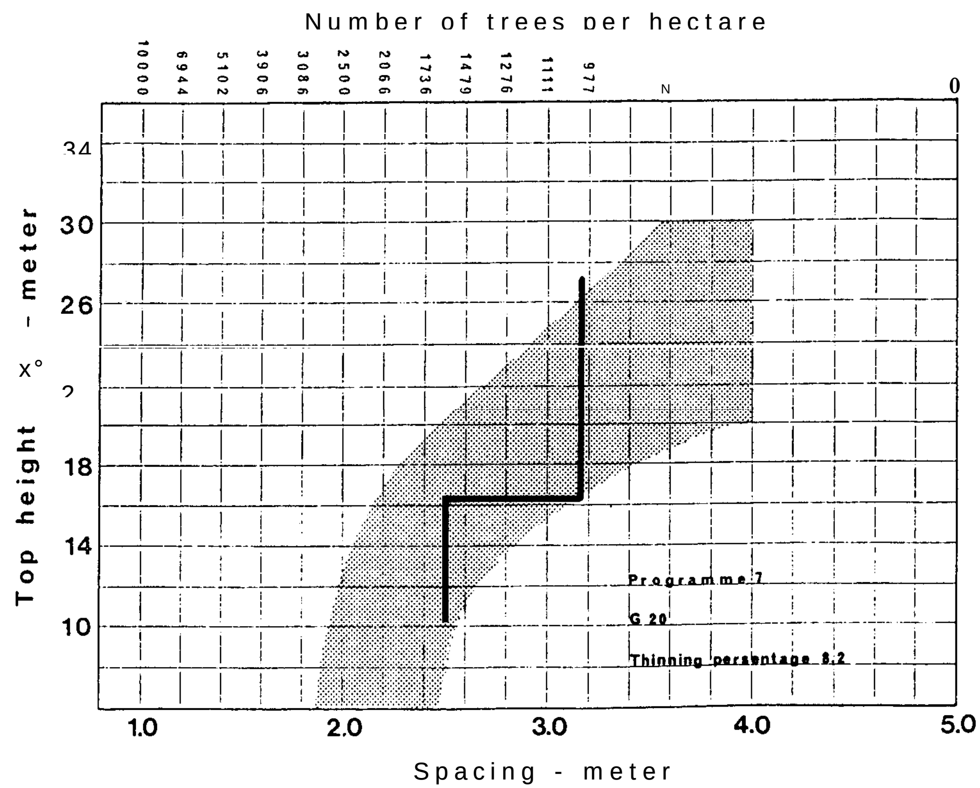


Figure 4 The relationship between spacing and tree height for Norway spruce (shaded area) with one proposed thinning.

Even one thinning is better than none for stability and saving wood. Figure 4 shows such an alternative with the thinning at a height of 16 m.

FINAL REMARKS

Most of this information is based on Norwegian data and on Scandinavian and North European forest conditions. In a very strict sense, the results presented are valid only for these regions. The general aspects, however, are valid under a wide variety of forest conditions.

Everywhere, it is important to secure proper regeneration, and to control its development by controlling competing vegetation, and, if necessary, by pre-commercial thinning. Control measures at these early stages of development are decisive for the future yield of the forests.

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Table 1 Categories in percentage of regenerated area in Akershus county and zero-square percentage (Z-S P).

Table 2 Spacing and number of trees per hectare, Norway Spruce.

Figure 1 Correlation between zero-square percentage and total yield (%) at 55% of rotation age.

Figure 2 Correlation between zero-square percentage and total yield (%) at full rotation (shaded area).

Figure 3 The relationship between spacing and tree height for Norway spruce (shaded area) with two proposed thinnings.

Figure 4 The relationship between spacing and tree height for Norway spruce (shaded area) with one proposed thinning.