GROWTH, STRUCTURE AND SHAPE CHARACTERISTICS OF A 12 YEAR OLD GREY ALDER STAND (ALNUS INCANA L. MOENCH).

N. Lust

State University of Ghent ; Faculty of Agricultural Sciences.

Laboratory of silviculture

Abstract

In the experimental forest Aelmoeseneie at Gontrode (Belgium), a 12 year old artificial plantation of grey alder has been analysed on growth, structure and shape characteristics.
In the plot some ten tree cells and tree pairs were examined in particular. The tree cells consisted of one central tree, which was surrounded by six other ones. The tree pairs were the dominant tree and the most dominated tree in these cells.
In the first place height, diameter, basal area and leaf mass were determined. Then, the vertical and horizontal structures were analysed, with special attention being paid as well to the social differentiation in the tree cells as to the crown areas. Finally, several tree shape characteristics were determined.
The alder grew very well. The internal competition and differentiation had already started. The position of the dominant trees, however, is not stabilised yet.
The treatment of the thicket, in continuity with the thinning, will be necessary in the next future.

TABLE OF CONTENTS

1. INTRODUCTION AND PROBLEMS

In the life course of a stand, the thicket is a very important phase. It is characterised by continuous dynamics. In this phase radical changes in the individual tree and the overall structure of the stand take place (Schädelin, 1942).

Several authors (Kurth, 1956; Kunz, 1953; Van Miegroet, 1956; etc.) have analysed the thicket phase for different species (beech, scots pine, ash), aiming at developing a better treatment concept. However, all these stands emanate from dense natural regenerations.
But even in homogeneous, even-aged, artificial stands, with a certain analogy to real plantations, intense dynamics occur. These have a considerable silvicultural importance.
For this reason, a 12 year old thicket (2 year old plants + 10 year old plantation) of grey alder was examined. The main purpose of this research was to find an answer to the following questions :

- what are the general characteristics of an artificial thicket ?
- how is such a thicket built up in the vertical and horizontal layers ?
- is there, at this age and under the present circumstances, already a social differentiation ?
- how do the crown and stem develop for the different tree types ?

2. SOME DATA ON GREY ALDER

Although grey alder (Alnus incana (L) Moench) is not generally considered as an economic valuable tree species a lot of research has already been spent on this species.
As grey alder is not native in western Europe, it isn't in Gontrode either. Its optimal natural range is found in the Baltic States, in the Alps and in the Carpathians. Although this species often appears on wet and fresh soils, near streaming water, Van den Burg en D. Ruyter (1976) could show it also produces good results in relatively dry soils.
The grey alder has a superficial root system. According to Ellenberg (1963) this is due to the root tubercles' considerable need of oxygen. Pizelle (1975) indicated that nitrification starts in spring time, with the appearance of the leaves and starting from a temperature of 20° C. This phenomenon reaches a peak during the months of June and July, decreases later on slowly and stops definitely when the leaves are falling down for some time. The grey alder is very well suited to the amelioration of poor degraded soils (Kelleberda & Dänko, 1979). This is also partially due to its humus quality. The high humus production of grey alder is especially favorable in sandy soils, a characteristic that was already known by Mouillefert (1898). Besides its soils improving potential (Knuchel, 1954; Johnsrud, 1978), grey alder is also very important to soil fixation. Rokita (1970) and Buzow (1978) found out that the tree species is very well suited to protect the river banks against erosion.

John Schiechtl and Schimitschek (1976) underlined that, due to its potential to fix the soil and to enrich it with nitrogen, grey alder is a very useful

tree species for the rehabilitation of forest areas which have been destroyed by fire.
Grodzinski (1970) and Grodzinska (1971), on the other hand, stress two other values of grey alder :

1. The food value of leaves and seeds for men and animals. The energetic value of this food source is proportional to the quantity of liped and can amount to 4.4 or even 6.8 kcal per gram dry weight.

2. It is a good indicator for SO_2 pollution. There is a very good relation indeed between the pH of the bark and the SO_2- percentage in the air.

3. OBJECT AND METHODOLOGY

The sample plot is situated in the Aelmoeseneie experimental forest. The average annual precipitation amounts to 820 mm and the average annual temperature varies between 10° C and 10.5°C. It has been planted on a poorly drained clay soil, near to a brook. A permanent ground water table is present at a depth of 40-60 cm. The pH-level of the soil equals ± 6.9, which implies a high saturation value : V = ± 85 %.
The parcel was used before as a permanent meadow. It was planted, without soil preparation and fertilisation in an equilateral triangular pattern, with sides of 3 m. The number of plants reached 1100 pro ha.

The plants originated from a private nursery and were 2 years old (S1T1) with a height of 50 to 120 cm.
The plot had a surface of 1965 m² and contained 216 trees.
Ten years after the plantation all trees have been measured : diameter, height, branch-free stem length, crown characteristics.
For more thorough research, additional specific survey units within the plot have been establised, viz. in tree cells and tree pairs.
Tree cells are survey units with a restricted area, formed by a " dominant " individual and the elements which have a direct crown contact with the dominant tree. In this case each cell contains 7 individuals, viz. 1 dominant tree and 6 neighbours. Dispersed over the stand, 10 such-like cells were thoroughly examined, 70 trees in all.

A tree pair is a survey unit within a tree cell, existing of two trees : a dominant individual and a dominated one. The dominant tree is the central tree, in other words the heighest one of the cell. The smallest one of the cell was chosen as the dominated tree.
In this tree cells and on the tree pairs additional measurements of crown and stem shape have been carried out.

4. GENERAL CHARACTERISTICS OF THE THICKET

4.1. Height

Information on grey alder growth is relatively scarce. Koster (1971) found that the height of 5 year old plants was ranging between 3.41 m and 4.56 m, corresponding to a mean annual height increment of 0.56 m or even 0.76 m. Verwey (1977) came to similar results : after 5 years, height ranged from 3.48 m to 4.60 m. After 10 years, height had increased to 8.2 or even 9 m.

In Norway, Börset and Langhammer (see van den Burg, 1978) found an average height of 9 m, which means an average annual growth of 0.75 m. Murnicks, for his part (see Van den Burg, 1978) found in Letland an average height of some 11 m with 12 year old stands, corresponding to an annual increment of 0.91 m.
In the plot at Gontrode grey alder has reached, after 12 years, an average height of 10.35 m $\pm$ 1.08 m ; that means a mean annual height increment of 86 cm.
The height growth can be considered to be good to very good. The variation in tree height is moderate to large, taking into account the relatively uniform planting circumstances.

Grey alder height growth very early attains its culmination maximum. According to Verwey (1977) it decreases after 7 years already. The results of Murnicks, Börset and Langhammer confirm this tendency. Also in the plot at Gontrode the culmination point has been reached after only 10 years.

4.2. Diameter, basal area and leaf mass

Koster (1971) found that, depending on cultivar and origin, grey alder reaches a diameter of 2.7 to 4.2 cm after 5 years. Verwey gives exactly the same results. After 10 years he measured diameters ranging from 10.5 to 10.8 m.
At Gontrode the average annual diameter (after 12 years) amounts to 11.4 cm $\pm$ 1.86 cm, corresponding to an average diameter increment of 0.94 cm per year. The variation is of the same order as with the growth height.
The diameter growth culminates also relatively soon with grey alder. Verwey (1977) situates this point around the age of 10 years.
The basal area is an interesting measure for the evaluation of the stand volume, the stand density and, consequently, for the treatment. In the plot the basal area is 11.4 m^2/ha. The average basal area is about 104.4 cm^2.

The quantity of leaf mass is an indication for the productivity and the efficiency of the stand. Bray and Gorham (see Van Miegroet, 1976) estimate the yearly production of leaves in a normal dense forest on average on 2.8 tons of dry matter/ha for the hardwoods and on 2.9 tons for the conifers. Duvigneaud (1984) estimates the normal production per ha forest in our regions on 11 tons of dry matter, distributed over 5 tons of wood (46 %), 4 tons of leaves and 2 tons of roots.
In the plot at Gontrode, the leaf fall was measured during the whole season. It could be concluded that the total leaf mass amounted to 3.64 tons/ha. In the course of the season the following observations were made :

- a high leaf fall from the beginning of July; at the end of July more than 1/4 (26.2 %) of the total annual leaf mass has already fallen down ;
- very little leaf fall between mid-August and mid-September ;
- in the second half of September the leaf fall was very high (18.6 %) ;
- at the end of September over 55 % of the leaves have already fallen ;
- the largest leaf fall occured in the second half of October (29.7 %).

4.3. The distribution of the stem number

In the stand canopy concerned, closure has already taken place. It means that the competition of the second degree, within the individuals themselves, is going on intensely.

From researches in young stands and thickets of spruce, Delvaux (1966) concluded that in very young stands the height distribution was rapidly becoming normal. This situation goes on as long as the trees do not suffer from mutual competition. Very quickly, however, after 5 to 7 years, the height distribution starts to deviate from normality. The curve now becomes asymetric. At that moment there are more high trees than low ones. The distribution curve shows a right asymetry.
As to diameter distribution, Mitscherlich (1970) demonstrates the contrary. Indeed, with a lot of trees height growth increases very strongly at the expense of diameter growth. Consequently, in differentiating young stands there are on one hand more high trees than lower ones and on the other hand more thin trees than large ones. The frequency distribution of diameter growth, which was originally symetric, has changed into a left asymetric curve.

To some extent, the stem number distribution of grey alder at Gontrode corresponds to the observations of Delvaux and Mitscherlich.
The trees reach a height ranging from 7 to 13.40 m.

height class (m)	7-8	8-9	9-10	10-11	11-12	12-13	13-14
% distribution of N	2.7	6.0	21.3	47.7	18.0	3.2	0.9

The highest frequency (47.7 %) is taken up by the classes 10-11. 87 % of the trees have a height between 9 and 12 m.

In a normal distribution 95.5 % of the observations are located between $\bar{x} \pm 2s$, viz. between 8.2 and 12.5 m, and 99.7 % of the surveys between $\bar{x} \pm 3\ s$, i.e. between 7.1 and 13.6 m. The data show, however, that only 94.7 % and 99 % of the trees are situated within the proposed height range. The distribution deviates slightly from the normal one. There is a right asymetry.

The diameter class distribution illustrates some remarkable points.

diameter class (m)	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14
% distribution N	0.5	0.9	1.8	6.0	11.6	19.9	18.0	25.0	12.0

	14-15	15-16	16-17
	2.3	0.5	1.4

- The diameter distribution is less sharp and more flattened than the height distribution (1 % = 16.3). Only 62 % of the trees are found in the class around the average (10-13), whereas this was 87 % with the height distribution.
- The highest frequency (25 %) appears in the class 12-13.
- The class with the average diameter, 11-12, contains only 18 % of the trees.
- To the left of the centre there is still a (small) peak.

With a normal distribution, 95.5 % of the trees have a diameter between 7.6 cm and 15.1 cm, and 99.7 % a diameter between 5.8 and 16.9 cm. In reality 94.9 and 99.5 % of the diameters are found between the respective calculated values. From this it can be concluded that the diameter distribution corresponds very closely to the normal distribution. At the moment a double trend can be observed : a slight left asymetry, but above all a right asymetry.

The frequency distributions, as well for height as for diameter, allows us to make the following conclusions :

- the internal competition among the trees is only a recent phenomenon ; it started just 1 to 2 years ago and its influence is still restricted;
- unlike the normal patterns of growth course, the competition affects more the height growth than the diameter growth; a possible cause might be a combination of large plant distance and a high chemical richness of the soil, by which a fast youth growth occurs and more heavy trees than normally appear.

4.4. Presentation of the tree cells and the tree pairs

Within the sample plot ten tree cells are examined, with the aim to analyse the relations among the trees on a small scale. Therefore these groups must be representative for the whole.
Comparison between the average height, the average diameter and the average basal area of the tree cells and the whole stand :

	$\bar{h}$(m)	s	$\bar{d}$ (cm)	s	$\bar{g}$ (cm²)
average of all tree cells	10.63	0.90	11.54	1.95	107.5
average of the stand	10.35	1.08	11.38	1.86	104.0

No significant differences can be shown between the tree cells and the whole stand.

Within the tree cells the relation between the dominant and the dominated trees (the smallest tree of the cell) is very instructive (Table 1).

Table 1 : Height (m), diameter (cm), basal area (cm²) of the dominant and the dominated tree

	heigth (m)			diameter (cm)			basal area (cm²)		
	Dom.	dom.	Dom./ dom.	Dom.	dom.	Dom/ dom	Dom	dom	Dom./ dom
1	12,1	10,3	85,1	13,6	8,5	62,5	145,19	56,65	39
2	11,6	9,1	78	13,6	9,95	73,1	145,16	77,7	53,5
3	11,1	8,7	78,3	13,15	7,4	56,2	135,7	41,98	31,6
4	11,7	10,2	87,1	16,25	8,55	52,6	207,29	57,34	27,66
5	12,2	10,4	85,0	12,95	11,9	91,9	131,65	111,16	84,4
6	13,1	10,2	77,8	10,8	13,85	128,2	9,49	150,58	164,51
7	11,1	9,8	87,8	9,45	9,10	96,3	70,01	65,0	92,8
8	11,3	8,0	70,8	14,10	5,85	41,5	156,0	26,85	17,2
9	11,4	9,7	85,1	11,80	9,3	78,8	109,27	67,89	62,1
10	13,4	9,7	72,3	13,15	9,3	70,7	135,65	67,89	50,0
gemidd.	11,9 $\pm$ 0,8	9,61 $\pm$0,78	80,7	12,88 $\pm$1,86	9,37 $\pm$2,22	75,1	132,6 $\pm$37,4	72,4 $\pm$35,2	62,2

- As far as height and diameter are concerned, the dominated individual is on average significantly smaller than the dominating one ($t = 6.98^{+++}$. $t = 3.92^{+++}$). The differences are statistically clearer with the height than with the diameter.

- The dominating trees are, on average, 24 % higher than the dominated ones ; as to the diameter they are 37 % stronger.
- The variation is larger with the dominated trees, especially as to diameter, which appears from s % (6.7 % - 8.1 %; 14.4 % - 23.7 %).
- The smallest difference in height between the trees of a tree pair reaches 1.35 m or 14 % . The largest difference amounts to 3.7 m, which corresponds to 38 %. In other words, height differences are not yet equally high everywhere.
- It is especially remarkable that in cell 6 the diameter of the dominated tree is 28 % larger than the one of the dominating tree. This is, however, the only case where this phenomenon occurs. Yet also in cell 7 the differences are very small. On the other hand the differences can be very large too, e.g. in the cells 3,4 and 8. In the latter the difference amounts to over 100 %.

These figures show that diameter development occurs much less regularly and that it does not occur analogously to height growth. The latter becomes clear also from the relation between height classes and diameter classes : in each class of one parameter, different values are found for the other one.

5. THE STRUCTURE

5.1. The vertical structure in the stand

The development of social differentiation is a specific characteristic of the thicket phase. Delvaux (1975, 1981) defines this phenomenon as the whole of mechanisms which collaborate to construct a coherent structure, to create a hierarchy and finally to establish a population, which corresponds to a " system " of a higher order.

To assess the social position of a tree within the whole stand, several methods have been developed.

It appears, however, that the well known IUFRO method is rather unsuitable for use in artificial plantations. As it is based upon the upper-height (= 12.06 m), over 97 % of the trees belong to the dominant storey.
In order to be able to detect more accurate differences, the study was based on crown liberation (Van Miegroet & Lust, 1972). This way, only the dominant trees of which the greater part of the lateral branches receives direct sunlight, belong to the dominant storey.

	upper storey	intermediate storey	lower storey
%	71.2	28.6	0.2

Notwhitstanding their young age, the large plant distance and the only recent canopy closure - and consequently the internal competition - almost 30 % of the trees belong to the intermediate stratum.

There is no question of a lower stratum

The intermediate stratum develops gradually. More and more individuals will descend to this lower social class. Also Kunz (1953) and Delvaux (1975) indicate that in equally aged stands social promotion does not exist. According to Delvaux (1964, 1975) the movements occur for the greater part in the period between the plantation and the start of the internal competition. These changes are a consequence of the disturbed hierarchy originated by the plantation crisis. In the nursery a strong correlation between genotype and fenotype has been built up. This order has, however, been disturbed by the plantation. Therefore the years after the plantations are to be considered as a recuperation period. By means of an adapted plant distance one has to strive for the repair of the link between genotype and fenotype, before the competition starts. In this way, the trees with the highest potential value will dominate at the moment of the canopy closure.

5.2. Social differentiation in the tree cells

The research of differentiation within tree cells permits to determine the dissimilarity of the trees on a small scale.
Within the cells the differences in climate, soil, water and oxygen supply and all kind of climatological influences are to be minimalised. Growth differences between trees are mainly due to two factors : genetic ability and plant crisis.

Generally speaking, it is confirmed that height differences within the cells are still restricted :

aver.height per cell (m)		aver.height dominant		the heighest but one		av. h. cell, without Dom.		dominated tree		the smallest but one	
$\bar{h}$	s	$\bar{h}$	s	$\bar{h}$	s	$\bar{h}$	s	$\bar{h}$	s	$\bar{h}$	%dom.
10.63	0.90	11.90	0.80	11.19	0.88	10.43	0.74	9.61	0.78	0.96	0.57

- the standard deviation from the average height is low ;
- the dominant tree is statistically different from the highest tree but one ($t = 2.5^{+}$); the height difference between both, however, only reaches 6 %;
- the dominant trees account for the variation within the cell in 5 out of 10 units (1,2,5,6,10).
- the dominated tree is not significantly smaller than the smallest tree but one ; both are equal in 3 out of 10 cells ;
- a distinction can often be made within the cells between a group of higher trees and a group of smaller ones.

The vertical projection makes the situation even clearer (Fig. 1).

5.3. The horizontal structure

In an artificial plantation with a systematical planting pattern, the real growth area of a tree can be determined by means of the model of Assmann (1961).
In this particular case the growth area = $b^2 \frac{\sqrt{3}}{2}$, where b = distance between the trees, viz. 3 m. Consequently,the individual growth area amounts to 7.74 m².
The theoretical crown projection = $b^2 \frac{\pi}{4}$ = 7.06 m².

In this way, the relation between crown projection and growth area accounts for 0.906.

The horizontal projections (fig. 1) were carried out in accordance with the guidelines of Badoux (1939) : the dotted line refers to once covered crown areas, the pointed lines to twice covered areas.

The crown rays have been measured on each tree in the four expositions. For the whole plot the following results have been obtained :

crown projection (m²/ha)	degree of cover	double cover m²/ha	%	triple cover m²/ha	%	mean projection m²/ha	s
12.94	1.29	3.69	28.5	0.27	2.1	11.8	2.8

- 4.6 % of the area is not covered ;
- the sum of all crown projections amounts to 12.9 m²/ha; the degree of cover attains 1.29 ;
- 28.5 % of the area is twice covered ;
- a restricted area (2%) even has a triple cover already ;
- the average crown projection/tree amounts already to 11.8 m², which is 53 % larger than the theoretical growth area.

The total crown projection is taken up for 72.5 % by the trees of the upper layer and for 27.5 % by the ones of the intermediate layer. The average crown projection in the upper layer = 12.0 m² a,d 11.6 m² in the intermediate layer. The difference is very small.
This proves, once again, that the differentiation is not yet definitive and that changes in the social classes are still possible. The relation between upper and intermediate layer concerning crown projection is nearly the same as the one concerning stem number (71-29).
It is remarkable that the results of a 12 year old grey alder stand correspond quite strong to those of a 35 year old spruce stand, as is demonstrated by Burger (1939).

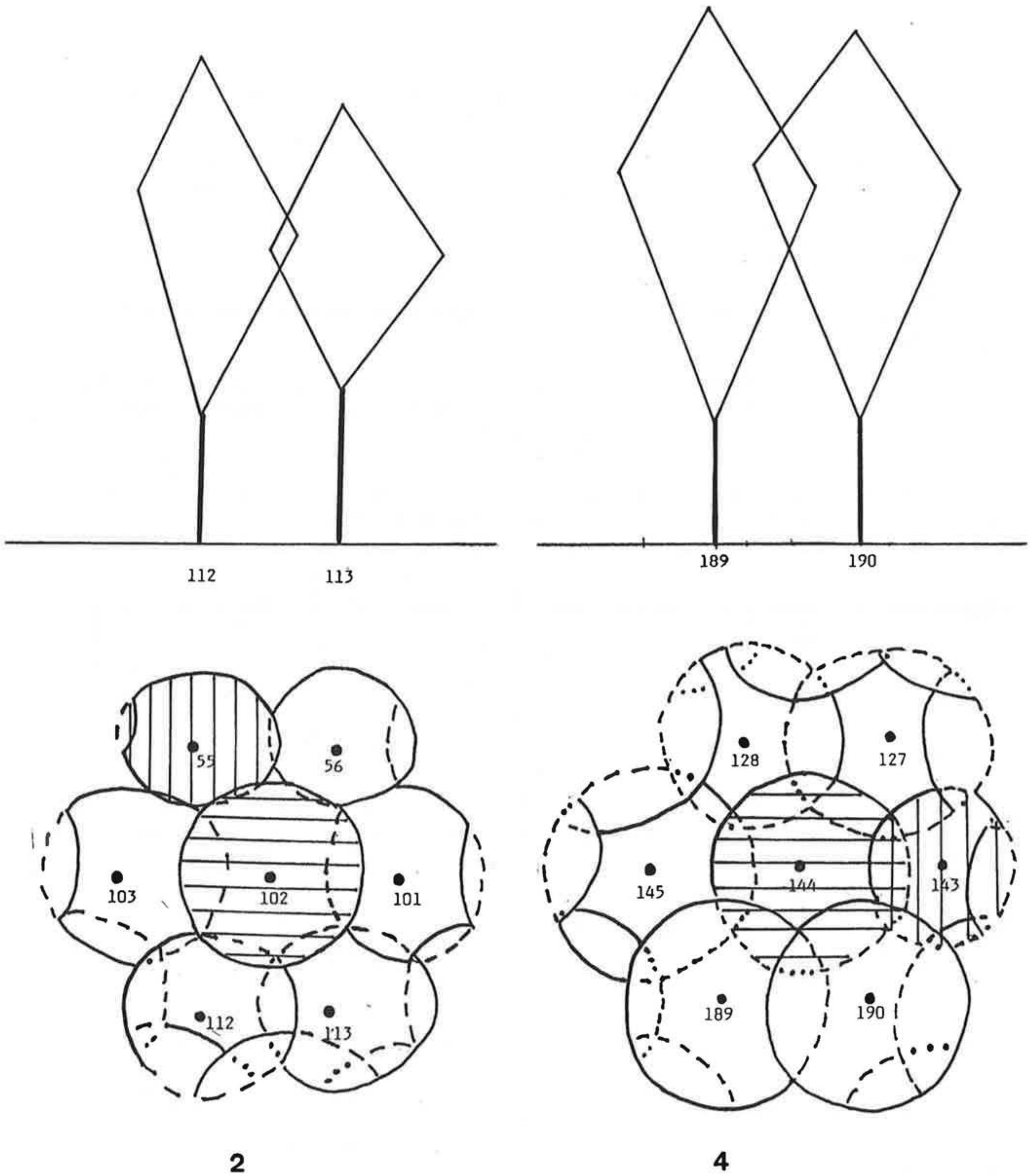

Fig.1. Vertical and horizontal projection of the cells 2 on 4

total	dominant	co-dominant	dominated	suppressed
12.158m^2	5042 m^2	4631 m^2	1143 m^2	1372 m^2
100 %	42 %	38 %	9 %	11 %
	80 %		20 %	

A thorough research into the horizontal structure has been carried out in the 10 tree cells (Tab. 2).

- The variation between the cells is relatively high : the largest cover accounts for 1.84 (cell 6), whereas the smallest one reaches only 1.5 (cell 2) ; the difference equals 60 %. Despite the generally large resemblances between the cells, there are also very clear differences already.
- Some 44 % of the soils is already twice or triple covered. A triple cover, however, is relatively scarce.
- The projection of the dominant tree is on average much lower than the one of the tree with maximal crown projection (12,4-15.0). A significant difference even exists between them ($t = 2.54^{+}$). Only in 3 out of 10 cells the crown projection of the dominant tree is the largest (2,3 and 8). In other cases the difference can become very important : up to 75 % in cell 7 (16.5 - 9.4 m^2). Dominance in height can not be compared to dominance in crown diameter.
- On average the crown projection of the dominant tree is significantly larger than the one of the dominated tree (12.4 - 9.8 m^2 ; $t = 4.4^{+++}$).
  The differences can be considerable (cell 8 : 14.5 - 6.1 m^2; 138 %). It is, however, remarkable that in four out of ten cells (6,7,9 and 10) the projection of the dominated tree is larger than the one of the dominant tree.

The situation is the most remarkable in cell 6

	h(m)	d(cm)	crown projection
dominant	13.1	10.8	13.8
dominated	10.2	13.8	19.9

The dominant tree is, of course, the highest one; yet it has a smaller stem and crown diameter. A certain analogy exists between the two latter parameters. The dominated tree has the greatest crown projection in cell 6.
It is also very remarkable that the dominant tree has the smallest crown projection in 3 cells (7, 9 and 10).

- Only in 4 cells is the crown projection of the dominated tree the smallest of all trees (1,2,4 and 8). On average the value of the dominated trees is even 19 % higher than the minimal crown projection.

- The difference between te largest and the smallest crown projection area is not always evident. It is clearly observable in 4 cells only 1,4,6 and 8) (see also fig. 1, cell 4).

Table 2 : Total crown projection and degree of cover per cell.

	crown projection m²	degree of cover	twice covered m²	twice covered %	three times covered m²	three times covered %	aver. projection m²	deviation	(1) max crown proj. m²	(2) min crown proj. m²	(3) proj. Dom. m²	(4) proj. dom. m²	(3)/(1)	(4)/(2)	(4)/(3)	(1)-(2) m²
1	85,2	1,56	39,2	46	7	8,2	12,2	3,4	14,9	5,0	11,9	5,0	0,79	1	0,42	9,9
2	63,1	1,15	26,7	42,3	3,1	4,9	9,1	2,0	12,4	6,3	12,4	6,3	1	1	0,50	5,8
3	79,8	1,46	34,1	42,7	4,9	6,1	11,4	2,0	14,0	8,8	14,0	9,1	1	1,03	0,65	5,2
4	95,5	1,75	48,2	50,5	8,4	8,8	13,6	2,6	15,6	8,2	14,1	8,2	0,90	1	0,58	7,4
5	95,2	1,74	42,4	44,5	7,8	8,2	13,6	2,2	16,3	10,6	16,0	11,6	0,98	1,09	0,72	5,7
6	100,9	1,84	52	52	10,9	11	16,4	3,6	19,9	8,8	13,8	19,9	0,69	2,26	1,44	11,1
7	84,0	1,53	44,5	53	7,0	8,3	12,0	2,6	16,5	9,4	9,4	9,5	0,56	1,01	1,01	7,1
8	72,6	1,33	34,7	47,8	3,1	4,2	10,4	4,8	14,5	6,1	14,5	6,1	1	1	0,42	8,4
9	75,4	1,38	22,5	29,8	1,3	1,7	10,8	2,0	14,1	8,3	8,3	10,1	0,58	1,21	1,21	5,8
10	77,8	1,42	22,3	28,6	1,5	1,9	11,1	0,9	12,5	9,9	9,9	12,5	0,79	1,26	1,26	2,6
aver. ± dev.	83,0	1,52	36,7	44	5,5	6,6	11,8	2,6	15,0 ± 2,09	7,8 ± 1,95	12,4 ± 2,51	9,8 ± 4,27	0,62	1,19	0,79	7,2

5.4. The determination of competition

In order to determine the competition between the trees, a lot of methodes have already been proposed (Bella, 1971; Arney, 1972 ; Barneaud-Brunet, 1973; and others ; see Delvaux, 1975; 1981).
These methods, however, are often ineffective as to indicate the tree with the greatest growth potential.
In this research we have tried to estimate the competition by assessing the free crown-projection area (FC). This is the part of the crown which is not covered by the adjacent trees and which is consequently free from direct radiation (Tab. 3).

1 = total FC per cell (m^2)
2 = average FC per cell (m^2)
3 = FC dominant tree (m^2)
4 = FC dominated tree (m^2)
5 = max. FC, in % of the crown area
6 = max FC in absolute figures
7 = min. FC in % of the crown area
8 = min. FC in absolute figures
9 = FC of the tree with max. crown projection area
10 = FC of the tree with min. crown projection area

The free crown projection area amounts on average to 62 m^2/tree

This means that on average 73.5 % of the crown receives a direct radiation. Taking into account the doubled and the triple cover, it means that a big part of the crown is little active in photosynthesis and growth. The crown part will, certainly with light demanding species such as grey alder, decline very quickly and die off, so that the branch free stem length can increase.

- The highest values of FC do not correspond to the greatest relative values per cell, e.g. :
  - cell 2 has a very low absolute value, yet a high relative value : 86 % of the crown area is free; this is the consequence of the low absolute value ;
  - cell 4 has a low relative value, viz. 64 % ; the trees in these cells have, for the greater part, the same sizes (with the exception of nr. 143 ; see fig. 1).
- The FC of the dominant tree is on average 29 % higher than the one of the dominated tree. Their relative values, however, are almost identical (69 - 67 %).
- The absolute values as well as the relative values of the FC of the dominant trees differ very strongly, ranging from 5,0 to 12,4 m^2 or from 51 to 100 %. The same tendency appears with the dominated trees, albeit for the greater part on a lower level (cell 6 again is an exception, with a very high FC value for the dominated tree ; moveover the high FC value is accompanied by a high relative value ; viz. 71 %).
  In almost each cell there is still a tree with a nearly complete F.C. Yet, this is only in one case the dominant tree (cell 2; fig. 1). Nevertheless this tree has in 7 out of 10 cells a higher FC value than the dominant one. Moreover the value is 40 % higher than with the dominant tree.

Table 3 : The free crown projection area per cell (m²)

	1	2	3	4	5	6	7	8	9	10
1	62,9	8,98	8,0	4,5	4,5	11,4	9,5	4,5	9,5	4,5
2	54,1	7,72	12,4	5,2	12,4	12,4	7,3	5,2	12,4	6,2
3	56,2	8,02	8,3	5,6	8,2	10,3	5,6	5,6	8,3	8,2
4	60,9	8,70	10,0	5,6	15,6	15,6	5,5	5,5	15,6	5,6
5	73,1	10,44	10,9	10,4	16,3	16,3	6,4	6,4	16,3	7,6
6	72,5	10,35	7,1	14,1	17,2	17,2	6,0	6,0	14,8	6,4
7	55,5	7,92	5,0	6,6	12,1	12,1	5,2	5,0	11,9	5,0
8	59,6	8,51	9,9	4,1	13,3	13,3	4,8	4,1	9,9	4,1
9	53,3	7,61	7,0	4,1	9,7	9,7	4,1	4,1	9,4	7,0
10	61,8	8,83	7,3	6,2	10,9	10,9	6,2	6,2	6,2	7,3
aver.	61,0	8,7	8	6,6	12,0	12,9	6,1	5,3	11,4	6,1

- The maximal FC value is on average 48 % higher than the mean FC value and 50 % higher than the FC value of the dominant tree. The variation between the maximal FC values is relatively large.

- In each cell trees with a low FC value are represented. The average value of the lowest FC amounts to hardly 47 %. It reaches a maximum of 71 % (cell 2) and a minimum of 35 % (cell 8).

- On average 75 % of the trees with maximal crown projection (cell 9) as well as the ones with minimal crown projection receive direct sun light.

Even though the FC of the tree with the maximal crown projection is, on average, very significantly different from the FC of the tree with the minimum crown projection ($t = 4.7^{+++}$), both trees have comparable growth possibilities. Therefore the assimilation potential in the former group is much larger than the one in the latter group. It is thus quite normal that the trees with the greatest FC value will have the most chances to dominate further.

This study confirms that the tominant trees, though they are naturally always the highest ones, in their present development phase do not always possess the biggest growth potential.

6. THE CROWN DEVELOPMENT

The crown is not a static part of the tree, but has every year an altered appearance. Mitscherlich (1970) stresses that the character of the tree crown is mainly determined by the following features : the development of terminal or lateral buds, the angle and bend of the branches and the crown density.
The crown shape is very important as a recuperation potential against external stresses. According to Möhring (1982) trees with a long crown, strong branches and short internodes are the most stable and resistant against snow pressure. Konopka (1975), on the other hand, shows that crown length and - in particular - the place of the centre of gravity of the tree are important growth characteristics for the determination of the resistance against external influences.

In order to characterise in this research the crown shape of grey alder the following parameter have been used : tree height, crown length, crown width, branch-free stem length, crown volume and crown mantle area (Burger, 1939 ; Badoux 1939 ; Van Miegroet, 1956 ; Assmann, 1961; Mitscherlich, 1970).
For the determination of the crown volume and the crown mantle area we started from the hypothesis that the light and the shadow crown are different in the four expositions. It was also accepted that each section of the crown should have a cone shape. Consequently the total crown exists of 8 parts, each of them equal to 1/4 of a cone.
In this way the following determinations were carried out for each crown section :

- volume = $1/4 \left(\frac{\pi}{3} h R^2 \right)$
- mantle area = $1/4 \left(\pi R \sqrt{R^2 + h^2} \right)$

The crown volume, and in particular the crown mantle area, are convenient parameters for the determination of the assimilation apparatus efficiency.

The crown development of the average 12 year old grey alder in the 10 cells can be described as follows :

- crown length : 8.53 ± 1.09 m, which is 80 % of the total crown length ;
- branch-free stem length : 2.17 m ± 0.96 m, which is 20 % of the total crown length ;
- crown width : 3.95 m ± 0.45 ;
- crown mantle area : 238.6 m^3 ± 48.3.

The branch-free stem length is still rather restricted. It is, however, expected to increase very soon.
The values of crown volume and crown mantle area amount to respectively 39.5 m^3/ha and 262.5 m^2/ha. These are very high values for a 12 year old stand. This can be explained by the fast growth, the good site and the large planting distance.

With the grey alder no significant differences were found between the light and the shadow crown :

	light crown	shadow crown
- crown length (m)	4.34 ± 1.14	4.26 ± 1.30
- crown volume (m^3)	18.29 ± 5.41	17.61 ± 6.47
- crown mantle area (m^2)	120.1 ± 24.6	118.7 ± 32.2

From the comparison between the light and shadow crown in the different exposition it is clear that both crown parts are just significantly different from the north side :

- the northern light crown is 11 % longer than the shadow crown (4.53 m ± 1.29 - 4.04 m ± 1.25 ; t = 2.35^{+})
- the volume of the northern light crown is 13 % larger than the one of the shadow crown (5.07 m^3 ± 2.02 - 4.42 m^3 ± 1.83 ; t = 2.51).

It is, however, not possible to indicate a direction, in which the crown develops most systematically.

As could be expected the measured crown parameters are mostly greater with the dominant tree as with the dominated one (Tab. 4). Only as far as the crown mantle area is concerned there are no significant differences. Moreover, the absolute differences hardly reach 8 %.

Table 4 : Crown development of dominant and dominated tree

	Dominant	dominated	t-value
Crown length (m)	9,38 ± 0,63 (79,5%)	8,01 ± 1,06 (82,7%)	3,60***
Branch-free st.(m)	2,44 ± 0,98 (20,6%)	1,67 ± 0,92 (17,2%)	2,66*
Crowh width (m)	3,95 + 0,38	3,49 + 0,6	2,19*
Crown volume (m^3)	37,14 ± 7,67	26,7 ± 11,32	2,4*
پوشش Crown mantle area (m^2)	246,19 ± 42,24	226,45 ± 49,66	1,1

The differences in crown length are the most reliable. For the stem length, on the contrary, the relative differences are the highest (26 %). This is for the greater part due to the inferior part of the crown of the dominated trees consisting of dead branches, which soon fall off.

7. SHAPE CHARACTERISTICS

The shape of a tree can be described by means of several parameters and indices, such as : degree of slenderness (h/d), crown index (Kl/D) and relative crown width (D/d). The degree of slenderness is a very good parameter to determine the tree stability (Pollanschutz, 1974) and to fix the suitable degree of thinning intensity (Leibundgut, 1966).

The crown index gives a good picture of the relation between crown mantle area and crown volume. An increasing crown index alters the relations in favour of the assimilation apparatus (Assmann, 1961).
The knowledge of the D/d value allows us to determine the average individual stand area

The average values amount to :

- h/d : 92.0 ± 12.25
- Kl/D : 212 ± 0.31
- D/d : 35.0 ± 4.43

The trees have a relative high d value, and in particular of D, which is due to the large planting distance. Taking into account the climatological circumstances, in particular the little snow danger and the general shape features, a thinning is not yet necessary.

These indices differ hardly with the two sub-groups, the dominant and the dominated trees. The differences are, however, statistically not significant, which is partly due to the relative large variation between the cells.

	dominants	dominated trees
- h/d	93.5 ± 14.0	101.2 ± 19.5
- Kl/D	2.23 ± 0.32	2.18 ± 0.28
- D/d	32/3 ± 3.07	36.3 ± 5.8

Certain correlations were examined both for the average tree as well as for the dominant and dominated ones. These correlations concerned morfological parameters on the one hand and tree height and stem diameter on the other hand (Tab. 5).

d = stem diameter on 1.30 m
h = total height (m)
D = crown diameter (m)
V_T = total crown volume (m^3)
V_L = volume of light crown (m^3)
V_S = volume of shadow crown (m^3)
O_T = total crown area (m^2)
O_L = crown area of light crown (m^2)
O_S = crown area of shadow crown (m^2)

With the average tree a number of significant relations could be demonstrated :

Table 5 : Relationships between several parameters and heigth or diameter (Y = a + b X = c X²)

X	Y	Average tree (cells) a	b	c	r	F	Dominant tree a	b	c	r	F	Dominated tree a	b	c	r	F
d	h	4,15	0,61	-0,02	0,54**	14,48**	5,6	1,02	-0,04	0,23	0,21	2,7	1,22	-0,05	0,76**	4,80*
d	D	0,43	0,46	-0,01	0,72*	37,09**	3,31	-4,50	7,23	0,74**	4,49*	3,9	-0,33	-0,02	0,91**	17,35**
h	D	-9,72	2,38	-0,10	0,50**	11,25**	-40,3	7,24	-0,29	0,42	0,78	5,85	-0,90	0,06	0,46	0,97
d	V_T	-18,18	6,53	-0,15	0,60**	19,29**	-57,6	14,27	-0,51	0,47	1,00	36,7	-1,27	0,52	0,89**	14,62**
h	V_T	-167,8	33,27	-1,31	0,50**	11,38**	-164,64	30,9	-1,16	0,31	0,38	2,57	-3,0	0,57	0,52	1,35
d	V_L	-16,55	4,56	-0,12	0,60**	19,11**	32,9	-2,58	0,12	0,32	0,41	22,93	-3,80	0,29	0,68*	3,02
h	V_L	-127,35	24,79	-1,03	0,51**	12,23**	-589,14	100,35	-4,11	0,64*	2,48	-191,2	40,15	-1,94	0,49	1,16
d	V_S	-1,35	1,90	-2,24	0,42**	7,43**	-91,9	17,05	-0,64	0,50	1,19	39,28	-7,59	0,48	0,87**	11,60**
h	V_S	-40,46	8,48	-0,28	0,35**	4,68*	422,18	-68,96	2,93	0,42	0,77	193,79	-43,15	2,51	0,48	1,05
d	0_T	149,7	9,31	-0,13	0,27*	2,67	249,31	-17,73	1,33	0,72*	3,92	501,7	-63,7	3,48	0,48	1,07
h	0_T	482,5	126,2	-5,44	0,25*	2,41	-7036,3	1209,07	-49,97	0,64*	2,43	302,52	-64,08	3,57	0,38	0,62
d	0_L	113,15	-1,84	0,20	0,22	1,80	86,23	-2,14	0,38	0,73*	3,97	408,5	-60,1	2,89	0,54	1,46
h	0_L	49,37	10,70	-0,37	0,09	0,32	-4461,8	751,7	-30,6	0,78**	5,46*	3160,5	-653,7	34,80	0,58	1,76
d	0_S	36,66	11,15	-0,33	0,21	1,67	163,08	-15,58	0,947	0,50	1,21	93,51	-3,64	0,59	0,68*	3,06
h	0_L	-531,5	115,4	-5,06	0,29*	3,29	-2591,4	459,9	-19,4	0,47	0,99	-36,5	13,17	0,26	0,51	1,26

1. Between stem diameter and tree height :

   $h = 4.15 + 0.91\ d - 0.02\ d^2$; $r = 0{,}54^{++}$; $F = 14.48^{++}$

   The stand height increases almost linearly with the diameter.

2. Between stem diameter and crown width :

   $D = 0{,}43 + 0{,}46\ d - 0.01\ d^2$; $r = 0.72^{++}$; $F = 37.09^{++}$

   The crown diameter increases linearly up to a stem diameter of 12 cm. Afterwards it decreases slightly, as a consequence of the increasing canopy closure.

3. Between the height and stem diameter :

   $D = 9.72 + 2.38\ h - 0.10\ h^2$; $r = 0.50^{++}$, $F = 11{,}25^{++}$

   The increase occurs also almost linearly.

4. Between stem diameter and crown volume (V_T; V_L ; V_S) :

   $V_T = -\ 18.18 + 6.53\ d - 0.15\ d^2$; $r = 0.60^{++}$; F : 19,29

   Almost a linear increase, though the increase of the volume decreases with an increasing diameter.

5. Between height and crown volume :

   $V_T = 167.8 + 33.27\ h - 1.31\ h^2$; $r = 0.50^{++}$; $F = 11.38^{++}$

   At the beginning the volume increases very strongly. The increase diminishes from a height of 10 to 11 m and is practically negligible from 12 to 13 m.

8. GENERAL CONCLUSIONS

On the experimental plot of grey alder in the Aelmoeseneie experimental forest at Gontrode (Belgium) the grey alder has, at an age of 12 years, the following average characteristics :

- height	11.6 m $\pm$ 0.9
- diameter	11.5 m $\pm$ 1.95
- basal area	107.5 m^2
- leaf mass	3.65 ton/ha dm
- degree of cover	1.29
- crown projection area	11.82 m^2 $\pm$ 2.78
- free crown projection area	8.71 m^2 $\pm$ 2.77

- crown length 8.5 m $\pm$ 1.1
- crown width 3.9 m $\pm$ 0.5
- branch-free stem length 2.2 m $\pm$ 1.0
- crown volume 35.9 m^3 $\pm$ 9.4
- crown mantle area 238.6 m^2 $\pm$ 48.3
- degree of slenderness h/d 92.0 $\pm$ 12.3
- crown index Kl/D 2.12 $\pm$ 0.31
- relative crown width D/d 35.0 $\pm$ 4.43

The grey alder has grown very well, which is not surprising given the richness of the site.
The crown closure occurred a couple of years ago, which started off the internal competition that will even increase in the future.

The differentiation is going on intensely. 30 % of the plants already belong to the intermediate storey. The present position of the dominant trees is, however, not yet consolidated. These trees are for several aspects inferior to elements of their immediate neighbourhood. This appears mainly from the crown projection and even more so from the free crown projection area.

The technique of cell formation is very convenient to follow the course of the differentiation on a small scale. Although on the one hand the cells resemble each other very much, on the other hand there are already important differences among them.

Finally, this research has also contributed to the formulation of some directives as to the treatment of artificial grey alders planted in a systematical pattern with large planting distances :

- in the youth a collective protection must be carried out, by controlling and dominating the impact of destructive forces ;
- the treatment must be individualised from the moment that the internal competition between the dominant trees becomes perceptible ;
- the treatment must have a positive character, directed at the group that has to be favoured.

This way, it is evident that the principles of forest treatment, formulated by Schädelin (1934) and Leibundgut (1966) are also suitable and useful for artificial forests with a plantation character.

LITERATURE

ASSMANN, E. (1961) Waldertragskunde. B.L.V. Verlagsgeschellschaft München, Bonn Wien.

BADOUX, E. (1939) De l'influence de divers modes et degrés d'éclaircie dans les hêtraies pures M.S.A.FV. 21 (1), (59-145).

BURGER, H. (1939) Der Kronenaufbau gleichalteriger Nadelholzbestände M.S.A.FV. 21 (1) (5-56).

BURGER, H. (1939) Baumkrone und Zuwachs in zwei heibsreifen Fichtenbeständen. M.S.A.FV. 21 (1) (147-176).

DELVAUX, J. (1964) Contribution à l'étude de l'éducation des peuplements.

DELVAUX, J. (1966) A propos de distribution de fréquence de diamètres et de hauteurs.
Essais préliminaires à l'étude du facteur compétition.
La compétition au niveau des classes sociales. Groenendaal-Hoeilaart Reeks B, nr. 32.

DELVAUX, J. (1974) Acquisition du rang social dans les jeunes plantations d'épicéa.
Groenendaal-Hoeilaart Reeks B nr. 39.

DELVAUX, J. (1981) Différentiation sociale. Schweiz. Z. Forstwes. 132 (9) (733-749).

DUVIGNEAUD, P. (1984). La synthèse écologique. Doin, Paris.

ELLENBERG, (1963) Vegetation Mitteleuropas mit dem Alpen. Stuttgart.

GRODZINSKA, K. (1971) Acidification of tree bark as a measure of air pollution in Southern Poland. Serie des sciences Biologiques 19, 189-195.

GRODZINSKI, W. (1970) Energy values of tree seeds eaten by small mammals. Oikos 21(1) (52-8).

KELEBERDA, I., DANKO, V.N. (1979) Biological methods of accelerating tree growth of plantation on industrial tips. ALOS. Vocoshilovgrad USSR. 4, 44-46.

KOSTER, R. (1971) Jeugdgroei van elzen. Populier 8 (4) 63-66.

LEIBUNDGUT, H. (1976) Studies on the mutuel influence of diff. tree species. Schweiz. Z. Forst 127(1) 776-771

MITSCHERLICH, (1970) Wald, Wachstum und Umwelt, Erster Band, Frankfurt am Main.

MOUILLEFERT, P. Traité des arbres et arbrisseaux (partie III) Paris p. 1129

PIZELLE, G. (1975 Seasonal variations in the nitrogenase activity of root nodules in A. glutinosa and A. incana and A. cordata.
Comptes Rendues Hebdomadaires des Séances de l'Académy des Sciences, France 281 (23) 1829-1832.

POLLANSCHUTZ, J. (1974) Erste ertragskundliche und wirtschaftliche Ergebnisse des Fichten Planzweterversuches. " Hauersteig ". 100 Jahre Forstliche Bundesversuchsanstalt Wien-Schönbrunn.

SCHAEDELIN, W. (1942) Die Auslesedurchforstung. Bern, Verlag Paul Haupt.

VAN DEN BURG, (1978) Groei van de zwarte els (Alnus glutinosa (L) in Nederland en de bodemvruchtbaarheid. Rijksinstituut voor onderzoek in de Bos- en Landschapsbouw, " De Dorschkamp " Wageningen nr. 143.

VAN DEN BURG en DE RUYTER, (1976) Enige gegevens over de groei en groeiplaatsen van de grauwe els " De Dorschkamp " Wageningen nr. 95.

VAN MIEGROET, M. (1956). Untersuchungen über den Einfluss der waldbaulichen Behandlungen und der Umweltfaktoren auf der Aufbau und der morphologischen Eigenschaften von Eschendickungen in schweizerischen Mittelland? M.S.A.FV. 32 (6) 229-370.

VAN MIEGROET, M. & LUST, N. (1972). Untersuchungen über die Entwicklungsdynamik von eingebutenen Aufforstungen von Korsikanischer Schwarzföhre. Sylva Gandavensis, 31, 1-17.

VAN MIEGROET, M. (1976) Van Bomen en Bossen. Gent, Story Scientia.

VERWEY, J.A. (1977) Onderzoek aan herkomsten en nakomelingschappen van els (A. glutinosa, A. incana en A. cordata) " De Dorschkamp " Wageningen, Uitvoerig verslag Band 15 nr. 1

VESELY, L. (1976) Die Kronenform der Buche als Einzeiger der Wachstumintensität des Baumes.