PRODUCTIVITY OF GREY ALDER (*ALNUS INCANA* (L.) MOENCH) STANDS

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Abstract

Area of grey alder stands is 190.6 thousand ha that is 6.8% of the total area of forests in Latvia with average volume 31.3 million m^3 4.9% of total yield is in the state forests, but 95.1% in the forests of other managers. Scientific literature affirms that grey alder is easy growing trees species. Its stands are quick - growing and wood has high heating capacity. Empirical data in 1 - 10 years old stands are collected from 25 m^2 sample plots, 15 in each stand. Data from older (11 - 30 years) stands are obtained by 6 - trees - sample - plot method, from 180 trees in each stand. Number of trees (y) in the stands diminishes with age (x) that is characterized by regression equation $y = 72534x^{-1.1488}$. The division of the number of trees in diameter classes characterizes distribution of trees diameters in stands and trees differentiation processes within the stands. At the age of 1 - 5 years, grey alder stems were in diameter classes under 2 cm but at the age 6 - 10 years - 2 and 4 cm. In 11 - 15 years old stands 89% of all the measured trees are included in four (4 - 10 cm) diameter classes. It pointed to growing differentiation of diameters of the trees. Starting from age 16 - 20 years, 76 - 89% of the trees were of four to five diameter classes (10 - 18 cm). The average standing volume in 11 and 15 year old stands was 110 m^3 ha^{-1} and it increased step by step to 180 m^3 ha^{-1} in the stands of age 26 - 30 years. The basal area in the age of 15 - 30 years varied between 20 - 26 m^2 ha^{-1}. The average diameter reached 15 cm in stands of 25 - 30 years.

Keywords: stand density, diameter, height, stem volume, stand basal area, yield.

Introduction

Grey alder historically has been considered as a 'forest weed' for a long period. It was paid not enough attention. Recently, more and more clear-cut areas are left for natural regeneration in Latvia. Grey alder occupies these areas very often. Therefore it is important to analyze regeneration processes of grey alder in clear - cut areas, evaluate different features of these stands, including productivity and aboveground biomass. We have to consider the use of grey alder in energy wood plantations, as well as utilization of its wood for boxes and furniture production.

White burning the wood, carbon dioxide is exhausted in the atmosphere in the same amount as the tree has been assimilating during its life span. It means that using wood for heating will do less harm to environment compared to fossil fuel. Ashes of wood can be used for soil fertilizing. During the last decade, demand for firewood is increasing.

Grey alder can grow in clay, loam, sand and silt soils. In fertile soils first productivity class stands trees can reach up to 25 m height and 30 cm diameter (Mūrnieks, 1950). Grey alder needs light, it does not stand shadow. At the same time it can well tolerate spring and autumn frosts and winter cold.

Grey alder can be considered as an easy - growing species because artiodactyls do not harm it in contrast to coniferous trees, asp and ash, that can be heavily browsed and destroyed. Generally, grey alder does not have dangerous pests and illnesses but it suffers from grey alder leaf - beetle *Agelastica alni* L. in years, when population density of this insect is high (Lange et al., 1978). There are also grey alder leaf-beetle *Melasoma aenea* L., grey alder curculio *Cryptorrhynchus lapathi* L., as well as other species which larva damage leaves or wood during supplementary feeding or hibernation (Plīse and Bičevskis, 2001). First signs of rot show off in the stems of grey alder just at the age of 21 - 30 years. Cutting grey alder at the age of 25 years, we can get timber of high quality almost without any decay. In mineral soils, there are more rot infected trees as in peat soils (Pīrāgs, 1962). In Voronez district, 60 - 80% of grey alder at age 50 - 60 years have rot caused by fungus *Fomes igniarius f. alni* Bond. mainly in the middle and foot of the stem destroying cellulose and lignin (Vaņins, 1956). Fungus *Taphrina epiphylla* (Sadeb) Sacc. can cause disease for the branches of grey alder (Vimba, 2005).

Grey alder has remarkable propagation abilities, especially by stems and root sprouts. Light seeds of grey alder are produced each year and wind disseminates them beyond borders of forest (Mūrnieks, 1950). Adjacent areas of grey alder stands are sown up to 50 meters from the borders, but wind can bring seeds even 100 - 150 meters far. Grey alder regenerates by roots sprouts very successfully. To get strong sprouts, grey alder, alike other species of deciduous trees, has to be cut in late autumn or winter when nutrients from aboveground part of the trees have moved to roots (Mangalis, 2004).

Grey alder is one of fast growing species because its reaches culmination of annual increment very early. Productivity class indicates potential fertility of soil in definite conditions. Productivity of the stand is characterized by stand yield per unit of area and time. Average increase of main yield of the stand culminates at age 16 - 18 years and then decreases stepwise. Stands of first productivity class have the highest average annual increment: 11.5 m^3 but to those of second productivity class - 9.0 m^3, and to those of third - 6.5 m^3 per a hectare in a year. Grey alder exceed other species of trees as wood producer. The most advantageous cutting age of grey alder is 17 - 20 years. The density of the cutting age stands is approximately 7 - 8 and volume - about 135 m^3 ha^{-1} (Mūrnieks, 1950).

Ozols and Hibners (1923) have pointed out that the cutting age of grey alder at riverhead of Lielupe is 15 years (Brants, 1929). In comparison with the other tree species, the short cycle of grey alder stands allows to obtain 2.5 - 3 times more wood from the same area during 100 years (Katkevičs and Lukašunas, 1986).

In few compartments experimental thinning has been done, when average height of trees in stand were 2 - 4 m, reducing stand density up to 1.5 - 2.0 thousand trees ha^{-1}. The result was excellent increase of increment (Zālītis, 2005).

In the light of developing usage of renewable resources in the energetic, mainly in heating, grey alder is considered as prospective trees species for burning trees biomass production. Growing grey alder for energy - wood is included in the forest energetic programs of Sweden and Austria (Daugavietis, 2006).

Successful regeneration, especially by sprouts, fast and rich wood production ability have given a motivation to form a typical group of coppice in some regions of Latvia, especially in those with sparse forest cover.

Grey alder covers 190.6 thousand ha or 6.8% of all forest area of Latvia, with total yields 31.3 million m^3 where 4.9% of total yield of grey alder stands are owned by the state and 95.1% - by the other managers (Valsts Meža dienests, 2006).

Mass heating capacity for pine is 20.59 MJ kg^{-1}, for spruce - 20.31 MJ kg^{-1}, for grey alder - 20.05 MJ kg^{-1} (Dolacis and Hrols, 1999). Judging by the heating capacity, wood of grey alder is worthy to be utilized as firewood and it could be used not only in stoves of individual houses but also in suitable central heating boilers of flat blocks. Production of woodchips is the most prospective variant of grey alder stands usage.

Naturally grey alder has short life and at the age of 30 it stops to give good increment. We can get 180 - 310 m^3 ha^{-1} of wood from a 30 years old stand in good growing conditions. This wood has high enough heating capacity. Considering the high productivity of grey alder stands, their wood heating capacity and diminished amount of hazardous emissions, grey alder has perspective in firewood production. In order to be able to make economic calculations about utilization of grey alder woodchips for heating, we have to evaluate productivity of stands of these species. The most significant work about grey alder productivity has been made half a century ago by Mūrnieks (1963).

In current investigation study of structure of grey alder stands are made, which is the aspect not included in the analysis by Mūrnieks, 1963.

The aim of the research: estimate productivity of the stands of grey alder *Alnus incana* (L.) Moench. at different age.

The tasks of the research:

1. to study structure of grey alder stands:
    - to analyze the pattern of changes of number of trees in stands of grey alder;
    - to obtain information on division of the trees in diameter classes;
2. to analyze indices of inventory of grey alder stands.

Materials and Methods

Forty - seven grey alder stands of different age classes, productivity classes and density are used to study the number of trees, different tree parameters and stand productivity in Jelgava, Bauska, Ogre, Aizkraukle, Jekabpils and Valmiera regions. Unthinned stands, usually coppice, are selected for the research. The obtained data are grouped by age classes with an interval - five years (Table 1). Data of the research at the stands of I and II age classes (1 - 10 years old) are obtained by dividing them into 15 round or rectangular sample plots with area of 25 m^2. They are located diagonally or in transactions. The measured trees

Table 1

Number of the researched stands by age class

Age class	I	II	III	IV	V	VI
Age (years)	1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30
Number of stands	3	4	11	13	7	9

are grouped by diameter classes of 2 cm. Trees with breast - high diameter up to 0.9 cm are included in nil diameter class. Heights of 15 - 20 trees are measured for calculation of the height curve of the stand.

Grey alder stands at age 11 - 30 years (age classes III - IV) are investigated using 6 - trees - sample plot method (Kramer and Akča, 1982). In each stand, 30 sample plots by 6 trees are arranged, so in total 180 trees are measured. The sample plots are arranged in even distance by the systematic principle, using transects by H.Kramer and A.Akča method (1982) (Fig. 1). In each sample plot, distance from its center to the middle of its nearest sixth tree is set, diameters and height of six trees are measured and their Kraft class is determined. First three Kraft classes are the dominant stand but the other two - suppressed stand (Skudra and Dreimanis, 1993).

For calculation of the number of trees per ha the following formulas have been used:

$$L_6 = 0.785 \cdot (2 \cdot R_6)^2 \quad (1)$$

$$N_n = \frac{5.5 \cdot 10000}{L_6} \quad (2)$$

$$Nvid. = \frac{\sum_1^n N_n}{n} \quad (3)$$

Where L_6 - area of the sample plot, m^2; R_6 - radius of the sample plot to the centre of the nearest sixth tree, m; N_n- number of trees per ha; $Nvid.$ - average number of trees per ha; n - number of the sample plots.

Inventory indices of grey alder are calculated using forest inventory methods as described in publications by Liepa, 1996, Sarma, 1949 and Kramer and Akča, 1982.

For data analysis (descriptive statistics, Hi - square, correlation) MS EXCEL is used. Distribution of the number of trees into diameter classes and their correspondence to normal distribution is tested by Hi - square method (Liepa, 1974; Arhipova and Bāliņa, 2003).

Results and Discussion

Structure of grey alder stands

The horizontal structure of the stands is characterized by a number of trees per hectare. It depends on age, stand density and on distribution of the trees in the stands. Information on distribution of the trees into diameter classes in different age classes is obtained and analyzed.

Vertical structure of grey alder stands characterizes the level of differentiation of the trees in stand at different ages that can be expressed as the number of dominant versus suppressed trees.

Number of trees in the grey alder stands

High number of trees haves been found in grey alder stands, that has an influence on tree crowns, in particular to their assimilation surface

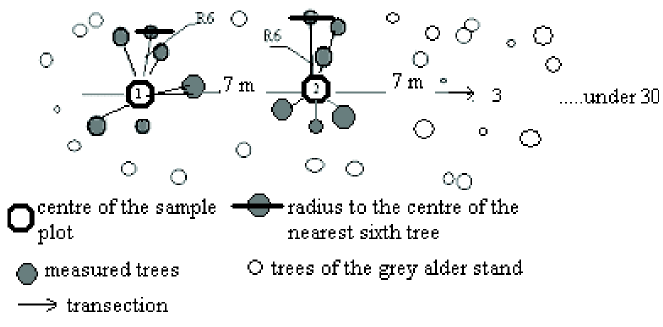

Figure 1. Six- trees- sample- plot method used in inventory of grey alder stands (Kramer and Akča, 1982).

through that also to wood increment of each particular tree. From the view of wood gathering, stands with fewer, bigger dimension trees are more advantageous than stands with large number of small trees. Solitary trees differ from trees growing in closed stands by their appearance and also biologically. Trees growing in stands are influenced by interactions and dependences that cause differentiation and other dynamic processes. The greatest variation of the trees is observed in each stand of grey alder: by height, diameter forms of crowns, their width, length and by quality of stems. Great differentiation of the trees is found: in the grey alder stands, some trees are developed very well but others are left behind, remaining small and form suppressed stand. In the stands of grey alder of III age class (11 - 15 years old), 15% of trees are suppressed, in stands of IV age class (16 - 20 years old) – 15%, in stands of V age class (21 - 25 years old) - 18% and in the stands of the VI age class (26 - 30 years old) - 16%.

In the grey alder stands at the age of 1 - 5 years, number of trees varies from 5240 to 21520 with average number 18480; at the age between 6 and 10 years - from 7120 to 10720 with average number 8680; at the age of 11 - 15 years - from 2130 to 6600 with average number 4270; between 16 and 20 years - from 1720 to 6200 with average number 2960; at the age of 21 - 25 years - from 1280 to 2180 with average number 1690 and between 26 - 30 years - from 910 to 2200 with average number 1510 (Fig. 2).

Distribution of trees in area is uneven also within one stand. It can be seen by coefficient of variation of the number of trees per plot, ranging from 5 - 64.5%. It means that places of high density are present in a stand and will have an influence on every individual tree and stand characteristics (parameters). The number of trees varies the most in new stands. With ageing of the stand, value of the coefficient of variation stabilizes. The analysis of a number of trees reveals, that using 6 - trees - sample - plot method representation error is - ± 122...2590 trees per hectare but the corresponding standard deviation - ± 481...4487. J.Ozols and E.Hibners (1923) and P.Mūrnieks (1963), have investigated a number of trees in grey alder stands in Latvia. Compared to tables by P.Mūrnieks, it was stated that the number of trees in first four age classes (1 – 20 years) is the closest to 2nd productivity class but those of age classes between 21 and 30 years - to 1st productivity class.

About 6.7% of the inspected trees up to the age of 30 have stem rot up to 1 meter height. The obtained data confirm the research by Dz.Pīrāgs, (1962) that it is possible to get an absolutely healthy grey alder wood until the age of 25 years.

The number of the trees (y) in grey alder stands minimizes with age (x). It can be described by the regression equation $y = 72534x^{-1.1488}$ (Fig. 3.).

For wood harvesting, stands with fewer trees and greater dimensions are more advantageous. In the researched stands, it was stated that in the stands of age of 13 - 18 years, the number of trees varied in interval 2 to 7 thousand trees per hectare.

Distribution of the number of trees by diameter classes

One of the most important stand characteristics is the distribution of trees in diameter classes. From this information conclusions about differentiation processes in stand can be drawn. A great number of diameter classes indicate heavy differentiation of trees and uneven allocation of trees within the stand when one part of the trees has insufficient access to resources for growth while the other - use them in full amount.

Dealing with the stands of first and second age classes (1 - 10 years), we cannot speak of correspondence of distribution to normal distribution by diameter classes because most of the trees are included in two diameter classes

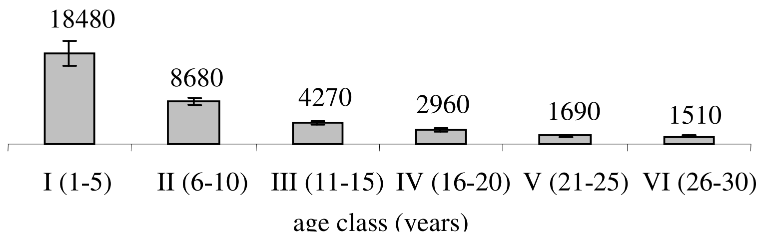

Figure 2. Average number of trees in grey alder stands in different age classes.

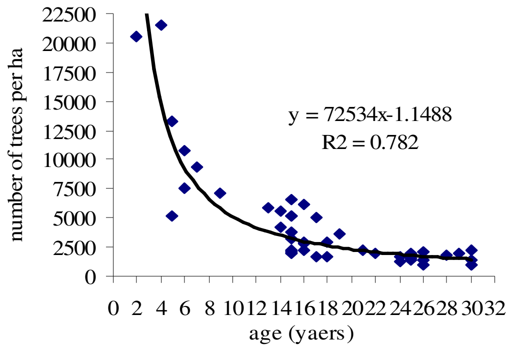

Figure 3. Changes in number of grey alder trees depending on age ($p < 0.05$).

with similar number of observations. In the rest of surveyed stands of different age classes, conformity to the normal distribution is seen not in all cases, in spite of small graphic differences between empirical and theoretical distribution. In age classes 4 – 6 (16 - 30 years) stands, after grouping all trees of one age class in one sample set, we have found that the diameter distribution of trees does not correspond to the normal distribution. The calculated value of Hi - square is more than the theoretical (level of significance $\alpha = 0.05$). Left asymmetry of the distribution of number of trees is observed in the fifth and sixth age classes (age 21 - 30 years). High number of thin trees in the stand can be explained by differentiation (as a result of competition among trees for resources) and lack of thinnings.

In 11 - 15 years old stands 89% of all the measured trees are included in four (4 - 10 cm) diameter classes. In 16 - 20 years old stands 89% of the trees are in diameter classes 6 - 12 cm, but in 21-25 years old stands - 76% of the trees compound four (10 - 16 cm) diameter classes. Similar division of the trees diameter classes is stated in 26 - 30 years old stands where 79% of the trees are in five (10 - 18 cm) diameter classes. Percentage of the number of trees in different diameter classes is shown in Table 2.

It is stated that the number of trees with diameter 22 cm and larger is a little bit over 3% in the stands of fifth and sixth age class. With ageing

Table 2

Distribution of the trees (%) in diameter classes depending on the age of the stand

Diameter class, cm	Age class interval, years					
	1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30
0	45.1	0.4	0.2	-	-	-
2	42.3	49.2	5.5	0.2	-	-
4	9.1	43.6	18.5	5.5	0.2	0.2
6	3.5	6.3	31.5	18.5	2.4	0.7
8	-	0.5	26.6	31.5	8.2	5.6
10	-	-	12.0	26.6	19.8	10.4
12	-	-	3.9	12.0	20.6	18.0
14	-	-	1.3	3.9	22.5	20.6
16	-	-	0.4	1.3	13.3	16.3
18	-	-	0.1	0.4	8.0	13.5
20	-	-	-	0.1	3.4	8.5
22	-	-	-	-	1.0	3.8
24	-	-	-	-	0.5	1.3
26	-	-	-	-	0.1	0.6
28	-	-	-	-	-	0.3
30	-	-	-	-	-	0.2

Table 3

Inventory indices of grey alder stands

Age classes (years)	Dg, cm	Hg, m	V, m^3	M, m^3 ha^{-1}	G, m^2 ha^{-1}	Density of the stand
III (11-15)	7.9 ± 0.26	11.1 ± 0.40	0.0271 ± 0.00199	110 ± 11.9	20 ± 2.0	10 ± 1.0
IV (16-20)	10.2 ± 0.60	13.3 ± 0.59	0.0547 ± 0.00892	140 ± 19.0	23 ± 2.6	10 ± 1.2
V (21-25)	13.6 ± 0.69	17.1 ± 0.77	0.1028 ± 0.01395	170 ± 19.4	24 ± 1.8	9 ± 0.8
VI (26-30)	15.0 ± 0.79	18.4 ± 0.70	0.1274 ± 0.01608	180 ± 20.9	26 ± 2.6	9 ± 0.8

of the stand, it is observed that differentiation level of the trees increases and they have wider range of diameter classes. At the same time only negligible number of trees is in smallest and largest classes.

Grey alder stand characteristics

Grey alder cutting age, mentioned most frequently in literature, is 15 years (Ozols, 1923, Brants, 1929, Mūrnieks, 1950, Katkevičs, 1986). That is why the stand characteristics of grey alder is analyzed starting from the third age class (Table 3).

The following symbols are used in the Table 3: Dg - average diameter, Hg- average height, V – average stem volume, G – stand basal area, M - average standing volume

Average diameter 7.9 cm (variation interval 6.4 - 9.0 cm) is found in eleven stands of the third age class. It reaches 15 cm and the dimensions suitable for wood processing in the 6^{th} age class. The average height has reached 11.1 m (variation interval 18.6 - 13.0 m). Average volume of stem has increased 4.7 times but the stand yield as well as average height of trees in stand - 1.6 times. Relatively small change in the stand yield, if compared to remarkable change of the volume of stem, is connected with constant and fast diminishing of number of trees per ha from 4300 to 1500. The majority of out competed trees decay in stand and are not utilized but they have a great ecological value.

During 10 - year period (from age classes 3 to 5) stand yield is increasing by 60 m^3 ha^{-1}, but during the last five years only 10 m^3 ha^{-1}. It is concluded that growing grey alder over 25 years will cause the loss of yield and could be recommended only if the aim is to get bigger dimension stems for processing in sawmills. During 15 years (from third to sixth age class) stands basal area has increased 1.3 times. The average density of the stands is high (9 - 10) in all the age classes. It indicates stands of great density and the connected differentiation processes accompanied by natural decrease in the number of trees. The diameter of the trees at the same age is bigger in stands of lower density. Thinnings in stands would decrease the number of suppressed and dying trees and increase dimensions of the trees in final felling. Such stands would produce wood suitable for different end - uses: firewood, boxes, furniture production.

The thinning of stands will be further investigated.

Comparing 40 surveyed stands at the age of 11 - 30 years with tables by P.Mūrnieks (1963), it is stated that in eleven cases stand yield is less than in full density stands of the third productivity class, in eighteen - corresponds to stand yield of the third productivity class, in four - is equal to growing stocks of the second productivity class, in five - to the first productivity class and in two - stand yield is higher than indices of the first productivity class.

Conclusions

1. The fastest decrease of number of the trees in natural grey alder stands is up to the age of 10 years.
2. In 11 - 30 years old stands 76 - 89% of trees are in 4 - 5 diameter classes between 4 - 18 cm.
3. At the age of 26-30 years the average diameter of trees reaches 15 cm, but trees with diameter 22 cm or more does not exceed 3% total number.
4. The average growing stock of grey alder reaches 170 m^3 ha^{-1} at the age of 21 - 25 years.
5. Growing grey alder over 25 years with high stand density is connected with decrease of the increment growing stock.
6. From the total amount of trees 15 – 18% is suppressed in grey alder stands at the age of 11 - 30 years.

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