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# The ancestral conservative tillage of silver fir in the 'Tisovik' reserve of the Białowieża Primeval Forest

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**Abstract.** The 'Tisovik'reserve, located in the Belarusian part of the Białowieża Forest, holds an isolated relic stand of silver fir, situated 120 km to the north-east of the main forest. In order to preserve this relic fir stand, a ancestral conservative tillage consisting of the Jd 92 trial (plot I) and the Jd 94 trial (plots II and III) was established between 1992 and 1994 in the Polish part of the Białowieża Forest on the territory of the Hajnówka Forest District. The growth and development of the progeny of 20 firs were characterized by means of long-term observations made in these trials. In 2000 (at the age of 18), the firs in the Jd 92 trial (plot I) reached an average height of 394.86 cm with a mean diameter at breast height of 42.42 mm and the average rate of survival amounted to 75%. In the Jd 94 trial, the rate of fir survival on plot II was 70% (at the age of 15) with an average height of 277.08 cm and a diameter at breast height of 36.62 mm, while on plot III only 50 trees with an average height of 198.6 cm and a diameter at breast height of 24.49 mm survived. The results of this study show that the fir progeny in the 'Tisovik' reserve is of high breeding value. Therefore, the silver fir seed stock of the 'Tisovik' reserve is suitable for the establishment of new plantations in the Polish part of the Białowieża Forest and the Mazury-Podlasie Region.

**Keywords:** *Abies alba* Mill., progeny test, Białowieża Primeval Forest, Poland

## 1. Introduction

The 'Tisovik' reserve located in the Belarusian part of the Białowieża forest holds an isolated relic stand of silver fir, located 120 km north-east of the main forest. From 1992–1994, an ancestral conservative tillage was established in the Polish part of the Białowieża primeval forest, consisting of the trials: Jd 92 (plot I) located in comp. 416 Ag and Jd 94 (plots II and III) in comp. 416 Cf in the territory of the Hajnówka forest district. The aim of the experiment was to:

1) preserve the gene pool of this relic fir population,
2) evaluate its breeding value,
3) establish a seed source in the future.

## 2. Methods

The planting material consisted of the fir seedlings raised from the seeds of 11 firs (Jd 92) collected in October 1992 and from 20 firs (Jd 94) collected in autumn 1994 in the 'Tisovik' reserve.

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### Site preparation

A fragment of the fresh deciduous forest habitat (Lśw) with three cut patches was selected for the establishment of the plantation, comprising the adjacent forest compartments 416 Ag and 416 Cf in the territory of the Wilczy Jar forest subdistrict, the Hajnówka forest district, the Białowieża primeval forest. The geographical position of the stand is determined by the coordinates: E 23°39'16'', N 52°42'30''.

The soils are Eutric Cambisols and Epdystric Cambisols on loamy sands. Birch with an average age of 78 years (40%), oak with an average age of 55 years (30%) and hornbeam with an average age of 35 years (20%) dominate the species composition of the stand. The ancestral conservative tillage consists of three sites - 0.22 ha plots, separated by 30 m-wide tree belts (Fig. 1). The whole area of the ancestral conservative tillage comprising the Jd 92 and Jd 94 trials was fenced.

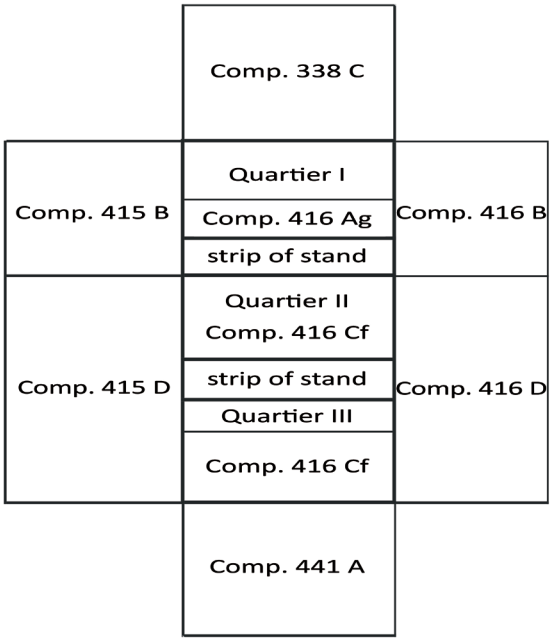



**Figure 1.** The sketch of the distribution of quarters on the fir-tillage in the Forest District Hajnówka

## Fir planting

**Jd 92**. 4-year-old fir seedlings were planted in October 1996 at a spacing of 1.3 × 1.0 m on plot I, comp. 416 Ag. Firs from each tillage were planted in a separate row, the beginning and the end of which was marked with a pole with the tillage number on it. Because of the uneven number of seedlings, the individual families were planted in one or more rows.

**Jd 94.** The well-developed 3-year-old fir seedlings were planted in autumn 1998 in two replications (plots II and III) in comp. 416 Cf, the Hajnówka forest district.

## Measurements and the assessment of performance of fir seedlings in the plantation

Field studies were conducted in the years 2000, 2004, 2006 and 2010. The following measurements were made:

a) tree height (cm) with an accuracy of max. 0.5 cm,

b) tree diameter at breast height (mm) with an accuracy of max. 0.1 mm,

c) root collar diameter (mm) with an accuracy of max. 0.1 mm.

The axial growth of firs was assessed according to the stem quality index:

1 – a properly developed stem,

2 – a leader growing out of the lateral shoot,

3 – a stem with a multi-shoot top (without a leader).

Fir survival (the percentage of live fir seedlings) in individual families was determined in a given measurement year.

Frost damage to fir seedlings was assessed only in 2000, in the Jd 92 trial according to the following scale:

1 – frozen leader,

2 – frozen lateral shoots,

3 – frozen whole plant.

The percentage of each type of frost damage was given for each tillage.

## Statistical analysis

The overall mean values for individual traits were calculated. On the basis of the overall means and the standard deviation, as well as on the basis of the means for individual families, the standardisation of traits of silver fir was performed in both trials and for each measurement year.

The standardisation of measurements of individual traits was performed according to the formula:

$$z_n = \frac{x_i - \bar{x}}{S} \quad [1]$$

where:

$x_i$ – *i* th measurement result (observed value of the variable),

$\bar{x}$ – arithmetic mean of the measurement in the analysed set,

S – standard deviation of the measurement in the analysed set,

$z_n$ – value of the *n*th trait in standardised units,

On the basis of the standardised data, the breeding value index for individual families ($H_R$) was calculated according to the following formula:

$$H_R = \frac{z_1 + z_2 + ..... + z_n}{n} \quad [2]$$

where:

$H_R$ – breeding value index of the tillage,

$z_{1\cdots n}$ –the value of the *n* trait in standardised units,

*n* – number of traits.

The calculated breeding value indices allow comparing individual tillages.

The statistical analysis of the measured and evaluated traits of silver fir was performed using the statistical package 'R' (R Development Core Team 2011) and the programme ASReml (Gilmour *et al*. 2009). The measured and evaluated traits were analysed according to the following formula:

$$Trait\ value = \mu + R_n + E_n \quad [3]$$

$\mu$ – overall mean for the trial,

$R_n$ – random effect of the *n* tillage,

$E_n$ – error of the trial.

Assuming a random design of the experiment, the heritability for the families from open pollination was calculated according to Wright's formulas (1976):

***Family heritability*:**

$$h_R^2 = \frac{\sigma_R^2}{(\frac{\sigma_E^2}{n} + \sigma_R^2)} \quad [4]$$

***Individual heritability*:**

$$h_i^2 = \frac{4\sigma_R^2}{\sigma_R^2 + \sigma_E^2} \quad [5]$$

where:

$n$ – mean number of trees in the tillage,

$\sigma_E^2$ – component of the error variance,

$\sigma_R^2$ – component of the tillage variance.

The error of heritability was calculated using the AsReml programme (Gilmour *et al.* 2009) according to the following formula:

$$SEh^2 = (\frac{\sigma_n^2}{\sigma_d^2})^2 (\frac{Var(\sigma_n^2)}{\sigma_n^4} + \frac{Var(\sigma_d^2)}{\sigma_d^4} - \frac{2Cov(\sigma_n^2 \sigma_d^2)}{\sigma_n^2 \sigma_d^2}) \quad [6]$$

where: $\sigma_n^2$ and $\sigma_d^2$ indicate, respectively, the variance of the numerator and denominator in the formula of heritability.

## 3. Results

### Survival and ground frost damage

The survival of seedlings in 2000 was found to be relatively high. The average percentage of live firs in individual ancestral conservative tillage ranged from 97.5% (8-year-old firs) to 98.8% (5-year-old firs; Table 1).

The year 2004 saw a marked decrease in the survival of fir, both within and between individual families. In the Jd 92 trial (plot I), the survival of seedlings was 81.1%, while in the Jd 94 trial, the average survival of seedlings was 59.8% (67.5% on plot II, 52.1% on plot III; Table 1).

The observations carried out in 2006 and 2010 showed that in the Jd 92 and the Jd 94 trial, only 3.4 and 3%, respectively, of the plants had not survived. It was also noted that some families showed a high survival rate. This group included the families: No. 1 (plot I and III), No. 16 (plot I), and Nos. 7 and 21 (plot II) (Table. 1).

Individual plants or groups of plants in the central part of the area were damaged by frost. There was no clear relationship between the height of the plants and the level of frost damage (Table 2). Differences between the families were very clear: firs of the families: 4 (31%), 5 (23%) and 17 (22%) proved to be the most susceptible to frost, while the families: 1, 16 and 21 (Table. 2) revealed the highest frost resistance.

### Axial growth

Before 2006, a marked increase in the percentage of fir seedlings with a well-developed leader was recorded. The year 2010 saw an increase in the percentage of firs with a secondary leader, especially on plot III (Table 3). The response of individual fir families to the factors causing disturbances in the axial growth of plants (stem deformation) varied considerably.

### Height and diameter growth

The results of the measurements of height growth traits of firs in the years 2000, 2004, 2006 and 2010 are given in Tables 4, 5 and 6. The studied population of silver fir featured a high variation in the growth traits within individual families, which was the result of tree freezing. The differences in the mean values for families and the overall means for the examined population on plots were less clear. The difference in the growth rate of firs on individual plots was another characteristic of the ancestral conservative tillage. Despite the relatively similar habitat conditions in the whole plantation area, the best growth conditions for firs were in the Jd 94 trial on plot II, while the poorest - on plot III (Tables 5 and 6).

### Jd 92 trial

The average height of firs (8-year-old; 4 years in the plantation) in 2000 was 54.46 cm with small differences between families. On the other hand, the differences in the height of the trees within individual families were very large (Table. 4). The correlation between the height and root collar diameter of the plants was explicit. Firs from the families: Nos. 15, 17 and 2 proved to be the best in terms of the breeding value, while firs from the tillage No. 4 were clearly the worst (Fig. 2).

In 2004, the overall mean height of the firs (12 years of age) was 120.26 cm, and the average height for the families ranged from 94 to 143 cm (Table 4). The differences in the height within individual families were very large.

In 2004, the overall mean diameter of the firs measured at the root collar was 24.38 mm, and the means for the families ranged from 17.24 to 30.33 mm (Table 4). The differences between individuals within families were very large (Table 4).

In 2006, the average height of the firs was larger by approximately 81 cm compared to the previous measurements and amounted to 201.13 cm on average. The mean for the families ranged from 163.60 to 227.33 cm (Table 4, Fig. 3).

In terms of the breeding quality ($H_R$), the ordering of families was similar as in 2004. (Fig. 2).

The 2010 measurements showed a 193-cm increase on average in the height of the firs beginning from 2006, which for the fir population on plot I amounted to 394.86 cm. The average height for the families ranged from 301.89 to 463.28 cm. The differences in the height of the trees within individual families were still large (Table 4).

The average annual height growth of the firs in the period 2000–2004 was about 9 cm per year; in the period 2005–2006 – about 40 cm; and in the period 2007–2010 - about

**Table 1.** Surviving (%) of the Silver fir in the tillage Jd92 (Quartier I) and the tillage Jd94 (Quartier II and III) in the compartment 416 Ag / 416 Cf the Hajnówka Forest District

| No. | Quartier I | | | | | | Quartier II | | | | | | Quartier III | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | family No. | planted X 1996 | % of living seedlings | | | | family No. | planted X 1998 | % of living seedlings | | | | family No. | planted X 1998 | % of living seedlings | | | |
| | | | X 2000 | IX 2004 | V 2006 | X 2010 | | | X 2000 | IX 2004 | V 2006 | X 2010 | | | X 2000 | IX 2004 | V 2006 | X 2010 |
| 1 | 1 | 3 | 100 | 100 | 100 | 100 | 1 | 24 | 100 | 63 | 63 | 63 | 1 | 9 | 100 | 100 | 100 | 100 |
| 2 | 2 | 336 | 97 | 75 | 74 | 71 | 2 | 59 | 98 | 86 | 86 | 47 | 2 | 24 | 88 | 25 | 25 | 25 |
| 3 | 3 | 75 | 74 | 54 | 51 | 49 | 3 | 93 | 100 | 88 | 88 | 84 | | | | | | |
| 4 | 4 | 70 | 100 | 84 | 84 | 84 | 4 | 134 | 90 | 84 | 84 | 84 | 4 | 124 | 98 | 68 | 68 | 68 |
| 5 | 5 | 258 | 90 | 65 | 65 | 60 | 5 | 96 | 100 | 82 | 82 | 82 | 5 | 50 | 96 | 30 | 20 | 20 |
| 6 | | | | | | | 6 | 50 | 100 | 86 | 82 | 76 | 6 | 50 | 94 | 52 | 52 | 52 |
| 7 | | | | | | | 7 | 23 | 100 | 100 | 100 | 100 | 7 | 100 | 99 | 50 | 50 | 50 |
| 8 | | | | | | | 8 | 104 | 104 | 81 | 73 | 73 | 8 | 125 | 97 | 53 | 53 | 53 |
| 9 | | | | | | | 9 | 50 | 50 | 36 | 35 | 35 | 9 | 109 | 88 | 49 | 49 | 49 |
| 10 | 11 | 66 | 100 | 92 | 88 | 79 | 11 | 48 | 48 | 39 | 39 | 38 | 11 | 124 | 98 | 55 | 55 | 55 |
| 11 | 12 | 38 | 97 | 79 | 71 | 53 | 12 | 47 | 47 | 36 | 36 | 36 | 12 | 55 | 93 | 89 | 87 | 67 |
| 12 | | | | | | | 13 | 41 | 41 | 25 | 21 | 21 | 13 | 53 | 98 | 36 | 36 | 36 |
| 13 | 15 | 333 | 100 | 87 | 86 | 86 | 15 | 100 | 100 | 82 | 82 | 71 | 15 | 75 | 100 | 33 | 33 | 33 |
| 14 | 16 | 18 | 100 | 94 | 94 | 94 | 16 | 50 | 100 | 68 | 62 | 54 | 16 | 100 | 96 | 41 | 41 | 41 |
| 15 | 17 | 327 | 100 | 81 | 81 | 81 | 17 | 50 | 100 | 54 | 50 | 38 | 17 | 101 | 100 | 65 | 65 | 64 |
| 16 | | | | | | | 18 | 93 | 100 | 57 | 48 | 48 | 18 | 74 | 97 | 55 | 55 | 55 |
| 17 | 21 | 27 | 100 | 81 | 74 | 74 | 21 | 17 | 100 | 100 | 100 | 100 | | | | | | |
| 18 | | | | | | | 22 | 32 | 100 | 84 | 84 | 84 | 22 | 50 | 94 | 46 | 40 | 38 |
| 19 | | | | | | | 23 | 16 | 100 | 50 | 50 | 38 | | | | | | |
| 20 | | | | | | | 29 | 39 | 100 | 49 | 38 | 38 | 29 | 56 | 96 | 38 | 38 | 38 |
| Total | | 1551 | | | | | | 1166 | | | | | | 1279 | | | | |
| % | | 100 | 97.5 | 78.5 | 77.4 | 75.0 | % | 100 | 98.8 | 75.9 | 73.0 | 70.0 | % | 100 | 96.3 | 51.8 | 51.0 | 50.0 |

**Table 2.** The proportional schedule of the fir stem quality in years 2000, 2004, 2006, 2010 in the tillage JD92 (Quarter I) and the % of frost damages in 2000 (thickened numbers between parentheses)

| No. | Family No, | 2000 8-year-old firs | | | | | 2004 12-year-old firs | | | | 2006 14-year-old firs | | | | 2010 18-year-old firs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *n* | stem quality | | | frosted % | *n* | stem quality | | | *n* | stem quality | | | *n* | stem quality | | |
| | | | **1** | **2** | **3** | | | **1** | **2** | **3** | | **1** | **2** | **3** | | **1** | **2** | **3** |
| 1 | **1** | 3 | 100 | | | | 3 | 100 | | | 3 | 98 | 2 | | 3 | 67 | 33 | |
| 2 | **2** | 325 | 62 **(5)** | 7 **(3)** | 31 **(10)** | **18** | 251 | 76 | 19 | 5 | 247 | 98 | 1 | 1 | 238 | 86 | 12 | 2 |
| 3 | **3** | 74 | 77 **(4)** | 7 **(1,5)** | 16 **(1,5)** | **7** | 54 | 89 | 9 | 2 | 51 | 98 | 2 | | 49 | 98 | 2 | |
| 4 | **4** | 70 | 67 **(10)** | 10 **(10)** | 23 **(11)** | **31** | 59 | 90 | 8 | 2 | 59 | 98 | | 2 | 59 | 93 | 7 | |
| 5 | **5** | 233 | 64 **(9)** | 9 **(5)** | 27 **(9)** | **23** | 166 | 79 | 14 | 7 | 167 | 95 | 1 | 4 | 154 | 83 | 12 | 5 |
| 10 | **11** | 66 | 75 **(3)** | 1 | 24 **(10)** | **13** | 61 | 97 | 3 | | 58 | 93 | 2 | 5 | 52 | 90 | 8 | 2 |
| 11 | **12** | 37 | 69 **(4)** | 9 | 22 | **4** | 30 | 83 | 10 | 7 | 27 | 100 | | | 20 | 90 | 5 | 5 |
| 13 | **15** | 333 | 59 **(2)** | 5 **(3)** | 36 **(12)** | **4** | 291 | 66 | 29 | 5 | 286 | 97 | 2 | 1 | 286 | 85 | 14 | 1 |
| 14 | **16** | 18 | 69 | 6 | 25 | | 17 | 82 | 18 | | 17 | 100 | | | 17 | 94 | 6 | |
| 15 | **17** | 327 | 66 **(9)** | 11 **(4)** | 23 **(9)** | **22** | 266 | 80 | 12 | 8 | 265 | 96 | 2 | 2 | 265 | 85 | 11 | 4 |
| 17 | **21** | 27 | 63 | 12 | 25 | | 22 | 77 | 18 | 5 | 20 | 90% | | 10 | 20 | 85 | 10 | 5 |
| Average | | | 70 | 7 | 23 | | | 84 | 12 | 4 | | 96 | 2 | 2 | 1163 | 87 | 11 | 2 |
| Total | | 1513 | | | | | 1220 | | | | 1200 | | | | 1163 | | | |

**Table 3.** The proportional schedule of the stem quality of the silver fir in 2004, 2006 and 2010 in the tillage Jd94 (Quartier II and III)

| No. | Family No, | Quartier II | | | | | | | | | | | | **Kwatera III** / Quartier III | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2004 9-year-old firs | | | | 2006 11-year-old firs | | | | 2010 15-year-old firs | | | | 2004 9-year-old firs | | | | 2006 11-year-old firs | | | | 2010 15-year-old firs | | | |
| | | n | 1 | 2 | 3 | n | 1 | 2 | 3 | n | 1 | 2 | 3 | n | 1 | 2 | 3 | n | 1 | 2 | 3 | n | 1 | 2 | 3 |
| 1 | 1 | 15 | 93 | 7 | | 15 | 93 | | 7 | 15 | 87 | 13 | | 9 | 67 | | 33 | 9 | 91 | | 9 | 9 | 78 | 22 | |
| 2 | 2 | 51 | 94 | 2 | 4 | 51 | 94 | 2 | 4 | 47 | 75 | 25 | | 6 | 100 | | | 6 | 66 | 17 | 17 | 6 | 67 | 33 | |
| 3 | 3 | 82 | 92 | 4 | 4 | 82 | 96 | 4 | | 78 | 93 | 6 | 1 | | | | | | | | | | | | |
| 4 | 4 | 113 | 92 | 8 | | 113 | 96 | 4 | | 113 | 86 | 11 | 3 | 84 | 72 | 4 | 24 | 84 | 88 | 6 | 6 | 84 | 83 | 17 | |
| 5 | 5 | 79 | 100 | | | 79 | 100 | | | 79 | 92 | 4 | 4 | 15 | 73 | | 27 | 10 | 90 | | 10 | 10 | 50 | 40 | 10 |
| 6 | 6 | 43 | 97 | 5 | 2 | 41 | 96 | | 4 | 38 | 94 | 3 | 3 | 26 | 65 | 8 | 27 | 26 | 96 | | 4 | 26 | 77 | 19 | 4 |
| 7 | 7 | 23 | 100 | | | 23 | 96 | 4 | | 1 | 100 | | | 50 | 68 | 12 | 20 | 50 | 84 | 10 | 6 | 50 | 88 | 10 | 2 |
| 8 | 8 | 81 | 94 | 6 | | 73 | 98 | 2 | | 73 | 85’ | 1 | 14 | 66 | 63 | 11 | 26 | 66 | -97% | | 3 | 66 | 73 | 24 | 3 |
| 9 | 9 | 36 | 89 | 11 | | 35 | 89 | 9 | 6 | 35 | 91 | | 9 | 53 | 71 | 6 | 23 | 53 | 70 | 15 | 15 | 53 | 79 | 15 | 6 |
| 10 | 11 | 39 | 87 | 10 | 3 | 39 | 87 | 13 | | 38 | 87 | 3 | 10 | 68 | 73 | 1 | 26 | 68 | 93 | 4 | 3 | 68 | 86 | 13 | .1 |
| 11 | 12 | 36 | 91 | 6 | 3 | 36 | 97 | 3 | | 36 | 94 | 3 | 3 | 49 | 80 | 20 | | 48 | 88 | 4 | 8 | 37 | 84 | 13 | 3 |
| 12 | 13 | 25 | 96 | 4 | | 21 | 90 | | 10 | 21 | 91 | 9 | | 19 | 85 | 5 | 10 | 19 | 100 | | | 19 | 58 | 42 | |
| 13 | 15 | 82 | 94 | 6 | | 82 | 95 | 4 | 1 | 71 | 94 | 3 | 3 | 25 | 52 | 4 | 44 | 25 | 100 | | | 25 | 68 | 28 | 4 |
| 14 | 16 | 34 | 91 | 9 | | 31 | 87 | 3 | 10 | 27 | 100 | | | 41 | 64 | 2 | 34 | 41 | 81 | 12 | 7 | 41 | 83 | 15 | 2 |
| 15 | 17 | 27 | 96 | 4 | | 25 | 76 | 16 | 8 | 19 | 100 | | | 66 | 71 | 2 | 27 | 65 | 83 | 8 | 9 | 65 | 77 | 18 | 5 |
| 16 | 18 | 53 | 92 | 6 | 2 | 45 | 98 | | 2 | 45 | 96 | 2 | 2 | 41 | 59 | | 41 | 41 | 97 | | 3 | 41 | 71 | 27 | 2 |
| 17 | 21 | 17 | 76 | 24 | | 17 | 88 | 12 | | 17 | 82 | 18 | | | | | | | | | | | | | |
| 18 | 22 | 27 | 96 | 4 | | 27 | 96 | 4 | | 27 | 93 | 7 | | 23 | 70 | 4 | 26 | 20 | 90 | | 10 | 19 | 90 | 10 | |
| 19 | 23 | 8 | 62 | 38 | | 8 | 88 | | 12 | 6 | 100 | | | | | | | | | | | | | | |
| 20 | 29 | 19 | 84 | 11 | 5 | 15 | 87 | | 13 | 15 | 100% | | | 21 | 61 | 10 | 29 | 21 | 86 | 14 | | 21 | 86 | 14 | |
| Average | | | 91% | 8 | 1 | | 92 | 4 | 4 | | 92 | 5 | 3 | | 72 | 4 | 24 | | 88 | 5 | 7 | | 76 | 22 | 2 |
| Total | | 890 | | | | 858 | | | | 801 | | | | 662 | | | | 652 | | | | 640 | | | |

**Table 4.** The characteristics of the development of the silver fir in the years 2000, 2004, 2006, 2010 in tillage Jd92 (Quartier I), compartment 416 Ac, in compartment 416 Ag, Hajnówka Forst District

| Family No. | Height (cm) $\bar{x}$ ±SD | Root collar diameter (mm) $\bar{x}$ ±SD | Stem quality* $\bar{x}$ ±SD | $H_R$ | DBH (mm) $\bar{x}$ ±SD | $H_R$ |
|---|---|---|---|---|---|---|
| 2000 : 8-year-old firs | | | | | | |
| 1 | 55.5±0 | 10.5±0 | 1.70±0 | -0.10 | - | - |
| 2 | 54.02±23.16 | 11.32±3.68 | 1.69±1.01 | 0.05 | - | - |
| 3 | 51.82±26.04 | 11.49±3.8 | 1.4±0.86 | -0.34 | - | - |
| 4 | 40.98±25.28 | 8.03±3.84 | 1.56±0.86 | -1.50 | - | - |
| 5 | 52.85±21.63 | 10.54±3.5 | 1.64±0.88 | -0.26 | - | - |
| 11 | 51.37±25.42 | 10.58±3.75 | 1.5±0.86 | -0.47 | - | - |
| 12 | 55.19±25.1 | 10.48±3.81 | 1.52±0.85 | -0.31 | - | - |
| 15 | 53.59±31.44 | 11.43±3.85 | 1.78±0.95 | 0.17 | - | - |
| 16 | 52.38±24.95 | 10.51±3.3 | 1.56±0.89 | -0.38 | - | - |
| 17 | 58.88±29.18 | 11.93±4.04 | 1.58±0.84 | 0.28 | - | - |
| 21 | 48.86±24.95 | 10.4±3.79 | 1.63±0.85 | -0.46 | - | - |
| Average | 54.46±24.82 | 11.25±3.78 | 1.65±0.85 | | - | - |
| 2004 : 12-year-old firs | | | | | | |
| 1 | 142.67±21.64 | 30.33±5.73 | 1.00±1 | 0.57 | - | - |
| 2 | 122.57±46.76 | 24.47±9.38 | 1.29±0.56 | 0.08 | - | - |
| 3 | 123.01±43.21 | 24.48±9.12 | 1.15±0.45 | -0.07 | - | - |
| 4 | 93.91±43.34 | 17.24±8.18 | 1.19±0.52 | -1.31 | - | - |
| 5 | 109.49±44.9 | 21.11±8.04 | 1.27±0.59 | -0.38 | - | - |
| 11 | 125.02±43.05 | 25.15±10.06 | 1.16±0.45 | -0.03 | - | - |
| 12 | 135.05±52.2 | 25.11±10.39 | 1.26±0.65 | 0.35 | - | - |
| 15 | 120.79±48.77 | 26.19±10.15 | 1.35±0.56 | 0.32 | - | - |
| 16 | 116.47±39.54 | 22.38±7.76 | 1.19±0.4 | -0.30 | - | - |
| 17 | 129.32±49.74 | 25.8±9.86 | 1.28±0.6 | 0.34 | - | - |
| 21 | 100.91±45.5 | 21.09±9.65 | 1.32±0.57 | 0.01 | - | - |
| Average | 120.26±47.76 | 24.38±9.71 | 1.28±0.56 | | - | - |
| 2006 : 14-year-old firs | | | | | | |
| 1 | 186.17±70.7 | 30.89±10.34 | 1.1±0.41 | -0.32 | - | - |
| 2 | 204.00±66.5 | 34.52±11.25 | 1.03±0.19 | 0.02 | - | - |
| 3 | 195.29±62.87 | 32.02±10.19 | 1.02±0.14 | -0.35 | - | - |
| 4 | 164.81±67.72 | 28.13±12.11 | 1.04±0.27 | -1.04 | - | - |
| 5 | 186.17±70.7 | 30.89±10.34 | 1.1±0.41 | -0.32 | - | - |
| 11 | 209.37±67.96 | 31.95±9.38 | 1.17±0.54 | 0.31 | - | - |
| 12 | 227.33±62.06 | 33.08±9.53 | 1±0 | 0.13 | - | - |
| 15 | 203.06±72.95 | 35.11±12.87 | 1.05±0.27 | 0.12 | - | - |
| 16 | 197.76±50.09 | 28.8±9.09 | 1±0 | -0.65 | - | - |
| 17 | 214.26±74.15 | 35.82±12.64 | 1.08±0.36 | 0.42 | - | - |
| 21 | 163.60±80.95 | 25.91±13.41 | 1.2±0.62 | -0.74 | - | - |
| Average | 201.13±70.98 | 33.72±11.98 | 1.06±0.32 | | - | - |

| Family No. | Height (cm) $\bar{x}$ ±SD | Root collar diameter (mm) $\bar{x}$ ±SD | Stem quality* $\bar{x}$ ±SD | $H_R$ | DBH (mm) $\bar{x}$ ±SD | $H_R$ |
|---|---|---|---|---|---|---|
| 2010 : 18-year-old firs | | | | | | |
| 1 | 397.17±80.54 | 62.33±17.62 | 1.33±0.58 | 0.37 | 44.33±12.06 | 0.46 |
| 2 | 414.10±148.77 | 65.76±29.95 | 1.16±0.41 | 0.21 | 44.33±12.06 | 0.30 |
| 3 | 391.38±99.93 | 60.10±24.11 | 1.02±0.14 | -0.45 | 46.29±25.11 | -0.27 |
| 4 | 301.89±150.57 | 42.97±23.88 | 1.10±0.30 | -1.46 | 42.35±18.95 | -1.47 |
| 5 | 354.68±136.83 | 52.62±25.15 | 1.23±0.53 | -0.48 | 27.85±20.36 | -1.18 |
| 11 | 394.89±124.43 | 60.65±26.10 | 1.12±0.38 | -0.18 | 36.60±21.86 | -0.49 |
| 12 | 463.28±98.95 | 69.85±23.27 | 1.15±0.49 | 0.67 | 43.37±20.96 | 0.71 |
| 15 | 396.13±146.62 | 66.39±31.28 | 1.18±0.43 | 0.15 | 52.50±19.59 | 0.63 |
| 16 | 385.00±111.29 | 53.06±20.50 | 1.06±0.24 | -0.64 | 44.47±25.89 | -0.54 |
| 17 | 420.36±147.93 | 67.76±31.18 | 1.20±0.50 | 0.41 | 36.88±17.57 | 0.15 |
| 21 | 341.68±164.37 | 54.80±31.51 | 1.20±0.52 | -0.55 | 49.53±26.45 | -0.21 |
| Average | 394.86±145.74 | 62.69±29.81 | 1.17±0.44 | | 42.42±20.88 | |

**Table 5.** The characteristics of the development of the silver fir in the years 2004, 2006, 2010 in the tillage Jd94 (Quartier II), in compartment 416 Cf Hajnówka orest District

| Family No. | Height (cm) $\bar{x}$ ±SD | Root collar diameter (mm) $\bar{x}$ ±SD | Stem quality $\bar{x}$ | $H_R$ |
|---|---|---|---|---|
| 2004 : 9-year-old firs | | | | |
| 1 | 65.00±19.03 | 12.13±3 | 1.13 | 0.60 |
| 2 | 64.40±19.67 | 14.03±5.91 | 1.04 | -0.57 |
| 3 | 62.00±26.21 | 13.31±4.27 | 1.11 | -0.57 |
| 4 | 80.45±29.23 | 15.21±5.02 | 1.08 | 0.33 |
| 5 | 82.85±26.19 | 17.86±8.6 | 1.01 | 0.65 |
| 6 | 93.44±36.05 | 20.26±7.24 | 1.09 | 1.67 |
| 7 | 86.00 | 17.00 | 1 | 0.60 |
| 8 | 86.72±27.68 | 19.25±5.42 | 1.06 | 1.17 |
| 9 | 63.36±20.68 | 15.35±4.11 | 1.11 | -0.18 |
| 11 | 79.30±29.08 | 15.46±4.91 | 1.16 | 0.57 |
| 12 | 72.97±2.17 | 15.14±4.2 | 1.11 | 0.14 |
| 13 | 68.08±31.48 | 14.50±5.87 | 1.04 | -0.36 |
| 15 | 62.16±17.59 | 14.16±3.45 | 1.06 | -0.57 |
| 16 | 52.06±16.53 | 11.07±3.29 | 1.14 | -1.21 |
| 17 | 62.26±22.8 | 13.46±4.35 | 1.04 | -0.74 |
| 18 | 69.96±28.7 | 13.00±4.5 | 1.11 | -0.33 |
| 21 | 56.75±25.28 | 14.03±5.33 | 1.25 | -0.93 |
| 22 | 63.61±20.23 | 12.48±2.69 | 1.06 | -0.80 |
| 23 | 50.50±20.28 | 11.88±2.13 | 1.38 | -0.4 |
| 29 | 62.68±27.5 | 13.26±3.74 | 1.21 | -0.19 |
| Average | 71.34±27.65 | 15.05±5.98 | 1.09 | |
| 2006 : 11-year-old firs | | | | |
| 1 | 117.13±29.19 | 23.51±5.27 | 1.13 | -0.25 |
| 2 | 107.76±31.04 | 21.93±6.58 | 1.1 | -0.72 |

| Family No. | Height (cm) $\bar{x}$ ±SD | Root collar diameter (mm) $\bar{x}$ ±SD | Stem quality $\bar{x}$ | $H_R$ |
|---|---|---|---|---|
| 3 | 103.02±40.91 | 21.8±7.72 | 1.04 | -1.00 |
| 4 | 150.31±48.67 | 27.96±8.21 | 1.05 | 0.77 |
| 5 | 139.38±43.12 | 29.26±10.23 | 1 | 0.54 |
| 6 | 164.32±54.69 | 28.42±9.31 | 1.05 | 1.12 |
| 7 | 149.74±47.17 | 28.9±9.05 | 1.04 | 0.84 |
| 8 | 157.75±46.65 | 27.61±7.3 | 1.02 | 0.97 |
| 9 | 113.94±33.75 | 22.89±8.48 | 1.23 | -0.64 |
| 11 | 132.36±48.72 | 23.39±7.45 | 1.13 | 0.06 |
| 12 | 130.36±39 | 22.95±6.86 | 1.03 | 0.05 |
| 13 | 127.52±50.7 | 23.38±8.66 | 1.19 | 0.14 |
| 15 | 119.51±31.04 | 22.8±6.58 | 1.06 | -0.30 |
| 16 | 98.1±35.84 | 18.69±6.29 | 1.23 | -1.30 |
| 17 | 113.76±40.69 | 20.97±6.83 | 1.32 | -0.07 |
| 18 | 138.17±45.88 | 26.26±8.36 | 1.06 | 0.33 |
| 21 | 111±48.49 | 20.15±7.63 | 1.17 | -0.66 |
| 22 | 139.67±22.37 | 26.06±7.6 | 1.08 | 0.40 |
| 23 | 90.5±29.54 | 19.07±6.04 | 1.25 | -1.00 |
| 29 | 115.4±51.54 | 22.77±7.32 | 1.27 | 0.70 |
| Average | 128.52±46.96 | 24.48±8.36 | 1.09 | |
| 2010 : 15-year-old firs | | | | |
| 1 | 315.67±116.8 | 40.73±22.58 | 1.4 | 0.31 |
| 2 | 222.9±80.46 | 26.46±12.77 | 1.3 | -0.92 |
| 3 | 238.95±87.16 | 28.3±15.27 | 1.09 | -0.66 |
| 4 | 296.49±95.21 | 38.21±17.15 | 1.18 | 0.11 |
| 5 | 281.81±97.37 | 35.22±17.64 | 1.16 | -0.05 |
| 6 | 339.76±97.77 | 46.94±22.18 | 1.13 | 1.17 |
| 7 | 252.00±0 | 32.10±0 | 1 | -0.81 |
| 8 | 322.66±86.05 | 44.56±16.27 | 1.29 | 1.14 |
| 9 | 275.03±95.45 | 39.83±15.18 | 1.17 | 0.16 |
| 11 | 299.16±78.81 | 39.02±16.84 | 1.29 | 0.58 |
| 12 | 277.72±88.95 | 37.67±16.41 | 1.19 | 0.10 |
| 13 | 246.81±114.6 | 30.87±23.1 | 1.29 | -0.44 |
| 15 | 259.99±79.97 | 33.17±13.78 | 1.07 | -0.33 |
| 16 | 234.41±85.73 | 32.44±15.41 | 1 | -0.97 |
| 17 | 251.21±104.2 | 37.04±15.64 | 1 | -0.54 |
| 18 | 296.93±88.59 | 39.55±14.45 | 1.07 | 0.21 |
| 21 | 223.41±93.63 | 28.16±17.42 | 1.53 | 0.42 |
| 22 | 248.74±84.88 | 35.03±17.47 | 1.22 | -0.03 |
| 23 | 266.67±96.73 | 36.2±21.57 | 1 | -0.42 |
| 29 | 272.6±123.2 | 45.87±18.63 | 1 | 0.19 |
| Average | 277.08±95.9 | 36.62±17.5 | 1.17 | |

**Table 6.** The characteristic of the development of the silver fir in the years 2004, 2006, 2010 in the tillage Jd94 (Quartier III), in compartment 416 Cf Hajnówka Forest District

| Family No. | Height (cm) $\bar{x}$ ±SD | Root collar diameter (mm) $\bar{x}$ ±SD | Stem quality $\bar{x}$ ±SD | $H_R$ | DBH (mm) $\bar{x}$ ±SD | $H_R$ |
|---|---|---|---|---|---|---|
| 2004 : 9-year-old firs | | | | | | |
| 1 | 45.71±14 | 11.43±2.07 | 1.86±1.07 | 0.30 | - | - |
| 2 | 49.33±20.55 | 13.00±3.00 | 1.00±0 | -0.76 | - | - |
| 4 | 62.42±35.28 | 15.22±8.81 | 1.56±0.88 | 0.34 | - | - |
| 5 | 33.07±9.55 | 8.47±2.05 | 1.53±0.92 | -1.76 | - | - |
| 6 | 49.92±17.38 | 12.04±2.90 | 1.75±0.94 | 0.12 | - | - |
| 7 | 56.08±27.33 | 14.54±4.87 | 1.63±0.87 | 0.50 | - | - |
| 8 | 45.63±17.66 | 12.65±3.80 | 1.68±0.89 | -0.27 | - | - |
| 9 | 52.61±23.29 | 15.71±6.22 | 1.53±0.86 | 0.48 | - | - |
| 11 | 46.12±18.24 | 13.77±4.93 | 1.62±0.92 | 0.08 | - | - |
| 12 | 52.08±19.19 | 14.58±3.92 | 1.60±0.93 | 0.31 | - | - |
| 13 | 43.94±13.31 | 12.56±3.42 | 1.28±0.67 | 0.79 | - | - |
| 15 | 35.56±9.58 | 10.1±2.32 | 2.00±1.00 | -0.85 | - | - |
| 16 | 48.46±19.21 | 12.28±3.75 | 1.69±0.95 | 0.20 | - | - |
| 17 | 48.62±16.00 | 13.25±3.47 | 1.55±0.89 | -0.17 | - | - |
| 18 | **53.23**±22.44 | 13.08±3.60 | 1.85±1.00 | 0.34 | - | - |
| 22 | 42.52±15.69 | 11.7±3.10 | 1.57±0.90 | -0.69 | - | - |
| 29 | 43.7±14.44 | 10.1±2.71 | 1.70±0.92 | -0.81 | - | - |
| Average | 49.90±22.65 | 13.34±5.2 | 1.63±0.92 | | - | - |
| 2006 : 11-year-old firs | | | | | | |
| 1 | 55.11±21.00 | 13.6±3.50 | 1.11±0.45 | -1.13 | - | - |
| 2 | 68.75±41 | 15.01±3.68 | 1.75±0.96 | -0.23 | - | - |
| 4 | 105.9±57.12 | 21.22±9.32 | 1.19±0.53 | 0.56 | - | - |
| 5 | 54.6±21.59 | 13.36±3.53 | 1.40±0.89 | 1.41 | - | - |
| 6 | 93.47±27.11 | 18.03±4.34 | 1.12±0.49 | -0.30 | - | - |
| 7 | 95.89±44.6 | 21.47±7.83 | 1.25±0.58 | 0.46 | - | - |
| 8 | 88.13±29.88 | 19.34±5.45 | 1.08±0.38 | -0.32 | - | - |
| 9 | 83.7±41.11 | 22.34±9.34 | 1.45±0.75 | 0.63 | - | - |
| 11 | 83.63±35.64 | 18.2±6.55 | 1.13±0.44 | -0.51 | - | - |
| 12 | 93.87±38.09 | 20.18±5.95 | 1.21±0.59 | 0.15 | - | - |
| 13 | 88.44±26.38 | 19.14±3.62 | 1±0 | -0.49 | - | - |
| 15 | 67.00±28.16 | 17.76±3.65 | 1±0 | -1.2 | - | - |
| 16 | 79.68±38.43 | 17.71±6.59 | 1.32±0.64 | -0.34 | - | - |
| 17 | 83.02±32.12 | 18.93±6.07 | 1.33±0.68 | -0.07 | - | - |
| 18 | 106.15±37.48 | 19.48±6.35 | 1.15±0.55 | 0.26 | - | - |
| 22 | 75.2±38.68 | 15.33±5.46 | 1.27±0.7 | -0.87 | - | - |
| 29 | 78.5±24.96 | 27±3.22 | 1.17±0.38 | -0.85 | - | - |
| Average | 89.47±40.86 | 19.58±7.22 | 1.23 | | - | - |

| Family No. | Height (cm) $\bar{x}$ ±SD | Root collar diameter (mm) $\bar{x}$ ±SD | Stem quality $\bar{x}$ ±SD | $H_R$ | DBH (mm) $\bar{x}$ ±SD | $H_R$ |
|---|---|---|---|---|---|---|
| 2010 : 15-year-old firs | | | | | | |
| 1 | 155.50±52.68 | 22.77±8.19 | 1.44±0.73 | -0.84 | 11.76±5.54 | -1.70 |
| 2 | 130.67±78.28 | 24.16±12.48 | 1.33±0.52 | -1.20 | 18.50±12.02 | -1.60 |
| 4 | 235.54±118.5 | 40.25±20.83 | 1.21±0.41 | 1.10 | 29.64±15.77 | -1.45 |
| 5 | 106.40±49.34 | 19.90±8.36 | 1.60±0.7 | -1.29 | 14.50±3.54 | -1.96 |
| 6 | 191.85±95.65 | 34.73±19.15 | 1.27±0.53 | -0.27 | 25.00±13.44 | -0.24 |
| 7 | 212.43±98.83 | 39.22±20.55 | 1.14±0.4 | -0.64 | 25.26±16.14 | -0.59 |
| 8 | 190.53±98.03 | 35.02±18.15 | 1.33±0.54 | 0.41 | 23.53±10.78 | 0.35 |
| 9 | 236.62±103.3 | 47.79±26.18 | 1.26±0.57 | 1.90 | 30.54±17.33 | 2.31 |
| 11 | 199.35±95.64 | 36.54±20.55 | 1.16±0.41 | -0.17 | 22.04±16.83 | -0.05 |
| 12 | 229.31±85.68 | 44.45±19.32 | 1.19±0.46 | 0.22 | 27.71±14.54 | 1.92 |
| 13 | 174.74±95.82 | 31.15±15.92 | 1.42±0.51 | -0.27 | 20.50±10.44 | -0.26 |
| 15 | 112.88±51.85 | 21.84±6.42 | 1.36±0.57 | -0.91 | 11.00±4.20 | -2.59 |
| 16 | 188.96±89.39 | 33.26±17.07 | 1.20±0.46 | -0.21 | 21.37±12.68 | -0.40 |
| 17 | 179.81±89.64 | 34.43±16.62 | 1.31±0.56 | -0.22 | 21.24±12.34 | -0.17 |
| 18 | 209.3±105.6 | 38.53±22.95 | 1.32±0.52 | 0.75 | 28.39±17.06 | 1.01 |
| 22 | 202.00±75.78 | 32.89±13.82 | 1.11±0.32 | -0.28 | 20.47±11.24 | -0.55 |
| 29 | 158.88±58.81 | 26.38±10.49 | 1.14±0.36 | -1.24 | 14.83±6.16 | -1.89 |
| Average | 198.64±99.42 | 33.14±10.81 | 1.25±0.49 | | 24.49±14.84 | |

48 cm per year. During 14 years of their growth in the ancestral conservative tillage, the differences in height growth between families were more pronounced (Table 4).

In 2006–2010, the average root collar diameter increased by 29 mm and was 62.69 mm. The average values for the families ranged from 42.97 to 69.85 mm (Table 4). The diameter of the firs at breast height was measured for the first time. The average diameter at breast height on plot I amounted to 42.42 mm and was 32% smaller than the average root collar diameter (Table 4).

**The Jd 94 trial**

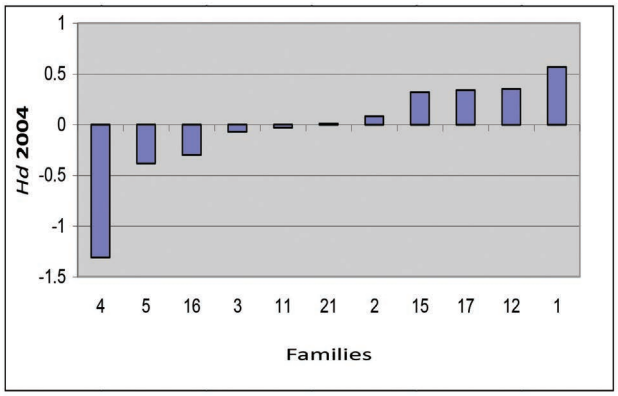
Despite the relatively similar habitat conditions, the growth of firs on plots II and III differed significantly. The dimensions of the firs on plot II were much larger than on plot III (Tables 5 and 6).

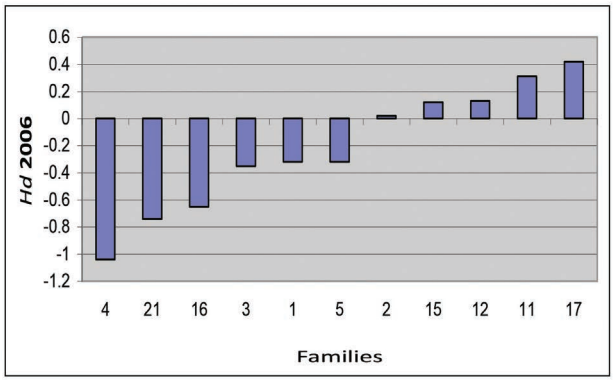
In 2004, the percentage of 9-year-old fir trees with a properly developed leader on plot II (6 years after planting) amounted to 91%, while on plot III it was only 72%. In addition, 24% of trees on plot III had multi-shoot tops (Table 3). As a result, the average height of the firs on plot III was 49.90 cm, and was 30% lower than the height of the trees on plot II (average 71.34 cm; Tables 5 and 6). Similar differences were found in the growth of the root collar diameter, yet the differences in these growth traits were relatively small between families, while very significant within individual families, regardless of the plot (Tables 5 and 6).

In 2006, the 11-year-old fir trees on plot II reached an average height of 128.52 cm and were 30% higher than the trees on plot III (average height was 89.47 cm). The differences between families were larger than in 2004. The difference in average height of the tillage on plot II was even up to 55% (families No. 23 and No. 6), while on plot III the difference was approximately 51% (families No. 5 and No. 18; Tables 5 and 6). Even greater differences in height were observed within individual families (Tables 5 and 6).

Significantly smaller differences in the growth of the root collar diameter of firs were found between plots (maximum 20%), as well as between and within families. Although the correlation between the height and diameter of firs was maintained, the effect of frost on the growth of the root collar diameter was significantly lower than on the height growth.

In 2010, the fir trees growing on plot II were 29% higher than the trees on plot III (Tables 5 and 6). The average diameter of firs at breast height was 36.62 mm on plot II, and 24.49 mm on plot III (Tables 5 and 6). The root collar diameter of the firs on plot III was additionally measured, because



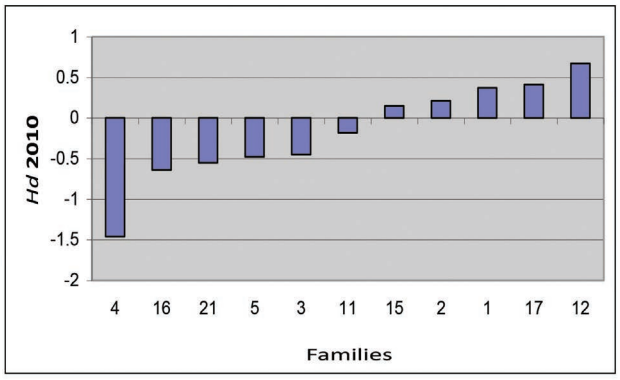




**Figure 2.** The index of breeding values of the silver fir families in tillage Jd92 in the years 2004, 2006 and 2010

approximately 15% of the trees did not exceed a height of 130 cm (Table 6).

As on plot I, the average differences between fir families on plots II and III were small in all the years in which the measurements were made. However, the differences in the height of firs between families were large and statistically highly significant (Table 7).

Initially, the average annual height growth of fir trees on both plots differed, but the differences disappeared over the years. The average annual height growth on plot II from 2004–2006 was on average approximately 19 cm per year, and from 2007–2010 approximately 27 cm per year. The average annual height growth on plot III from 2004–2006 was approximately 13 cm, and from 2007–2010 approximately 27 cm.

## The family breeding value

In 2000, the families Nos. 17, 15 and 2 on plot I (Jd 92 trial) performed best, while the tillage No. 4 showed the lowest breeding value, always occupying the same place in the ranking throughout the study period (Table 4, Fig. 4). In the years 2004, 2006 and 2010, the families 12, 11 and 1 were classified to the group of the best families (Table 4, Fig. 2).

In 2004, the families Nos. 6, 8, 5, 7, 1, 11 and 4 on plot II (Jd 94 trial) performed best, while the families Nos. 16 and 21 showed the lowest breeding value (Table 5). In subsequent measurement years (2006 and 2010), the families Nos. 29 and 18 were classified to the group of the best families, while the families Nos. 3, 23, 2 and 7 showed the lowest breeding value (Table 5, Fig. 3). The ranking of the families changed over years. Only tillage No. 6 always performed best, while tillage No. 16 occupied the last place in the ranking (Table 5, Fig. 3).

The firs on plot III (Jd 94 trial) showed a much greater variation in the breeding value $H_D$ than the firs on plots I and II. There was no single tillage to retain its position in the breeding value ranking. In subsequent measurement periods, the $H_R$ index for some of the families increased (families Nos. 9 and 18), while it decreased for other families (Table 6, Fig. 3).

To conclude, it should be noted that although the differences in the breeding value index ($H_R$) for the families on plots II and III are not statistically significant, they reveal the nature of changes in the development and adaptation of various fir families.

## The genetic evaluation of families

The heritability indices were calculated for plots II and III taken together on the basis of the measurement data from 2010. Less numerous families were excluded from the cal-

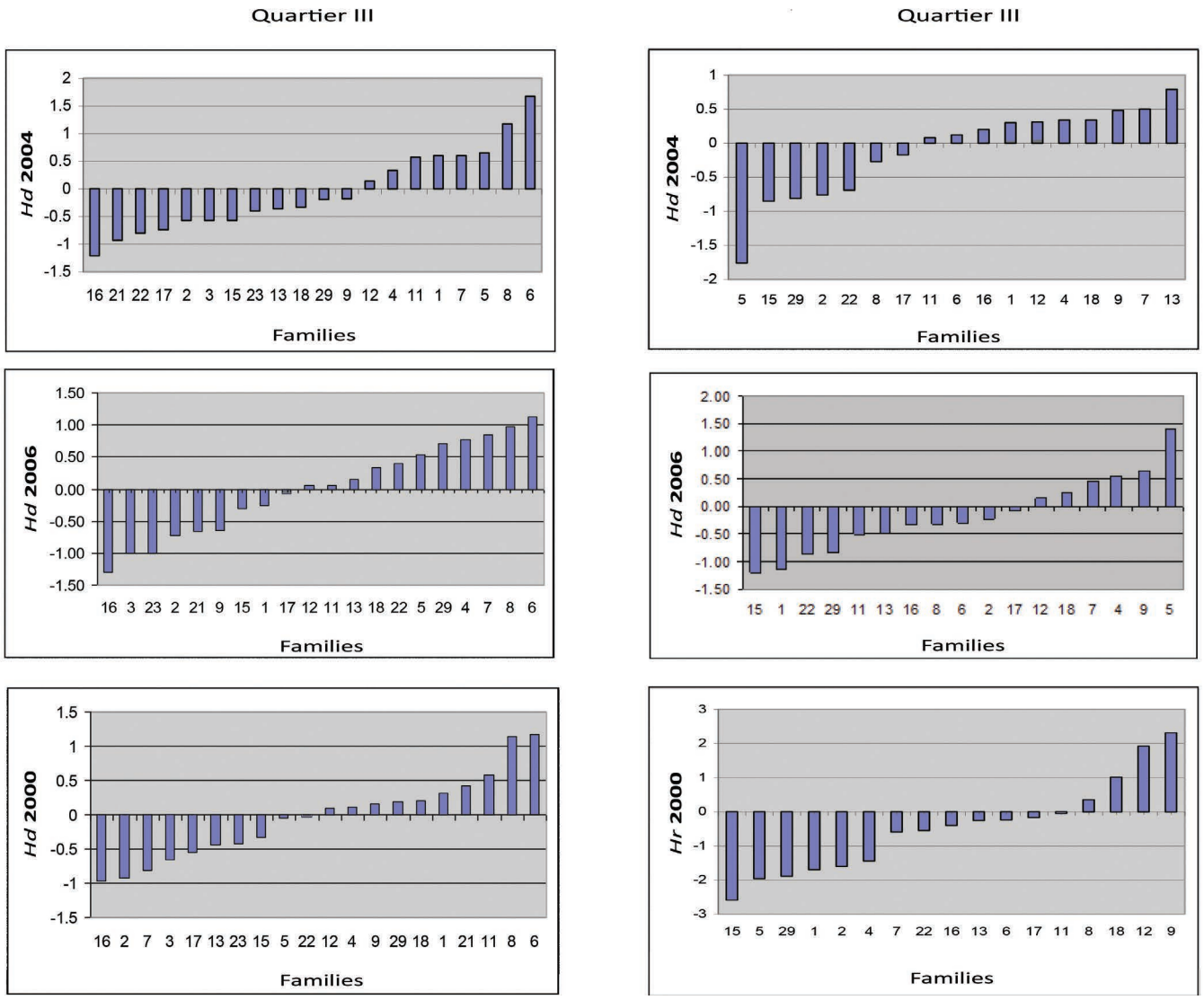



**Figure 3.** The index of breeding values of the silver fir families in tillage Jd94 (Quartier II and Quartier III) in the years 2004, 2006 and 2010.

**Table 7.** Analysis of variance of the characters of the 15-year-old fir families in tillage Jd94 (the height, DBH, the root collar diameter)

| Feature | Source of variation | Degrees of freedom | Sum of Squares | Mean Square | *F* | *p* |
|---|---|---|---|---|---|---|
| Height | family | 18 | 861804 | 47878 | 4.519 | 1.03e-09 *** |
| | residual | 1420 | 15043350 | 10594 | | |
| DBH | family | 18 | 19619 | 1089.9 | 3.686 | 3.2e-07 *** |
| | residual | 1124 | 332328 | 295.7 | | |
| Root collar diameter | family | 14 | 22990 | 1642.1 | 4.565 | 6.93e-08 *** |
| | residual | 592 | 212952 | 359.7 | | |

**Table 8.** Single ($h_i^2$) and progeny ($h_R^2$) tree heritability enumerated on the ground given of measuring in 2010 on the tillage Jd94 (Quartier II and Quartier III)

| Feature | Variance component of | | Single heritability | | Progeny heritability | |
|---|---|---|---|---|---|---|
| | progeny | error | $h_i^2$ | error | $h_R^2$ | error |
| Height | Be | 10589.2 | 0.173 | 0.0739 | 0.764 | 0.0806 |
| DBH | 13.6823 | 295.45 | 0.177 | 0.0801 | 0.769 | 0.084 |
| Root collar diameter | 39.7195 | 371.918 | 0.386 | 0.1744 | 0.885 | 0.0509 |

culations: tillage No. 23 for its heritability of height and diameter at breast height, and families Nos. 1 and. 2 for their heritability of the root collar diameter.

Individual ($h_i^2$) and family ($h_R^2$) heritability indices indicate the range of additive heritability that the mother passes to her offspring. On the tillage level, the heritability index ($h_R^2$) was high and amounted to: 0.764 for height, 0.769 for diameter at breast height and 0.885 for root collar diameter (Table 8). The indices of individual heritability of the examined traits ($h_i^2$) were low and ranged from 0.386 to 0.173 (Table 8).

## 4. Discussion

The growth of juvenile silver fir is threatened mainly by environmental factors such as spring frosts and deer. The observations made in the 'Tisovik' fir reserve as well as in the man-made fir stands and clumps of fir trees in the Białowieża (Gryka 2013), Borecka (Rydzewski 2013) and Romincka (Fiećko 2013) primeval forests show that plants from natural regeneration are not damaged by spring frosts. In plantations, however, nearly all the fir seedlings are, to a greater or lesser extent, damaged by such frosts. Particularly, severely damaged are seedlings in the first 4 years of growth in the plantation. After this period, the survival of fir remains more or less on the same level.

The results of an analysis of growth and development of the offspring of 20 families of silver fir from the 'Tisovik' reserve in the ancestral conservative tillage located in the territory of the Hajnówka forest district, shows a satisfactory growth of this species in the fresh deciduous forest habitat (Lśw) in the Białowieża primeval forest. The family heritability index of silver fir is high, which indicates a high possibility to improve the breeding traits.

This is also confirmed by the studies by Gončarenko and Savickij (2000). The presented research results lead to the conclusion that firs Nos. 1, 3 and 17 showing the greatest polymorphism should be selected from among the 20 firs as the most valuable (Gončarenko, Savickij 2000). The presented data do not differ from those reported in the literature on fir provenances (Skrzyszewska 1999, 2003). They indicate great possibilities for improving the growth traits through the selection of the best families.

The level of genetic variation of the offspring of silver fir from the 'Tisovik' reserve is low compared with other populations of this species (Pawlaczyk, Bobowicz 2011).

Fir grows very well in the north-eastern regions of Poland. This is confirmed by the observations of the growth of single fir trees and small clumps of fir trees planted in the early 20th century in the Borecka and Romincka primeval forests (Fiećko 2013; Rydzewski 2013).

## 5. Conclusions

The above-presented observations show that silver fir grows well on fresh deciduous (Lśw) and fresh mixed deciduous (LMśw) forest habitats in north-eastern Poland.

Due to its genetic diversity, intensive seed production, good growth parameters, good health condition and native, natural origin, silver fir from the 'Tisovik' reserve deserves special attention, and its derivative tillage should be established not only in the Białowieża primeval forest, but also in the lowland areas in Poland and Belarus.

Two fir stands in comp. 453 Aa (97 trees) and comp. 498 Cg (34 trees) located in the territory of the Białowieża forest district should be regarded as a seed source to be used as the forest basic material for the proven breeding values and fast natural regeneration of this species. The fenced area in comp. 453 Aa should be extended from 0.25 to 1.0 ha in order to protect the natural regeneration of silver fir.

With the next revision, the range of planting of silver fir should be extended to the Baltic and Mazury-Podlasie nature-forest regions. To establish fir plantations in these regions, it is advisable to use the populations of silver fir growing on the eastern limits of its occurrence in the lowland and piedmont areas.

## Conflict of interest

None declared.

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