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# Quality selection in young oak stands

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**ABSTRACT**: The paper deals with an experiment that was established at Opočno Experimental Station of the Forest and Game Management Research Institute (CR) in an oak small pole stage in 1952 to test whether Schädelin's (1942) tending method worked out for beech stands is suitable for oak stands. Development and growth of the oak stand without tending are analysed, and the influence of repeated positive selection and of definitive selection of target trees on the oak stand is described. The result of the 50-year experiment is that Schädelin's tending method is suitable also for oak stands. However, it is rational only if the choice of candidates from the small pole stage is focused on vital straight trees.

**Keywords**: *Quercus robur* (L.); tending; increment; quality

Schädelin's theory of stand tending published in 1942 is based on his idea that changes in the height structure occur in both directions and that the timely and repeated release of higher-quality trees can increase their value production. As he was aware of the fact that his concept was a theoretical one and was constructed only on the basis of experience, he hoped that it would be confirmed by exact proofs. Leibundgut and Schütz, Schädelin's successors, were the first to undertake this task. As early as in 1943 Leibundgut established a verification experiment whereas its results were published in 1976 (Leibundgut 1976). He stated that downward changes prevailed both in young growths and in small pole stages and tending measures did not change this trend substantially. On the other hand, positive selection contributed to an increase in diameter increments of released trees and in the number of high-quality trees. According to Schütz (1979) twenty similar experiments were established in Switzerland at that time. Besides Switzerland experiments with positive selection in young oak stands were also established in other countries (Chroust 1958; Korpeľ 1964; Kenk 1976; Mosandl et al. 1991). The other experiments with the tending of oak stands were aimed at a comparison of the effects of low thinning and high thinning from the aspect of their production and were conducted mostly in older stands (Bryndum 1966; Spellmann, Dies 1990; Schaper, Röhrig 1983; Assmann 1961; Krahl-Urban 1959, etc.).

## EXPERIMENTAL OBJECT AND METHODS

*Locality*: Halín Forest District, Administration of Kristina Colloredo-Mansfeld's Forests in Opočno (50°16´NL, 16°06´EL).

*Site*: Hilly area in Předhůří Natural Forest Region in the Orlické hory Mts., at an altitude of 260 m above sea level. The site is situated on a moderate slope of 10° gradient, southern exposure. The soil type is brown humus-carbonate soils rich in nutrients. The parent rock is Upper Cretaceous marl. Typologically, it is classified to the group *Fageto-Quercetum*. Average annual temperature is 7.6°C, annual precipitation amounts to 660 mm.

*Experimental object and methods*: The forthcoming oak (*Quercus robur*) small pole stage originated in 1930 by natural regeneration and by additional sowing of acorns while it was locally improved with elm, beech, pine and spruce. Since the age of 10 years, when the highest trees reached ca 4 m and stand density was about 25,000 trees per ha, assistance cuttings started to be carried out to remove crooked trees from the upper storey but care was taken to avoid canopy openings. Trees were either cut off or pruned below the crown at a height of 1–1.5 m

Fig. 1. Oak small-pole stage (22 years) before the first thinning

above the ground. Pruned stems regenerated and created the ground storey covering the soil surface. Trees of the 3rd and 4th class were left to natural differentiation and mortality. In fact, it was Schädelin's assistance cutting.

At the age of 22 years, when the experiment was established, the number of non-truncated oaks was about 6,000 individuals per ha and ca 5% of other species (Fig. 1, Table 2). Breast-height diameters ranged from 3–12 cm and heights from 2–12 m. Trees of the 2nd tree class with slightly crooked stems prevailed in the stand. Trees of the 1st class had the straightest stems while trees of the 3rd class had the most crooked stems. There were about 16,000 truncated living oaks per ha in the understorey.

Four comparative plots (30 × 40 m, 30 × 40 m, 40 × 40 m and 20 × 40 m) were laid out in the stand of an area 1.5 ha (Fig. 2). The smallest plot in the middle of the young growth was influenced by assistance cutting to the smallest extent and therefore it was left to natural development. Tending measures were intended to be taken on the other plots. Each plot was separated from the adjacent one by a 3 m isolation band where the same interventions as on the relevant plot were carried out.

After the survey of plots and their permanent stabilisation trees were numbered and measurement points at a height of 1.3 m were marked on non-truncated trees. Diameters at breast height and at a height of 30 cm above the ground, total height and height of the setting of the green crown were measured, and the trees were divided into four tree classes (dominant, co-dominant, sub-dominant and truncated). Trees were also classified into four classes according to crown size, stem form and number of epicormic shoots. Homogeneity and confrontation of plots were checked by *T*-test (Chroust 1958).

In the first 25 years breast-height diameters were measured each year, then after 10 years; heights were measured at irregular intervals. A sample tree method was used to measure the size of crowns and their foliage. Mensurational and dendrometric

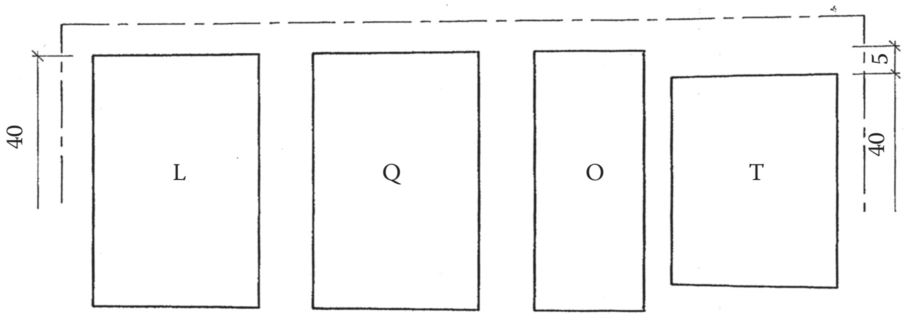


Fig. 2. Situation and dimensions of plots

Table 1. Diameter classes (cm)

| Class | 3 | 2 | 1 | Range |
|---|---|---|---|---|
| Age 23 | 2–4.6 | 4.7–7.3 | 7.4–10+ | 2–10 |
| 33 | 3–6.6 | 6.7–10.3 | 10.4–14+ | 3–14 |
| 43 | 3–8.6 | 8.7–14.3 | 14.4–20+ | 3–20 |
| 58 | 9–14.6 | 14.7–20.3 | 20.4–26+ | 9–28 |
| 73 | 14–19.3 | 19.4–24.7 | 24.8–30+ | 14–33 |

Table 2. Data on experimental plots at the time of experiment establishment before tending measures in spring 1952 (at the age of 22 years)

| Plot | Area (ha) | *N* (trees) | $N_{ha}$ (trees/ha) | *BA* ($m^2$/ha) | *Ho* (m) | *d* (cm) | *h* (m) | *H/d* |
|---|---|---|---|---|---|---|---|---|
| 0 | 0.08 | 470 | 5,890 | 17.2 | 9.6 | 6.1 | 8.1 | 133 |
| Q | 0.12 | 724 | 6,030 | 19.4 | 9.7 | 6.4 | 8.4 | 131 |
| T | 0.16 | 974 | 5,920 | 17.9 | 9.2 | 6.2 | 8.2 | 135 |

Table 3. Number (*N* per ha) of trees at the age of 23 years according to tree classes and stem form on plot 0 and Q after the first thinning and after 50 years (age 73 years)

| Plot | Straight | | | | Slightly crooked | | | | Crooked | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | Q | | 0 | | Q | | 0 | | Q | |
| Age | 23 | 73 | 23 | 73 | 23 | 73 | 23 | 73 | 23 | 73 | 23 | 73 |
| Class 1 | 1,358 | 70 | 1,386 | 39 | 639 | 27 | 438 | 35 | 71 | 13 | 51 | 0 |
| Class 2 | 905 | 148 | 589 | 212 | 1,159 | 81 | 797 | 62 | 512 | 272 | 163 | 78 |
| Class 3 | 0 | 59 | 0 | 40 | 625 | 88 | 652 | 35 | 527 | 129 | 654 | 53 |
| Total | 2,263 | 277 | 1,978 | 291 | 2,423 | 196 | 1,888 | 132 | 1,110 | 414 | 868 | 131 |

| Total number of trees at the age | on plot 0 | plot Q |
|---|---|---|
| of 23 years | 5,796 | 4,730 |
| of 73 years | 887 | 554 |

parameters were calculated by usual methods. Due to their relative character (Abetz 1989; Sikora 1967) changes in tree classes were replaced by changes in absolutely measurable diameter classes (Table 1). They were constituted by dividing the diameter range at the beginning of the studied period into three classes of the same width. Getting to a higher class or, on the contrary, descending to a lower class or dying off indicated the direction of the change.

The problem was solved by a conventional comparative method when the development and growth of a stand without thinnings (plot 0) were investigated and compared with the stand tended by:

– quality thinning (repeated positive selection) (plot Q),
– high thinning with marked target trees (definitive positive selection) (plot T),
– low thinning (it is not evaluated in this paper because it is not its subject) (plot L).

*Experiment genesis*: The first thinning was performed in 1952 in the following way:

(1) On a plot designated by the letter Q, which was designed for quality selection, trees with straight stems and crowns of corresponding sizes, so called candidates, were sought. Their height ranged from 7–11 m and breast-height diameter from 4–8 cm. The length of the stem part under the crown was 4–7 m. A majority of them were trees of the first and second, and also third tree class. The third class did not comprise any trees with sufficiently straight stems. In a subsequent step trees in their vicinity oppressing them were removed. The stems were marked with a vertical, ca 10 cm coloured bar above the registration number as a symbol of straight stem. Negative

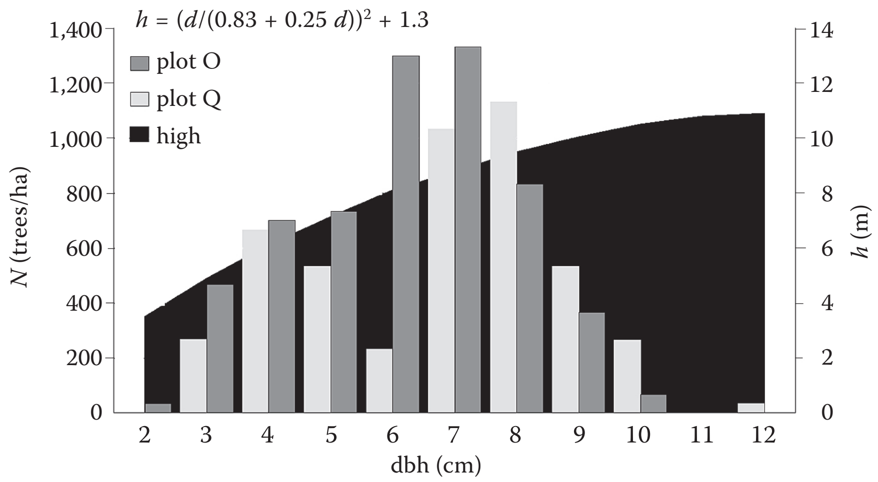


Fig. 3. Diameter distribution and height curve of plot 0 and plot Q after the first thinning at the age 23 years

Table 4. Percentage changes in diameter classes on plot 0

| Age | 23–33 | | | | | 33–43 | | | | | 43–73 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Change | *D* | ↓ | 0 | ↑ | *N* | *D* | ↓ | 0 | ↑ | *N* | *D* | ↓ | 0 | ↑ | *N* |
| Class 1 | 0 | 30 | 70 | 0 | 57 | 0 | 44 | 56 | 0 | 72 | 5 | 43 | 52 | 0 | 39 |
| Class 2 | 7 | 31 | 55 | 7 | 90 | 22 | 17 | 55 | 1 | 155 | 70 | 19 | 11 | 0 | 93 |
| Class 3 | 70 | 0 | 21 | 9 | 33 | 70 | 0 | 26 | 4 | 125 | 96 | 0 | 4 | 0 | 58 |

*D* – dead standing trees; ↓ – trees descending to a lower class; ↑ – trees getting to a higher class; 0 – trees maintaining their position; *N* – number of trees in classes

selection was carried out only in poor-quality overtopping trees. Further thinnings were repeated in a similar way after 5 years at first, then after 10 years and finally in the last 30 years after 15 years. If any candidates were deformed during the period concerned, attention and care were focused on other nearest trees of better quality. It is to note that trees seeming to be of better quality at that time were preferred. Trees of the fourth tree class and truncated ground storey were left on the plot. After 40 years, i.e. at the age of 60 years, elect trees were identified.

(2) A plot designated by the letter T was designed for high thinnings with definitive target trees. They were sought out, marked and released in 1963 (at 33 years of age) when their characteristics were more distinct. By that time only low-grade overtopping trees were removed at the same time as on plot Q.

(3) The stand on plot 0 was left to natural development without any tending measures.

## RESULTS

### Development and growth of the stand without thinnings (plot 0)

At the age of 23 years there were 5,797 trees/ha on the plot 0, their diameters ranged from 2 to 10 cm and their heights from 3 to 10 m (Fig. 3). Stand basal area was 18.4 m$^2$ and stem volume was 83 m$^3$ (Table 6). Dominant trees with straight trunks prevailed in this stand (Table 3). Over the first 10 years 1,567 of trees died and the number of living trees dropped to 4,230 individuals (Table 6). Among the dead trees there were almost all trees with breast-height diameter smaller than 4.6 cm and a part (7%) of the trees with diameter 4.7–7.3 cm. No tree from the first diameter class (7.4–10 cm) died in this period (Table 4).

Diameter increment in the first decennium was proportionate to breast height diameter (Fig. 4): it was around 0.7 mm/year in the thinnest trees of the third class (2.0–4.6 cm) while it amounted to around

Table 5. Breast-height diameter at the beginning of the period and mean annual diameter increment of the mean tree of a constant set of 50 trees on plot 0, Q and T

| Age | Plot 0 | | Plot Q | | Plot T | |
|---|---|---|---|---|---|---|
| | *d* (cm) | *id* (mm) | *d* (cm) | *id* (mm) | *d* (cm) | *id* (mm) |
| 23 | 8.1 ± 0.9 | 3.0 ± 0.7 | 8.5 ± 1.9 | 3.0 ± 0.9 | – | – |
| 33 | 10.7 ± 2.2 | 3.5 ± 0.7 | 12.0 ± 2.2 | 3.9 ± 1.6 | 12.1 ± 2.4 | 4.3 ± 1.1 |
| 43 | 14.2 ± 2.4 | 2.7 ± 0.9 | 15.9 ± 3.5 | 3.3 ± 1.5 | 16.9 ± 3.0 | 4.4 ± 2.2 |
| 58 | 18.3 ± 3.2 | 2.2 ± 1.2 | 20.9 ± 5.6 | 2.9 ± 2.8 | 22.9 ± 4.4 | 3.9 ± 1.9 |

Table 6. Mensurational parameters of the stand on plot 0

| Age | *N* (trees) | *BA* (m$^2$) | *V* (m$^3$) | *d* (cm) | *h* (m) | Dead trees | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | *N* | *BA* (m$^2$) | *V* (m$^3$) |
| 23 | 5,797 | 18.43 | 83.1 | 6.3 | 8.2 | – | – | – |
| 33 | 4,230 | 26.81 | 170.0 | 8.4 | 12.2 | 1,560 | 2.34 | 9.6 |
| 43 | 2,780 | 30.78 | 251.1 | 11.8 | 16.0 | 2,323 | 5.94 | 26.2 |
| 58 | 1,537 | 36.70 | 367.0 | 17.4 | 20.0 | 1,243 | 8.36 | 54.8 |
| 73 | 887 | 34.71 | 380.0 | 22.3 | 22.4 | 650 | 9.30 | 70.6 |

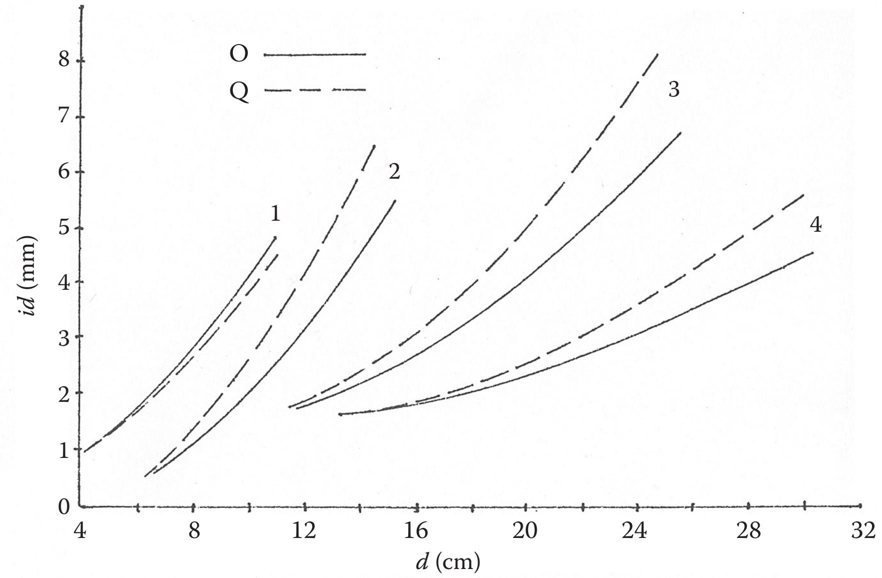

Fig. 4. Mean annual diameter increment in relation to breast height diameter on plot 0 and plot Q at the age 23–33 (1), 33–43 (2), 43–53 (3), 53–63 (4)

2.7 mm in the thickest trees of the first class (7.4 to 11 cm). In this class the increment of 70% of the trees was so high that after 10 years they also got to the class of the thickest ones (10.4–14+ cm). On the contrary, the increment of 30% of the trees was lower and they were placed into the second class after 10 years. In the second class about 55% of the trees maintained their position thanks to their sufficient increment, 7% got to the higher class thanks to their increased increment, 31% descended to a lower class and 7% died. Seventy per cent of the trees died in the third class (Table 4).

In the subsequent period mortality was still higher and a higher number of trees descended from the 1st class (44%). Only 56% of the trees remained in the first class. Only 1% from the second class got to the higher class (Table 4).

The diameter range enlarged from initial 2–10 cm to 2–14 cm as a result of the higher increment of thicker trees and mean tree diameter increased from 6.3 to 8.4 cm (Table 6). The diameter of the mean tree of a constant set of 50 trees from the class of the thickest ones increased from 8.1 cm to 10.7 cm and true increment from 3.00 mm to 3.5 mm/year (Table 5).

In the next 30 years changes in diameter classes occurred with the same intensity and in the same direction. Five per cent, 70% and 96% of the trees died in the 1st, 2nd and 3rd class, respectively. 43% and 19% descended to a lower class. Only 52% and 11% maintained their position in the respective class (Table 4). Only 9% of trees survived until the age of 73 years. Their breast-height diameter was at least 6 cm at 23 years of age.

Diameter increments of most trees decreased from the second decennium (Table 5, Fig. 4) but the relation the thicker the tree, the higher the increment remained valid. While diameter increment decreased with age and tree number also diminished, the increment of stand basal area and standing volume also decreased (Table 8). In the last period *BA* of dead trees were higher than *iBA* of living trees and that is why *iBA* of the stand were negative (Table 8). That is why *BA* of the stand at 73 years of age decreased to 34.7 m$^2$.

As for the height structure development during 50 years, the proportion of the 1st tree class decreased from 35% to 12%, but that of the 2nd tree class increased from 44% to 56%. The proportion of straight stems of the 1st tree class decreased from 23% to 8%. On the contrary, in the second tree class the proportion of straight trees did not change (15 to

Table 7. Percentage changes in diameter classes on plot Q

| Age | 23–33 | | | | | 33–43 | | | | | 43–73 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Change | *D* | ↓ | 0 | ↑ | *N* | *D* | ↓ | 0 | ↑ | *N* | *D* | ↓ | 0 | ↑ | *N* |
| Class 1 | 0 | 66 | 34 | 0 | 59 | 0 | 13 | 87 | 0 | 38 | 28 | 19 | 53 | 0 | 36 |
| Class 2 | 0 | 44 | 56 | 0 | 34 | 7 | 23 | 69 | 1 | 102 | 44 | 12 | 37 | 7 | 52 |
| Class 3 | 58 | 0 | 42 | 0 | 38 | 51 | 0 | 47 | 2 | 65 | 85 | 0 | 13 | 2 | 46 |

*D* – dead standing trees; ↓ – trees descending to a lower class; ↑ – trees getting to a higher class; 0 – trees maintaining their position; *N* – number of trees

Table 8. Mean annual periodic increment of basal area (*iBA* $m^2$), volume (*iV* $m^3$) and total periodic increment over 50 years

| Period | Plot 0 | | Plot Q | | Plot T | |
|---|---|---|---|---|---|---|
| | *iBA* | *iV* | *iBA* | *iV* | *iBA* | *iV* |
| 23–33 | 0.84 | 8.66 | 0.88 | 9.03 | 0.67 | 7.33 |
| 33–43 | 0.39 | 8.11 | 0.88 | 10.54 | 1.06 | 11.74 |
| 43–58 | 0.39 | 7.33 | 0.34 | 6.78 | 0.76 | 8.80 |
| 58–73 | –0.20 | 0.86 | 0.52 | 6.95 | 0.27 | 4.53 |
| Total | 16.2 | 297 | 30.5 | 401 | 32.7 | 391 |

Increment of living trees only

16%), but the proportion of crooked trees increased from 19% to 47%. The number of high-quality trees in the two upper classes was 218 individuals per ha (Table 3).

According to mean stand height (Table 6) the stand is classified to absolute height class 2 (26) of the Yield Tables of the Czech Republic (Černý et al. 1996). It is evident that from 30 years of age the stand without improvement fellings had by 60% more trees, by 20% larger basal area and by 13% higher standing volume than the values given by the tables. Only breast-height diameter of mean stem was smaller by 15% at the beginning of the period, later it was smaller by 3%.

### Quality selection (plot Q)

The number of trees in the stand on plot Q at the age of 22 years was higher by 2% (6,030 trees/ha) than on plot 0 and the diameter range was larger by 2 cm. The tallest trees were higher by 1 m. A total of 1,305 trees with diameter from 3 to 8 cm were removed from the vicinity of trees with straight stems and corresponding crowns by the first thinning; these were mostly co-dominant trees and also dominant and sub-dominant trees. A majority of these trees had slightly crooked and crooked stems. Some trees with straight stems were also cut. The number of trees with straight stems – potential candidates – was 1,975 (Table 3). Their mean diameter was 7.6 cm, height 9 m and the spacing 2–3 m. The thinning intensity was 21% as for the tree number and 8% in terms of the basal area. The range of diameter distribution did not basically change after this intervention because tree diameters after thinning ranged from 3 to 12 cm again (Fig. 3), but the tree number decreased to 4,730 individuals per ha and the basal area was reduced from 19.5 $m^2$ to 17.9 $m^2$ (Table 9).

In the course of two subsequent thinnings made within a decennium 810 trees of mean diameter 6.8 cm and basal area 2.9 $m^2$ were cut (Table 9). Co-dominant trees were mostly cut like in the first thinning; dead standing trees were also felled whereas their number (1,122 trees/ha) was almost the same as on the control plot (Tables 6 and 9). The majority of the previously truncated trees died as well as a part (58%) of the trees of the third diameter class left to cover the ground and to form vertical canopy.

In the first period diameter increment of trees was proportionate to breast-height diameter similarly like on plot 0, and true increment of the thickest trees was also identical (3.0 mm/year) (Table 5, Fig. 4). The diameter structure changed and enlarged to 3–16 cm and diameter classes enlarged to 3 to 7.3 cm; 7.4–11.7 cm; 11.8–16 cm.

Diameter increment increased in the next ten years when true increment of the mean tree of a constant set was larger by 11% than on plot 0 (3.5:3.9 cm).

Crown width was correlated with breast-height diameter according to the equation:
– crown width $CW$ (m) = –0.202 + 0.236 $d$ (cm)
– crown projection $CP$ ($m^2$) = –1.528 + 0.292 $d$ + 0.022 $d^2$

Table 9. Mensurational parameters of the stand on the quality plot

| Age | *N* | *BA* ($m^2$) | *V* ($m^3$) | *d* (cm) | *h* (m) | Thinning/dead trees | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | *N* | *BA* ($m^2$) | *V* ($m^3$) |
| 23 | 4,730 | 17.91 | 86.7 | 6.9 | 8.8 | 810/1,122 | 2.96/0.30 | 14/1 |
| 33 | 2,798 | 23.75 | 163.0 | 10.4 | 13.5 | 635/475 | 7.55/2.04 | 58/11 |
| 43 | 1,688 | 25.00 | 210.4 | 13.7 | 16.5 | 135/662 | 1.92/7.69 | 16/57 |
| 58 | 891 | 28.20 | 296.1 | 20.1 | 21.0 | 191/146 | 4.80/2.61 | 42/13 |
| 73 | 554 | 31.21 | 359.4 | 26.8 | 23.5 | | | |

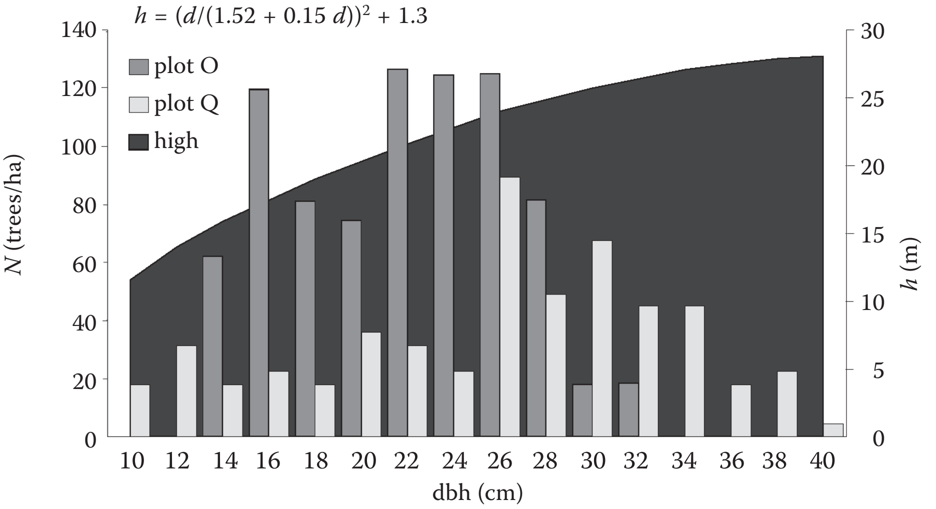


Fig. 5. Diameter distribution and height curve of 73 years old oak stand without thinning (plot 0 – line) and after 50 years selection thinning on plot Q

and increment on dbh according to the equation:

– *id* (mm) = –0.228 + 1.276 *CW* (m) (at the beginning of the growth period)
– *i dbh* area ($cm^2$) = –5.14 + 2.78 *CP* ($m^2$) (Chroust 1975).

The changes in diameter classes were more intensive in the first decennium than on plot 0 because 66% and 44% of trees descended from the 1st and 2nd class, respectively. On the contrary, 42% of trees maintained their position in the 3rd class while on plot 0 it was only 21%. No tree got to a higher diameter class (Table 7).

At the age of 33–43 years trees continued to descend from higher to lower classes, but their numbers were lower than on plot 0. In the third class only 51% of trees died while in the second class 7% died and 23% descended. Only 13% of trees descended from the first class compared to 44% on 0. This trend of smaller changes continued also in subsequent years (Table 7). Even though candidates were released, there was not a marked increase in the number of trees getting to higher classes although their diameter increment increased (Table 10). After 40 years the breast-height diameter of high-quality trees was 25.1 cm, being larger by 1 cm than that of high-quality trees on plot 0 (Table 10).

The representation of tree classes at the age of 73 years was identical to 0 because the proportion of trees of the 1st tree class decreased from 40% to 13% and the proportion of 2nd tree class increased from 33% to 63%. There were differences in qualitative structure when the proportion of straight stems of the 2nd tree class increased from 12% to 38% and was higher by 22% (63 trees) than on plot 0 (Table 3).

As a result of the higher diameter increment particularly in thicker trees the number of trees with breast-height diameter 31–40 cm at the age 73 years was 3.3 times higher in the stand with quality selection than in the untended stand.

The higher diameter increment was reflected in the increment of basal area and stem volume (Table 8). Periodic increment *iBA* of living trees in the second period was twice higher than on plot 0. In the subsequent period (43–58), when a thinning was made after 15 years, *iBA* decreased to 0.34 $m^2$ and *iV* to 6.8 $m^3$. It was caused by high mortality of declining trees left in the stand. Nevertheless, total increment of *iBA* over 50 years of living trees was 1.9 times higher on plot Q and *iV* was 1.3 times higher than on plot 0.

The basal area at the age of 73 years was 31.2 $m^2$, being by 10% smaller than the basal area of untended stand; the standing volume (359 $m^3$) was lower by 5%. The largest difference was in the number of trees that was lower by 37% in the stand with quality selection. On the other hand, the mensurational parameters of plot Q were almost identical with tabular values for

Table 10. Mean annual diameter increment of mean tree in the set of 30 target trees and of parallel ones from the set of 30 candidates on plot Q and on plot T

| Period | Plot 0 | | Plot Q | | Plot T | |
|---|---|---|---|---|---|---|
| | *d* (cm) | *id* (mm) | *d* (cm) | *id* (mm) | *d* (cm) | *id* (mm) |
| 33–43 | 12.3 ±1.1 | 3.7 ± 0.5 | 12.1 ± 2.2 | 4.0 ± 1.6 | 12.1 ± 2.3 | 4.7 ± 1.2 |
| 43–58 | 15.8 ±1.7 | 3.0 ± 0.8 | 16.1 ± 3.4 | 3.4 ± 1.4 | 16.8 ± 3.1 | 3.8 ± 1.2 |
| 58–73 | 20.3 ±1.8 | 2.5 ± 1.1 | 21.3 ± 5.5 | 2.8 ± 1.5 | 22.6 ± 4.4 | 3.6 ± 1.7 |
| Age 73 | 24.0 ± 2.6 | – | 25.1 ± 7.1 | – | 28.1 ± 5.5 | – |

Table 11. Mensurational parameters of the main stand on the target plot (T)

| Age | $N$ (trees) | $BA$ ($m^2$) | $V$ ($m^3$) | $d$ (cm) | $h$ (m) | Thinning/dead trees | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | $N$ | $BA$ ($m^2$) | $V$ ($m^3$) |
| 23 | 4.850 | 17.01 | 77.6 | 6.7 | 8.3 | 460/703 | 1.90/2.60 | 9/13 |
| 33 | 3.687 | 21.81 | 141.7 | 8.7 | 12.5 | 806/712 | 5.87/1.80 | 38/7 |
| 43 | 2.169 | 26.59 | 221.0 | 12.5 | 16.3 | 812/363 | 8.31/2.15 | 44/11 |
| 58 | 994 | 29.73 | 309.2 | 19.5 | 20.8 | 81/244 | 1.24/6.20 | 10/59 |
| 73 | 669 | 32.53 | 368.2 | 24.9 | 23.1 | – | – | – |

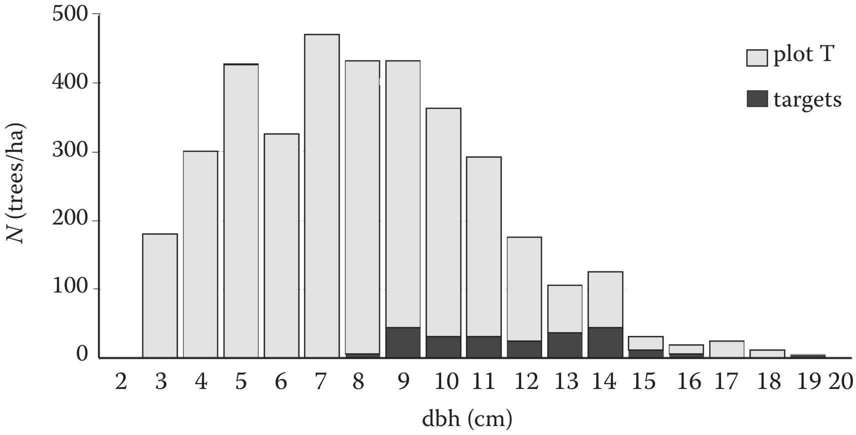


Fig. 6. Diameter distribution of the stand and target trees of 33 years old oak stand on plot T (1963)

absolute height class 26 because a difference in tree number was 0.5%, in basal area 4.7% and in standing volume 3%. The breast-height diameter of mean tree and total increment differed from the tabular values only by 2.7% and 3.8%, respectively (Table 9).

**Quality selection with target trees (plot T)**

The stand density and structure at the time of experiment establishment were similar like on the other plots (Table 2).

After the first negative high thinnings at the age of 22 years the number of trees decreased to 4,850 individuals per ha (Table 11).

At the age of 33 years, when mean stand height was 12.5 m and tree number was 3,687 individuals per ha (Table 11), forty target trees were identified and marked on a plot 0.16 ha in size, i.e. 250 trees per ha. The number was 2.5 times higher than recommended by Abetz and Ohnemus (1994). These trees mostly belonged to the class of co-dominant and also of dominant and subdominant trees if they had straight stems and adequate crowns. Their quality was considered more important than their vitality and their increments were assumed to increase after their release. Their diameter ranged from 9 to 19 cm ($d$ = 11.6 ± 2.8 cm) and height from 10 to 18 m. After they were marked, they were released in the crown canopy, and vegetating truncated undergrowth and a part of sub-dominant trees were removed at the same time so that the target trees could be underplanted with beech and lime. Underplanting was carried out after 2 years, at the age of 35 years.

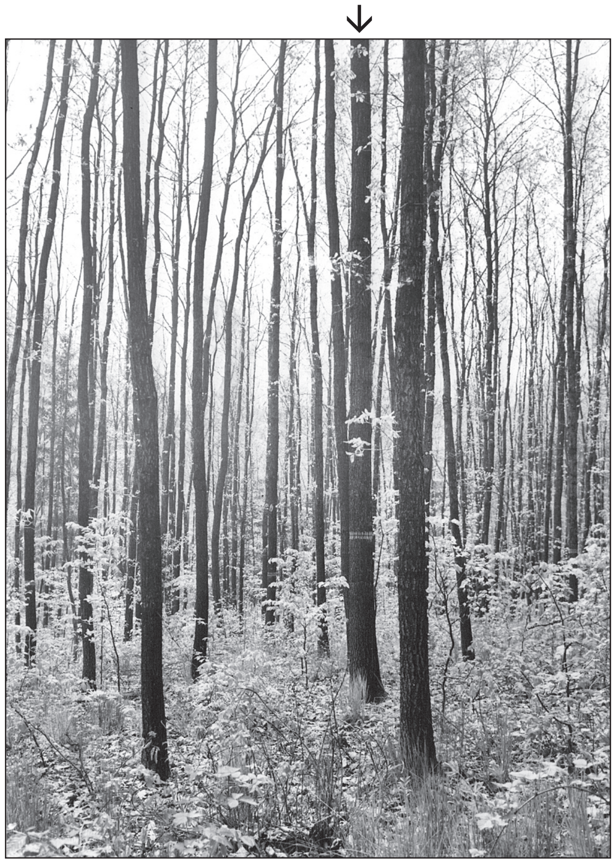

Fig. 7. Target trees on plot T at the age of 41 years (1971)

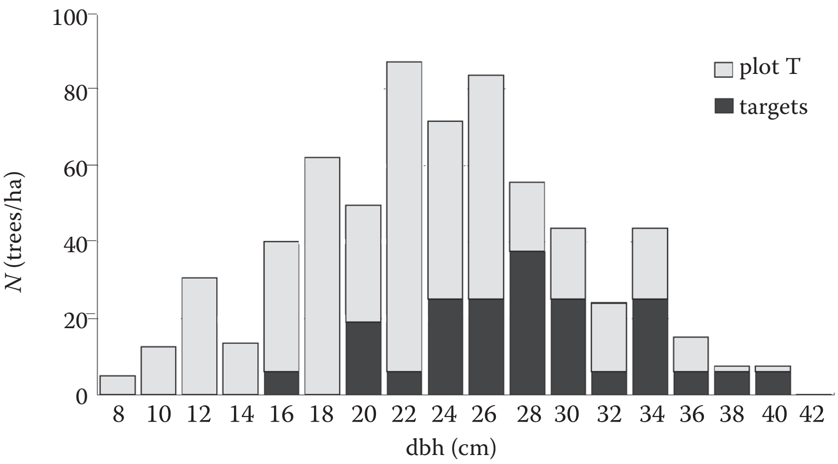


Fig. 8. Diameter distribution of the stand and target trees at the age of 73 years

In the period of 33–43 years, when thinnings were concentrated in the vicinity of target trees, in thirty out of these trees their diameter increment increased by 17% compared to the mean tree of the parallel set of trees on plot Q, and by 27% compared to trees of set 0 (Table 10). While in ten trees it stagnated at 4.0 ± 1.7 mm, the increment of five (16%) trees of the second class was so high (6.0 ± 1.4 mm/year) that they got to the class of the thickest trees.

In the last 20 years, out of the original 40 trees, ten trees died (25%) (root rot) and six individuals had crooked stems. After 50 years breast-height diameters of target trees ranged from 15 to 40 cm, the mean value was 28.1 ± 5.5 cm. It was by 3 cm higher than the mean diameter of trees in the parallel set of candidates on plot Q and by 4 cm higher than in set 0.

At the age of 73 years the number of all trees decreased to 669 trees/ha, basal area increased to 32.5 $m^2$ and the volume to 368.3 $m^3$ (Table 11). The total periodic increment over 50 years on basal area (32.7 $m^2$) was higher by 2.2 $m^2$ than on plot Q but volume increment was by 10 $m^3$ lower (Table 8).

The lower story, the height of which was from 3 to 6 meters after 40 years, developed from the underplanting with shade-tolerant broadleaves trees.

Fig. 9. Target trees on plot T at the age of 73 years (2003) (a, b)

The number of beech trees was about 850 individuals/ha with mean diameter 5.2 cm and basal area 1.8 $m^2$/ha, the number of lime trees was ca 770 individuals/ha with mean diameter 8.1 cm and basal area 4.0 $m^2$/ha.

## SUMMARY

The stand density on plot 0 that was left without tending measures was slowly reduced and basal area increment decreased. Nevertheless, the number of trees at 73 years of age was higher by 33% than given by the Yield Tables of the CR (Černý et al. 1996) for absolute height class 26, and the basal area and standing volume were higher by 23% and 26%, respectively. On the contrary, the breast-height diameter of mean tree was smaller by 4%. It means that the diameter increment of trees was small and thinner trees prevailed in the stand. These were mostly straight trees.

Quality selection increased both the diameter increment of trees in all diameter classes and the increments of basal area and standing volume. The increment at breast height correlated with the crown width while the increment of basal area correlated with its projection. The number of trees with straight stems increased by 16%, and after 50 years the number of trees above 30 cm in the stand was 3.3 times higher than in untended stand.

Compared to the plot with quality selection the growth of the stand with target trees was lower by 2.5% only if measured by volume production but at 73 years of age it comprised by 43% less trees with diameter above 30 cm and by 15% less trees with straight stems. The periodic diameter increment of 75% of target trees was by 35% higher than in the parallel set of "candidates" and their breast-height diameter was by 12% larger at 73 years of age. Although 25% of target trees died and the quality of some trees deteriorated, 24 trees and/or 150 trees/ha high-quality trees remained on the plot. The diameter increment of target trees that were released in a concentrated way from 33 years of age was higher than the increment of candidates that were released gradually (the better tree was always released).

## DISCUSSION

The findings from the experiment conducted to verify Schädelin's ideas about the effect of his quality thinning on the development and growth of oak small pole stage are as follows:

(1) It is not rational to seek and free trees in the lower trees class because their revitalisation occurs only exceptionally, like in pine stands (Abetz, Chroust 2004).

(2) In the small pole stage where thinnings were performed there were 1,818 crop trees/ha. It almost corresponds to the number of trees considered by Schädelin (2,000–3,000 trees per ha). In Korpel's (1964) experiment the number of crop trees in the small pole stage was 1,700 individuals per ha.

(3) In agreement with Leibundgut (Leibundgut 1976) the release of crop trees (candidates) was found to influence diameter increment positively. A systematic release of target trees resulted in a larger increment.

(4) Diameter increment and basal area increment were proportionate to crown width and horizontal projection; the thicker the tree, the larger the increment (Utschig, Pretzsch 2001; Lockow 2003; Reushler et al. 1993).

(5) In the stand with repeated quality selection and in the stand with target trees the number of high-quality trees at the age of 73 years is twice to three times higher than the number of target trees (90–100) recommended by Abetz and Klädtke (2002).

(6) The selection of candidates and target trees at the small pole stage is a premature and risky practice because in spite of their initial high quality they may be deformed in the course of time (Kennel 1979; Richter 1979; Spellmann, Dies 1990; Assman 1961; Mosandl et al. 1991). Not even the high vitality, considered as a primary trait for target trees (Abetz, Klädtke 2000; Abetz 1989; Kenk 1976), prevented their infection by rot and their mortality.

(7) In the course of fifty years a majority of changes in diameter and tree classes was in a downward direction in all stands (Leibundgut 1976; Schaper, Röhrig 1983) while Schädelin's assumption of changes towards higher classes was confirmed only in 2% and 7% of the cases. Therefore an effort to grow elect trees from less vital although good-quality trees is doubtful.

(8) In connection with the fact that the number of high-quality trees in the untended stand at the age of 73 years is twice higher than expected at the maturity age there arises a question whether it would not be more reasonable and effective to continue negative selection that started at the stage of assistance cuttings until the small pole stage or pole-stage stand and only when the stem part reached the length of 10 m to begin positive selection of candidates and target trees as recommended by Schütz (1987). The canopy

maintained until the age of fifty years would ensure regular annual rings, and long and clean stems (Wagenknecht 1962).

## CONCLUSION

Although the experiment did not confirm Schädelin's theory of changes taking place in young stands, the application of his stepwise selection of candidates is suitable even for oak stads. However, its labour consumption is high (Schütz 1987) because it operates on the basis of frequent care of an excessively high number of trees (ca 2,000 individuals) but only about 5% of them require such a care. This is the reason why its rational choice of canditates is focused only on vital straight trees, or implemented selection variant by Abetz (1974), Abetz and Klädtke (2002) in the form of target trees (Z-Bäumen). It can be considered more reasonable but only if the prescriptive number (80–100 trees per ha) is increased to a double stock like recommendied Assmann (1961) for beeach stands.

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## Jakostní výběr v mladých dubových porostech

**ABSTRAKT**: Článek pojednává o experimentu, který byl založen Výzkumnou stanicí VÚLHM Opočno v r. 1952 v dubové tyčkovině za účelem ověření, zda výchovná metoda SCHÄDELINA (1942), vyvinutá v bukových porostech, je vhodná i pro porosty dubové. Je analyzován vývoj a růst porostu bez výchovy a popsán vliv opakovaných pozitivních zásahů a zásahu jednorázového na dubový porost. Výsledkem bylo zjištění, že Schädelinova metoda je vhodná i pro dubové porosty a je efektivní za předpokladu, že výběr jakostních stromů se od stadia tyčkovin soustředí jen na vitální jedince.

**Klíčová slova**: *Quercus robur* (L.); výchova porostu; přírůstek; jakost

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