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Evaluation of the corridor method for oak (*Quercus* sp.) cultivation using research objects in the Mircze and Kościan Forest Districts as an example

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Abstract. The corridor method of oak (*Quercus* sp) cultivation is an old, forgotten silvicultural method. It was developed around the turn of the 19th and 20th century on the south-eastern borders of Poland (Podole, Wołyń) and Russia and made use of other species such as hornbeam, linden and birch as a cover for oak, which is a tree species sensitive to frosts. The nowadays recurring phenomenon of oak disease initiated a search for silvicultural alternatives and thus the usefulness of reviving the corridor method for oak regeneration was investigated by examining existing tree stands established in this way. Our research plots were located in five young stands and two in mature as well as old stands.

In the stands of the 2nd and 3rd age classes, the density of oaks was observed to be 1500–3500 /ha, which accounted for 30–50%. The density of oak in old stands (7th age class) was similar to model-predicted values. Furthermore, the corridor method gave very good production results as exemplified by the oak stands growing on the fresh broadleaved site, which had a very high stand quality index. In addition, the species composition was observed to diversify throughout these oak stands' development, thus supporting arguments for the conservation and preservation of oak-hornbeam forests. To summarise, the prerequisites for the success of the corridor method are systematic cuts of young stands (forest cultures and thickets) to inhibit the growth of accompanying undesired species and limiting the number of grazing animals.

Keywords: oak, corridor method, oak cultivation, forest regeneration, stand tending

1. Introduction

Over the 250-year old history of European forestry, a range of methods for growing oaks (*Quercus* sp.) have been developed. Some of them have fallen into disuse, yet a choice of oak growing techniques was evoked by Andrzejczyk (2007, 2009, 2011). Contemporary silviculture concerning semi-natural forests uses both the experience of past generations of foresters and new research (Zajączkowski 2003, Bernadzki 2011) as a comprehensive combination of tradition and modernity. In recent times, interest in alternative methods of oak regeneration has been increasing. Attempts to use these methods are every so often dictated by various reasons, including difficulties in oak regeneration with the use of traditional methods (e.g., planting in rows or in groups). In research undertaken in consequence of irregularly occurring periods of oak dieback, more and more attention has been paid to silviculture as a tool to increase oak stand resilience. The appropriate method of regeneration and properly performed tending treatments at each stand developmental stage may have a significant positive effect on shaping the resistance of oak solid stands (Bernadzki, Grynkiewicz 2006, Paluch, Gil 2006). For this purpose, Bernadzki and Grynkiewicz (2006) pointed out the possibility of using the corridor method of oak cultivation, while stressing the importance of shaping mixed stands to decrease the silviculture risk.

The corridor method of oak cultivation developed at the turn of the 19th and 20th centuries and was implemented in the forests situated in the erstwhile south-eastern Poland (Podole, Wołyń) and in Russia. The method included planting additional tree species as the admixture protecting frost-

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sensitive oak, with a positive effect on the oak environmental conditions and growth as well as wood quality (Jodko 1936). In the pages of the forest periodical Sylwan from 1910, one can find confirmation of the utility of the title method and its widespread use in the forests of the Tula area (Dobruwiński 1910).

The method was described in more detail in the textbook by Sokołowski (1930), and afterward – by Tyszkiewicz and Obmiński (1963). As stated by these authors, the corridor method was instigated by a Russian researcher – Molczanow, who at the end of the 19th century applied in practice the cultivation technique, which later developed in the so-called corridor method. It consisted of planting or sowing oak in rows, on 0.5 m x 0.5 m square sites – designated in 1–2 m wide corridors shaped within the natural regenerations of various species trees growing at a considerable distance from each other (4–8 m). The distance of oaks in rows was about 1 m when planted or 0.75 m in the case of sowing, and seedling density was about 2.5 thousand specimen/h. The planting was usually performed several years after clear-cutting; thus, a vegetation cover for newly planted oak seedlings had been already shaped. As the trees were growing and treated with tending, larger and larger gaps were formed around them, and visible corridors were formed along the rows (Tyszkiewicz, Obmiński 1963). Russian foresters referred to this method as making a 'fur coat' ('szuba') around oak seedlings. At an early age, the oak trees were provided with a side shielding by other tree species, and the tending treatments were carried out carefully to ensure that seedlings had adequate access to light. As it was emphasised, oak likes to grow 'dressed in "szuba" but with bare head'. Jodko (1936) suggested oak planting in rows about 4 m apart, and then replenishing the gaps between the rows with different species of trees.

In modern times, the corridor method of oak cultivation is rarely used. In seeking rational silvicultural solutions for continual oak dieback, the Forestry Research Institute analysed the results of using the corridor method – based on data from only a few existing mature stands established in this way.

The aim of the present study was to evaluate the corridor method of oak cultivation in view of the silvicultural practice, based on the stands at various stages of development as well as to assess the suitability of the method to achieve silvicultural objectives in the fresh broadleaved forest site.

2. Study objects and methods

The study objects were tree stands with the share of oak (2nd, 3rd, 5th and 7th age classes), earlier established using the corridor method. In the 1980s, in the Forest District Mircze (Lublin Regional Directorate of State Forests – RDLP Lublin, south-eastern Poland), several areas were regenerated by planting the main and admixture tree species at the same time; hence, the method analogous to the corridor oak cultivation was used. The oak was planted in the 'corridors' (distance between rows: 3–4 m and within a row: about 1 m), that is, the initial density of seedlings (about 2.5–3 thousand specimen/ha) was reduced as compared to that recommended (6–8 thousand specimen/h) by the 'Silvicultural Principles' (DGLP 2012). For the purpose of this study, in 23–48 years old stands, three 4-are study plots were established in five forest units selected in the fresh forest sites. The study plots M1, M2, M3, M4 comprised forest stands with prevailing oak of the 2nd age class, whereas the plot M5 comprised oaks of the age class 3a. A brief forest valuation of the plots is presented in Table 1.

Notwithstanding the admixture tree species listed in the species composition of every forest stand, in each stand under the study, there occurred hornbeam, as well as relatively small populations of lime and hazel. There were also observed admixtures of valuable species, such as: sycamore and cherry.

Additionally, 2 study plots were established within the Forest District Kościan (Poznań Regional Directorate of

Table 1. Characteristics of selected stands in Mircze Forest District, established according to the corridor method of oak cultivation (SILP database 2009)

Forest subdistrict	Forest compartment	Stand code	Age [years]	Species composition*	Stand density index	Stand quality index
Terebiń	32d	M1	32	9Db 1 Brz	0.7	II
Terebiń	32f	M2	27	9Db 1 Js	0.9	II
Terebiń	46h	M3	27	9Db 1Js	0.9	II
Terebiń	47k	M4	23	8Db 2Js	0.9	II
Dołhobyczów	184c	M5	48	4Db4Brz1Js 1Gb	0.8	I

*Db – oak, Brz – birch, Js – ash, Gb – hornbeam

State Forests – RDLP Poznań, western Poland), within oak stands at the age of 82 and 128 years, growing in the fresh forest site (Table 2). The stands were regenerated using the corridor method, which was reflected in the distribution of trees within the plots in the measurement year and confirmed in personal communication with forest managers. In each study object, there was established 1 study plot (25-are) – representative of the oak stands under the study. In the stand K1, with differentiated species composition, a fragment with a solid oak stand was selected for further measurements. Oak trees were planted in rows alternately with two rows of birches, which were later removed – before planting the hornbeam undergrowth (personal communication with the forest division manager). During the study period, the height of hornbeams in K1 stand was up to the bases of the crowns in the main stand. The average distance between the measured oak rows was about 4 m. In the undergrowth of the stand K2, there prevailed bird cherry (under tending treatments) and planted beech seedlings. Within the K2 plot, the average distance between oak rows was about 4 m.

The following oak features were measured within all the experimental plots: DBH, the total tree height and the height of the living crown. Each oak was classified into one of 2 categories: prospective (good) and all the other. Prospective trees were characterized by very good/good trunk quality, vitality and well-shaped crown.

In each surveyed stand, an analysis of tree density was performed using the method given by Bernadzki (2006). The author estimated the growth space for one prospective tree, and this result was used to determine adequate density of prospective oaks under the present study (Table 3).

3. Results

In the stands of the 2nd age class, the fresh forest site was clearly dominated by pedunculate oak admixed with hornbeam and valuable species, such as lime, sycamore, ash and cherry. In several stands, birch constituted an important component. The populations of tree species competing oak – mainly hornbeam and birch, occurring in the main stand – was small in the studied stands and did not exceed 200 specimen/ha. The density of oaks within the study plots ranged from 1.5 thousand to 3 thousand specimen/ha, which can be considered as up to the recommended standard. In general, 80–90% of oak population within almost all the studied stands (M1, M2, M3, M4) constituted the prospective trees. Outstandingly, in M5 stands with accompanying birch admixture, just 70% oaks were evaluated as prospective (Fig. 1). Depending on the study plot, the average DBH ranged from 9.4 cm to 15.4 cm, the average tree height – from 10.2 to 15.5 m, and the average crown length – from 5.4 to 7.2 m (Table 4). The range of obtained values, even with the similar age of the observed tree

Table 2. Characteristics of selected stands in Kościan Forest District, established according to the corridor method of oak cultivation (SILP database 2009)

Forest subdistrict	Forest compartment	Stand code	Age [years]	Species composition*	Stand density index	Stand quality index
Turew	143 d	K1	82	6Db2Md2Dbc	0.8	II
Turew	134 k	K2	128	10Db	0.8	II

*Db – oak, Md – larch, Dbc – red oak

Table 3. Growth space and sufficient density of oaks in subsequent development phases (Bernadzki 2006)

Stand development phase (approximate height)	Approximate growth space of one future tree [m^2]	Sufficient density of future oak trees [pcs/ha]
High undergrowth (up to a height of about 5 m)	5–10	1000–2000
High pole stand (up to a height of about 15 m)	10–20	500–1000
Second storey of the stand (height above 15 m)	> 20	at least 200–300

stands, indicated great possibilities to shape stand features by means of tending treatments. The records of precedent tending cuts carried out within the studied stands indicated fewer treatments performed in M5 area, when compared with other plots under the present study. On all the observed plots, young oaks had trunks of high quality (without branches), the average height of the living crown was almost 60% of the total tree height, which means that throughout stand development, the initial and subsequent density of oak and accompanying tree species promoted the trees of good quality. Figure 2 shows the relative length of the crown in the studied stands, which ranged from 45% to 55% of the total tree height. Hornbeams and other species had effects on quality of oak trunks, and this contributed to the improvement of the main stand silvicultural quality. In the stands shaped that way, oak trees showed excellent height increase, and under the observed site conditions (fresh forest), they achieved fully satisfactory, high, (or even slightly higher as compared to the recommended standard) values of growth characteristics. The latter was determined based on the data collected in the field, as available valuation descriptions had underestimated factual oak productivity on the rich soils in the examined forest site (black soil with high percentage of humus and soils formed from clay-loam deposits). The evaluated silvicultural quality, density and growth characteristics of M1, M2, M3, M4 oak stands (mixed with hornbeam) were better as compared with M5 stand (mixed with birch).

The results of the evaluation of the corridor method performed in the oak stands of older age classes were also satisfactory. In the stand of the 5th age class (K1), the average DBH of oaks was 30.7 cm, the average height was 25.3 m, and the crown length – 15 m (the average relative crown length was 40%). Oak trees were of good silvicultural quality, with properly formed crowns and straight trunks. Their density was 252 specimen/ha and even though it was lower than the recommended standard, the stand total volume did not differ from the model values (Tab. 5).

In the solid oak stand K2, the trees showed good health condition. The average DBH was 49.9 cm, the tree height – 30.3 m, and the crown length – 20.1 m (the average relative crown length – 66%). Oak trees were of good silvicultural quality, had properly developed crowns and straight trunks.

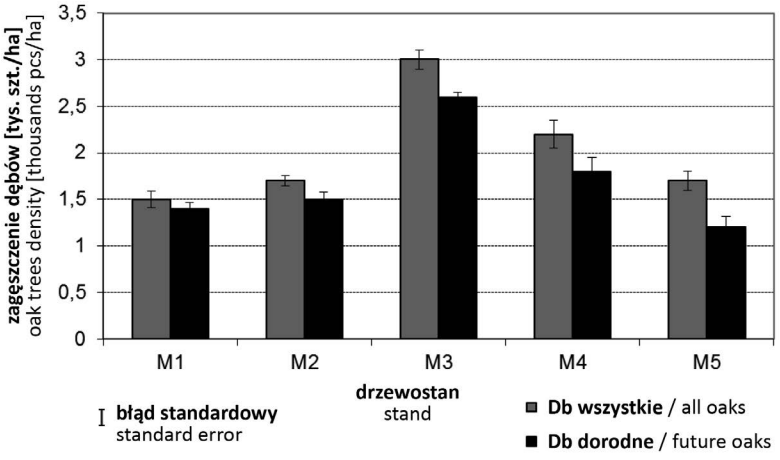

Figure 1. The density of all and future oaks in the studied stands of Mircze Forest District (explanations of symbols M1–M5 in table 1)

Table 4. The average values of biometric parameters of oaks in stands of the 2nd and 3th age classes, established according to the corridor method in the Mircze Forest District

Forest subdistrict	Forest compartment	Stand code	DBH [cm]	Height [m]	Crown length [m]
Terebiń	32d	M1	15.4	15.5	7.2
Terebiń	32f	M2	13.7	13.9	6.3
Terebiń	46h	M3	11.8	13.5	6.3
Terebiń	47k	M4	9.4	10.2	5.4
Dołhobyczów	184c	M5	10.3	11.0	5.5

Their density was 124 specimen/ha – almost identical to the standard density, and the stand total volume exceeded the predicted standard value by 17%.

4. Discussion

The reduction of the initial number of oak trees in the forest stand can be justified not only by the need to lessen the physical contact between seedlings, but also – to accomplish the appropriate oak density (100–120 specimen/ha) within the future mature stand (Szymkiewicz 1966). The results of the present study show such density in old tree stands with oak share that were established with the use of the corridor method. In the observed stands M3 and M5, the oak density exceeded the model values. The number of trees per 1 ha in 3 younger stands (M1, M2 and M4) was considerably lower (about 50–60%) than the standard values elaborated by Szymkiewicz (1966). Nevertheless, consistent with Bernadzki (2006), it can be assumed that the number and growth space of prospective oak trees under the study were satisfactory.

Other tree species were planted between the oak corridors, and among others, these were birch and hornbeam. The use of such a method of oak regeneration on fertile soils was dictated primarily by seedling shortages as well as manpower and equipment scarcity. The chances of success in experimental oak cultivation with the use of the corridor method were quite high due to the relatively low populations of grazing animals. However, by reason of the likelihood of oaks being suppressed by faster growing admixture species, indispensable intensive tending treatments were performed (removing tops and ringing competitive trees). These were not carried out carefully and systematically in each and every stand, which resulted in non-implementation or partial implementation of the silvicultural goal. For example, in the studied stand M5, birch became an important component, although it was initially supposed to constitute a temporary admixture species.

The adequate silvicultural value of oak stands at various ages – established by the corridor method – indicates the prospect of growing good quality oak at considerably reduced initial density and in the presence of accompanying species, which is doable already in the early stages of stand development. The basic problem in oak cultivation is to secure seedlings against frost until they reach the height of 1.5–2 m, that is, until 6–8 years after planting (Andrzejczyk 2009). The prerequisites for success are: proper, systematic tending (consisting mainly in inhibiting the growth of planted admixture species) and the control of grazing animals. During continuous dieback of oak stands, the described me-

Table 5. The average values of biometric parameters of oak trees and oak stands on the study areas in the Kościan Forest District

Forest compartment	Volume [m^3/ha]	Number of trees [pcs/ha]	Volume according to yield tables* [m^3/ha]	Number of trees according to yield tables [pcs/ha]	DBH [cm]	Height [m]	Relative crown length [%]
143d	255	252	262	299	30.7	25.3	40
134k	395	124	338	126	49.9	30.3	66

* Szymkiewicz B. 1966. Tablice zasobności i przyrostu drzewostanów [Yield tables of forest stands]. PWRiL, Warszawa, 1–159.

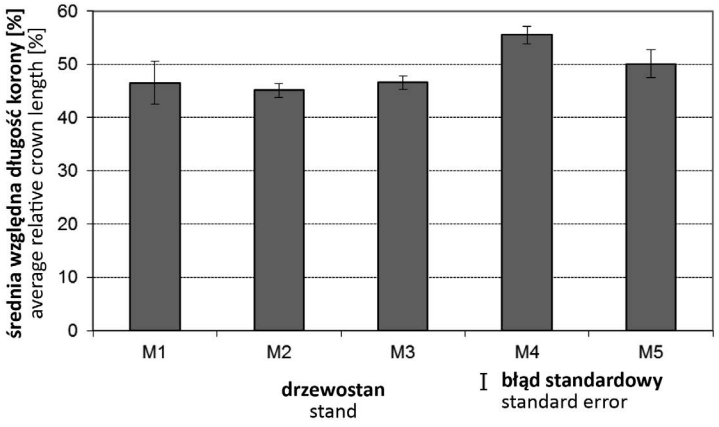

Figure 2. The average length of oak crown in the studied stands of Mircze Forest District (explanation of symbols M1–M5 in table 1)

thod has already been recommended as one of the solutions as regards oak cultivation in Poland's forests (Bernadzki 2006, Bernadzki, Grynkiewicz 2006, Paluch, Gil 2006).

From the very beginning of the development of the planted oak stand, a considerable (sometimes dominant) share of admixture species (hornbeam, lime and other deciduous species occurring in oak-hornbeam forests) is conducive to the species composition of the forest natural habitat comprising multispecies composition of oak-hornbeam forests – habitats protected under the Natura 2000 network. It seems that the discussed method would enable shaping a valuable tree stand in terms of both ecological and economical objectives. Grünebaum et al. (1993) came to similar conclusions in their study on sessile oak stand established using the corridor method (sowing on 2 m wide strips, 4 m apart). The examined trees at the age of 120 years reached the average height higher than 30 m and 38 cm DBH. The stock size was 438 m^3/ha, and the number of trees was 238 specimen/ha. The technical quality of the trees examined was not any worse than that in the stand developed from natural regeneration.

In modern forestry, there exists a variety of ways of oak regeneration, based on the concept same as that in the corridor method, that is, planting alternate rows of oak and other tree species (final or temporary admixture) (Andrzejczyk 2007, 2009). In most cases, the admixture species are planted, for example, every fourth row or else – every other row. Oak seedlings can also be planted every 3 m, and the remaining area is left for natural regeneration of admixture species (pine – in fresh mixed forest sites or hornbeam – in fertile sites). It is also possible to artificially introduce admixture species in a later stage of stand development (thicket). The approach described above, reminiscent of the classic corridor method, reduces silvicultural risks and is fully justified under the conditions of oak dieback. A similar method of oak cultivation was also used in Western Europe, for example, in Austria, where the planting standard was from 2 to 4 thousand specimen/ha, and every other row was planted with shielding admixture (hornbeam, lime). Spontaneous emergence of trees such as aspen or birch complemented the stand species composition (Hochbichler 1993).

The corridor method of oak regeneration can be treated as a rational alternative to the other methods of introducing this species, for example, traditional planting at a relatively high density or following the 'square site method' by Szymański (1986).

5. Conclusions

1. Already at early stages of stand development, the corridor method ensures good quality oak growing at a significantly reduced initial density and in the presence of admixture species. At the same time, multispecies composition maintained starting from early stages of stand development promotes conservation of the oak-hornbeam habitat.

2. The corridor method of oak cultivation gives very good production results under broadleaved forests conditions. Stands reach growth characteristics of the first or superior growth classes.

3. In the stands of the 2nd and 3rd age classes, that were established by means of the corridor method, oak density ranges from 1.5 to 3.5 thousand specimen/ha, which is 30–50% of the density given in the standard recommendations ('Tables of tree stand volume and increment'). With time, the tree density in old growth stands reaches almost the model value characteristic for the 7th age class.

4. The prerequisite for the success of establishing an oak stand by the corridor method is carrying out tending treatments consisting mainly in inhibiting the growth of admixture species, as well as controlling the number of grazing animals.

Conflict of interest

The authors declare no potential conflicts.

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Authors' contribution

R.P, W.G. – concept, methodology, literature review, field measurements; R. P. – statistics; R.P., W.G. – manuscript preparation.