

Cutting practices in mature stands of *Tilia cordata* Mill.

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Abstract

The right timing for replacing mature and over-mature forest stands with a young generation of trees is evident as it ensures continuity in forest management. The study aimed to assess the efficiency of cutting practices in mature stands of *Tilia cordata* Mill. Mono-dominant and poly-dominant, even- and different-aged linden tree forests in the southern Urals were studied. The study found that in the first years following the small scale forest cutting practices (the Murakhtanov method), retention trees of *Tilia cordata* Mill. showed longer crowns (by 0.3 ± 0.01 m) and higher crown diameter indices (by 0.11 ± 0.04 m). A single selection showed that nectar secretion potential was 2.1 ± 0.06 mg/flower in the first assessment year, the index was 1.8 ± 0.03 mg/flower in the control forest area where no trees were cut. In the third assessment year, nectar secretion potential rose to 4.1 ± 0.04 mg/flower, while the index fell to 2.0 ± 0.01 mg/flower in the control forest area. The comparative analysis of the shoot growth capacity in stools of different diameters showed that shoots regrew from 82% of stumps. Shoots did not regrow from stumps affected by rot, those ones destroyed in the cutting process, and also from stumps of 59 – 62 cm in diameter.

Key words: coppice shoots; nectar-producing tree; regeneration; small-forest cutting; *Tilia cordata* Mill.

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1. Introduction

Forest stands of *Tilia cordata* Mill. (henceforth referred to as TC) make up the bulk of the primary deciduous forests (Bauhus et al. 2010). In temperate forests, TC is the most widespread (Bauhus et al. 2010; Samsonova 2012; Kulakov 2013) among the four species of the *Tilia* genus growing naturally in Europe. Growing in less than 5% of forests (Forest Peoples Program 2017), the species population varies significantly across Europe (Bauhus et al. 2010; Harmon et al. 2013). TC grows in a wide range of environments. In Northern Europe, the species grows as far as Central Sweden and southern Norway (Svejgaard 2003; Pigott 2012). In the south, the species prevails in forest stands as far as Northern Greece and the Northern Iberian Peninsula. TC stands extend from Northern Ireland to the TransUrals (Gellini&Grossoni 1998; Pigott 2012).

Compared to other deciduous woody plants, TC is less sensitive to temperatures and soil fertility (Konashova et al. 2018; Sultanova et al. 2019). Broad adaptability of the species is recognised by most researchers (Hölscher et al. 2005; Bréda & Badeau 2008; Popescu et al. 2014; Gilman et al. 2016; De Jaegere et al. 2016; Lundmark et al. 2017). Due to its high shade tolerance when young

and thanks to its advantageous vegetative reproduction, TC can be considered a competitive species. The shade tolerance varies from moderate (Popescu et al. 2014) to high (Pigott 2012) in the species. This feature mainly depends on the growth stage, climatic aspects, and geographical location (Diekmann 1996). A relatively high occurrence of the linden tree may be accounted for by its vegetative origin as the species grows through coppice shoots and root suckers. TC produces more coppice shoots than oaks and hornbeams. Also, the linden coppice shoots have higher length and diameter growth indices (Pigott 2012; Sultanova et al. 2019). Due to the aspects mentioned earlier, the linden tree is widely used in protection forests, urban greening practices, and for commercial wood and nectar-related purposes.

Among all *Tilia* species, TC is of the highest value due to its full ecological range and numerous silvicultural advantages, when growing in mixed forest stands in particular (Pigott 2012). TC can prevail in the canopy formation, often mixed with genera such as *Quercus*, *Acer*, *Betula* (Tóth et al. 2012; Beaune et al. 2013). The TC shows good growth indices when mixed with *Carpinus betulus* L., *Picea abies* (L.) Karst, *Abies alba* Mill. and *Pinus sylvestris* L. (Jaworski et al. 2005). In the southern Urals, the TC stands build a complex dynamic system

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characterized by population-related, environmental, geographical, and biocenotic features. TC grows in the area of 1148.4 thousand hectares on the territory of the Republic of Bashkortostan (henceforth referred to as RB), occupying 22% of the forest-covered lands with a total reserve of 209.3 thousand m³.

The area of 157.7 thousand hectares is devoted to the ‘nectareous linden’ working circle in RB. The efficient application of TC for honey-related purposes can be reached through forming a composite, uneven-aged forest stand with two and more layers. Uneven-aged forest stands ensure continuous production for commercial wood and nectar-related purposes and increase the nectar secretion period in the trees.

The principal objective of successful forest management is to enhance productivity, improve the age and quality structure in TC stands, appropriately use wood resources as well as ensure regeneration of linden trees. There are many forest management practices aimed at obtaining efficient and continuously productive TC stands. Priority is placed on various cutting practices as they have a long term effect (Ministry of Natural Resources and Ecology of the Russian Federation 2016, 2017; Sultanova et al. 2019). Cutting practices ensure the rapid growth of stool coppice shoots. The coppice method is a crucial factor in the successful regeneration of deciduous forests (Popescu et al. 2014; Sultanova et al. 2019). The selection of trees for cutting is based on several factors, such as economic, qualitative, and bio-ecological characteristics of wood species. The key point in determining the cutting practice parameters is the selection of trees for cutting, taking into account their environmental biological and qualitative characteristics (Crecente-Campo et al. 2009; Ministry of Natural Resources and Ecology of the Russian Federation 2016, 2017). The following criteria are employed by some researchers to assess the efficiency of cutting practices: the forest standing volume, growth, stand density, and tree growing area (Gellini & Grossoni 1998; Crecente-Campo et al. 2009; Li et al. 2017).

Although TC is widely distributed in Europe, few studies described its growth and productivity. The studies focused on growth aspects in various environments. For example, Böckmann (1990) presented growth stage tables reflecting changes in the forest stand volume to the growing area and geographical location in Germany. Many data are available on linden tree regeneration based on various cutting methods. However, most of the studies considered the self-reproduction of linden tree forest stands without regard to the parent canopy structure. The issue of forest productivity with the prevailing TC has not been adequately addressed. With that in mind, it is crucial to determine optimal parameters and cutting methods ensuring productive linden tree forest stands for commercial wood and nectar-related purposes.

The study aims to assess the efficiency of cutting practices in mature TC stands. The practices ensure the

growth of continuously productive linden tree forest stands and improve their production indices.

Long-term comprehensive studies on the efficiency of cutting practices in mature TC stands were conducted. There are three hypotheses put forward in the study. In essence, the age of the mother stand and the cutting area determine the efficiency of the small-scale cutting in the nectar-producing part of the forest stand (1); the season of the narrow-strip clear-cutting in linden forests (summer, winter) determines the composition of the next regeneration (2). The third hypothesis (3) of the variability in TC nectar productivity was particularly crucial for the study.

2. Materials and methods

2.1. Research design

Experiments were conducted in the PTA of the Nurly forest district to evaluate vegetative regeneration potential in linden trees. The forest stands affected by winter and summer cutting operations in 1993 were studied. The full forest quality assessment was conducted to evaluate the regeneration processes. Based on the study measurements, forest indices of the linden tree were analysed, natural regeneration processes were assessed, and statistical indices of the tree stands were calculated.

2.2. Study sites

Mono-dominant and poly-dominant, even- and different-aged linden tree forests of the southern Urals were studied. An experimental study was conducted in 1986–2018. The study encompassed forest assessment, nectar production, regeneration indices based on the cutting practices, timber production aspects in mature and over-mature TC stands. The experiment used seventeen permanent trial areas (PTA). The trial plot areas ranged from 0.5 to 2.7 ha.

Trial area establishment was performed based on the regulatory requirements under the Russian industry standard 56–60–83 ‘Trial areas for forest management. The establishment method included the optical measurement in determining bio-morphological indices (for instance, trunk diameter, trunk height, crown width and length). The natural regeneration on summer and winter clear-cuts was analysed to specify the number of shoots in the coppice, their height, and the diameter at the root collar. The visual assessment of the trees used indicators of the crown length including flowers and the number of generative organs in the crown layers. The Abney level was used to measure the crown height and length. The quantitative study of flowering was conducted on the type trees (done in the North-South and West-East directions), the crown of the type trees was divided into two-meter segments along the length. Blotting up with

filter paper, or washing and rinsing procedures were used to extract the nectar from the linden flowers.

The trial was performed in goutweed type forests of Gafuri and Ufa districts of RB, Russia.

Natural regeneration establishment was analysed on the sites where winter and summer clear-cut operations were performed within the goutweed linden tree stand aged 70 years of the Nurly forest district. Long-term experiments were performed in the Krasnoyarsk and Tabyn forest districts to assess the efficiency of small scale forest cutting (the Murakhtanov method). Small-scale forest cutting is performed under the following technical parameters: the length of the cutting strips does not exceed 1,000 m, the width is 50 – 100 – 150 m, and the number of the retained nectar-producing linden trees is 50 – 75 – 100 per 1 ha (Murakhtanov 1972).

2.3. Equipment used

Textolite calipers, Suunto optical height meter, Bitterlich angle gauge, and a tape measure were used in the measurement operations.

2.4. Statistical analysis

Methods of variational statistics, the correlation, and regression analysis, as well as Microsoft Excel and Statistica 6.0 application packages, were employed to process experimental data. The Student's t-test was used to compare the same-named properties. The coefficient of variation (V, %) was calculated to assess the variation of properties.

2.5. Limitations of the study

Currently, there is insufficient objective evidence for providing a rationale for forest cutting practices and operations used in linden tree forest management for particular purposes.

3. Results

Small scale forest cutting practices aim to preserve nectar-producing potential of linden tree forest stands and prevent the death of trees. The study performed in the Krasnoyarsk forest district established the efficiency of the small-scale forest cutting practice (the Murakhtanov method). The cut areas were located close to an apiary farm. The cutting area varied from 0.5 to 3 hectares. While harvested, 100 TC trees with the best growth and flowering indices were retained as nectar-producing trees on each site.

Experimental site inventories conducted in the first decade after felling revealed that the retained TC trees produced 1.4 times more flowers in the good blooming years than in the stand unfelled (Table 1).

However, 20 years after cutting, the nectar trees stopped producing, and the study areas were overgrown with the hazel (Fig. 1).

The first decade showed dieback of 8 – 22% retained nectariferous trees; in the second decade a 52 – 69% rate with the crown broken in 26% of the trees were reported. Currently, 8 – 20 dying trees with regular breaks have remained out of 100 seed trees on the study forest sites. A more significant number of seed trees have remained on the sites with an area of up to 2 ha.

Similar experiments were conducted in the Tabynsky forest district of Gafuri forest area. The small-scale forest cutting was performed in the forest stand made up of 6L – 2B1Ewe – 1As (see Table 1 for explanation) (aged 75 years old) with growth class 3, 0.6 forest stand density in 1.2 ha area. Sixty flowering linden trees were retained after cutting.

Over the three years after the small-scale cutting, all of the retention trees demonstrated longer and wider crowns (by 0.3 ± 0.01 m in length and by 0.11 ± 0.04 m in diameter). A single selection showed higher nectar secretion potential accounting for 2.1 ± 0.06 mg/flower in the first assessment year, compared to the 1.8 ± 0.03 mg/flower in the control forest area where no trees were cut. In the third assessment year, nectar secretion

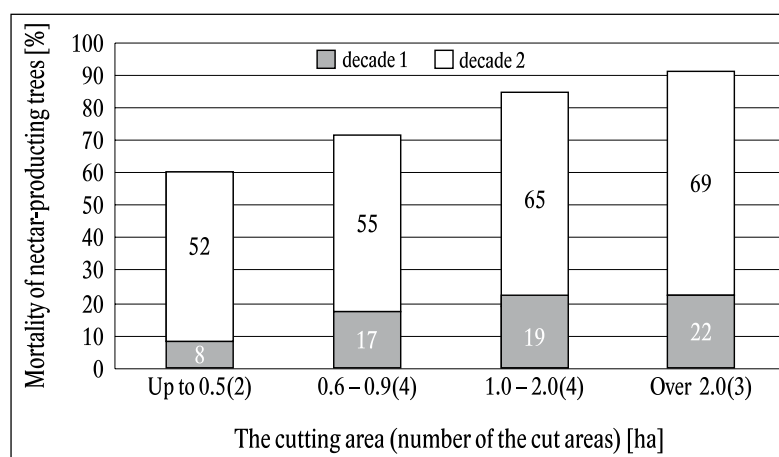


Fig. 1. The mortality rate in nectar-producing linden related to the cutting area.

Table 1. Forest stand characteristics in the cut areas after small-scale felling.

Planning quarter / stratum no.	Area [ha]	Decade 1			Decade 2			Decade 3			
		number of nectar-producing trees	undergrowth species composition (quantity of linden trees) [thousand trees/ha]	number of nectar-producing trees	undergrowth species composition (quantity of linden trees) [thousand trees/ha]	number of nectar-producing trees	composition	age [years]	height [m]	type	stand density
25/13	2.5	100	7Ewe – 3L (8.3)	82	7Ewe – 3L (2.7)	9	7Ewe – 3L	25	8.0	nm	0.6
14	2.7	100	6L3 – Ewe – 1M (15)	73	5L – 4Ewe – 1M (3.3)	11	4L – 4Ewe – 2M	24	10	gw	0.5
15	2.5	100	5L – 3Ewe – 2M (17)	79	4L – 4Ewe – 2M (3)	8	5Ewe – 3L – 2M	24	9.0	gw	0.5
17	1.0	75	5L – 3Ewe – 2M (18)	61	4L – 4Ewe – 2M (3)	11	5Ewe – 3L – 2M	24	9.0	gw	0.6
18	2.0	100	5L – 3Ewe – 2M (18.5)	84	4L – 4Ewe – 2M (2.9)	19	5Ewe – 3L – 2M	23	8.0	gw	0.7
24	1.9	100	6L – 2Ewe – 2W (17)	81	6L – 2Ewe – 2W (5.2)	15	6L – 2Ewe – 2W	21	8.0	gw	0.5
25	2.0	100	5Ewe – 3M – 2L (14)	77	5Ewe – 3M – 2L (1.1)	13	5Ewe – 3M – 2L	21	6.7	nm	0.6
26/18	0.5	50	7L – 2M – 1Ewe (18.5)	46	4L – 3We – 2M – 1Ewe (2)	20	4L – 3We – 2M – 1W	22	6.5	gw	0.6
19	0.8	50	5L – 2M – 2We – 1Ewe	41	4L – 3M – 2We – 1Ewe (2)	17	4L – 3M – 2We – 1Ewe	22	6.0	gw	0.6
20	0.9	75	5L – 3M – 2Ewe (12.7)	60	4L – 3M – 2Ewe – 1We (2)	21	4L – 3M – 2Ewe – 1We	22	5.0	gw	0.6
21	0.6	50	6L – 2Ewe – 2M (15.1)	41	4L – 2Ewe – 1We – 3M (2)	14	4L – 2Ewe – 1We – 3M	22	6.0	gw	0.6
25	0.7	50	7L – 2M – 1Ewe (16.2)	44	5L – 2M – 2We – 1Ewe (3)	12	4L – 3M – 2We – 1Ewe	25	10	gw	0.6
Control forest site		10L + Ewe, Age = 85 years H = 19 m, D = 30 cm SD = 0.6, Vol = 210 m ³ /ha		10L + Ewe, Age = 100 years H = 22 m, D = 32 cm SD = 0.6, Vol = 260 m ³ /ha				9L – 1Ewe, Age = 109 years, H = 21 m, D = 32 cm, SD = 0.5, Vol = 210 m ³ /ha			
25/8	15	Undergrowth 5M – 3Ewe – 2L, aged ten years old 4.0 m, 2 thousand trees/ha		Undergrowth 5M – 3Ewe – 2L, aged 15 years old 4.0 m, 4 thousand trees/ha				Undergrowth 4M – 4Ewe – 1L – 1We, aged 20 years old, 3.0 m, 2 thousand trees/ha			
Control forest site		Understorey hazel, bird cherry; thick		Understorey hazel, bird cherry; thick				Understorey Hazel, bird cherry, raspberry; thick			

The following abbreviations are used in the table:

L – Linden, M – Maple, Ewe – European white elm, W – willow, We – Wych elm; nm – nettle and meadowsweet, gw – goutsweet; hzl – hazel, raspb – raspberry, mid-leve – mid-level; H – height, D – diameter, SD – stand density, Vol – forest volume.

potential rose to 4.1 ± 0.04 mg/flower, while the index fell to 2.0 ± 0.01 mg/flower in the control forest area. The Student's t-test was used to assess the difference in nectar production potential between the seed trees of the control forest site and the cut area. The first year demonstrated a statistically insignificant difference. The third assessment year showed significant variations in the nectar amount secreted by tree flowers in the cut areas and the control site. $t_{\text{fact}} = 2.36 \geq t_{\text{theor}} = 2.04$ ($P = 5\%$, $n_1 + n_2 = 37$). At the end of the tenth period, the retention trees started dying.

Forest cutting practicon, particularly on the coppice type cutting performed in linden forests. The findings are confirmed by robust vegetative regeneration of linden trees resulted from rapid coppice shoot growth (Matula et al. 2012; Sultanova et al. 2019).

Repeated forest inventory of linden tree regeneration in the study areas showed that distribution in natural diameter class varied significantly (Fig. 2): A multimodal curve with a left side asymmetry ($Ka = 0.15$) reflected the summer cut area. The winter cut area was represented by a similar multimodal curve that had a distinct asymmetry ($Ka = -3.88$).

The analysis of the linden coppice shoots distribution resulted in the following findings. In essence, TC stands mixed greatly with *Acer platanoides* and *Ulmus glabra* were represented by multimodal curves with an asymmetry reflecting smaller diameters due to the species competition. Statistical data of linden tree assessment are presented in Table 4.

Table 2. Biometric indices of TC coppice shoots

Stump diameter [cm]	The number of shoots [pcs.]	Root collar diameter [cm]			Shoot height [m]		
		average	minimum	maximum	average	minimum	maximum
Summer cutting							
32	3±1.4	2.73±2.00	1.2	5	1.83±1.44	1	3.5
35	9±1.1	2.33±0.94	1	3.5	1.72±0.23	1.5	1.8
40	7±1.8	2.67±0.25	1	4.2	1.99±0.51	0.4	2.8
42	3±2.0	2.53±0.83	1.6	3.2	1.97±0.15	1.8	2.1
46	4±1.1	2.68±0.36	2.4	3.2	2.00±0.08	1.9	2.1
Winter cutting							
16	5	4.70±0.51	2	6	3.58±0.30	2.2	4.1
18	3	4.67±0.21	4.5	5	3.27±0.15	3	3.7
20	5.4±1.5	3.40±1.16	1.1	7	3.12±0.52	1.7	5.1
22	4±1.1	2.38±0.63	1.5	5.1	2.57±0.11	1.5	3.6
26	7±3.1	3.93±0.58	1.5	5.9	3.13±0.42	1.7	5.2
28	11	3.27±0.69	1.5	6	2.91±0.57	2	4.5
30	8.5±3.1	3.23±0.77	1.3	6	3.10±0.40	1.5	5.6
36	9.4±3.8	3.34±0.78	1.5	7	2.99±0.53	1	4.6
40	9.5±3.1	3.17±0.67	1.1	6.8	3.31±0.29	1	4.7
42	6.5±4.9	3.69±1.12	2	6.5	3.83±0.67	3.2	5.1
46	10±3.3	3.19±0.56	1	5.5	3.31±0.29	1.7	5
50	9±2.9	2.67±0.53	1	5.2	2.97±0.41	1.5	4.5
56	12	4.46±1.60	2.5	6.1	3.36±0.44	2	4.6
60	12.6±5.7	3.31±0.59	1	8	3.09±0.29	1.5	5.2

Regeneration processes were analysed to show that forest cutting practices significantly encouraged vegetative regeneration of the TCs. A year later, coppice shoots density was considerably higher on the winter clearings compared to the regeneration indices of the summer-cleared glades. The comparative analysis of the shoot growth capacity in stools of different diameters showed that shoots regrew from 82% of stumps. Shoots did not regrow from stumps affected by rot, those ones destroyed in the cutting process, and from stumps of 59 – 62 cm in diameter. The most significant number of shoots was observed on stumps of 30 – 42 cm in diameter (Table 2).

The study found that the cut areas mainly featured coppice shoot regrowth for 25 years. *Ulmus laevis* and *Acer* trees prevailed in the summer cut areas. TC and *Ulmus laevis* trees prevailed in the winter cut areas (Table 3).

Table 3. Regeneration indices in the cut areas to the cutting season (1995 and 2018 inventory years).

Cutting season	Wood species	Height [m]		Number	
		average	maximum	thousand trees/ha	%
1995 inventory					
Winter 1993	L	1.20	2.30	36.6	87.3
	M	0.35	0.50	5.1	12.2
	Ewe	1.20	1.75	0.2	0.5
Total				41.9	100
Summer 1993	M	0.40	0.50	5.8	71.6
	L	1.00	2.00	2.3	28.4
Total				8.1	100
2018 repeated inventory					
Winter	L	3.31	6.70	1.100	47.8
	Ewe	2.75	4.90	1.100	47.8
	M	2.43	4.69	0.100	4.4
Total				2.300	100
Summer	L	2.41	5.30	0.300	8.1
	Ewe	2.98	3.42	3.200	86.5
	M	2.63	4.70	0.200	5.4
Total				3.700	100

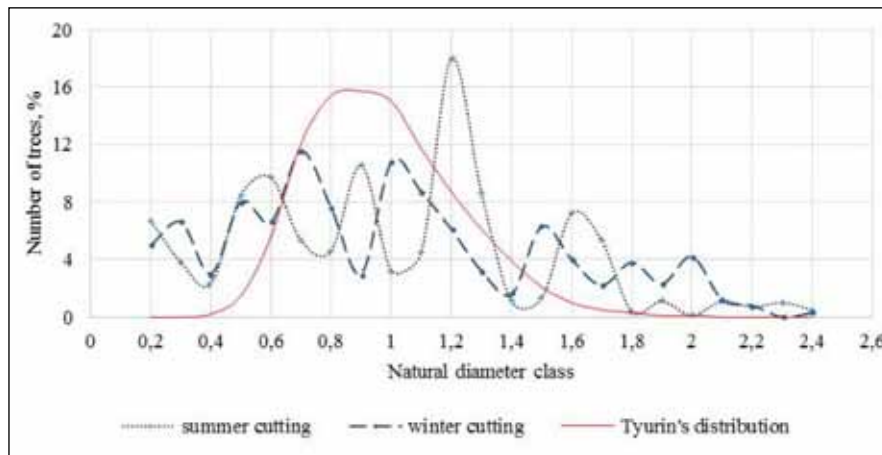


Fig. 2. Linden coppice shoots distribution in diameter classes (2018 inventory).

Table 4. Statistical indices of linden tree regeneration.

Statistical indices	Cutting season	
	summer	winter
Diameter [cm]		
Mean diameter [cm]	7.1	7.9
Standard error [cm]	0.3	0.2
Coefficient of variation [%]	28.7	18.4
Asymmetry	0.15	-3.88
Minimum [cm]	0.5	0.5
Maximum [cm]	11.1	12.9
Selection volume	75	229
Reliability level	1.24	0.77
Height [m]		
Mean diameter [cm]	2.41	3.31
Standard error [cm]	0.07	0.07
Coefficient of variation [%]	0.2	0.1
Minimum [m]	0.5	0.5
Maximum [m]	5.3	6.7
Reliability level	0.03	0.01

The statistical analysis showed that the calculated coefficient of variation indicated a significant deviation from the mean values for the summer cut area ($V = 28.7\%$), and a moderate deviation for the winter cut area ($V = 18.4\%$).

4. Discussion

To choose the practice and procedure of cutting for higher productivity indices is crucial to deciduous forests in European countries (Bürgi 1999; Pukkala et al. 2014; Jacobsen et al. 2018). Many forest researchers point out the need to adjust forest harvesting operations based on the forest site specifications and biological features of the species harvested. So cutting operations should be more adapted to specific conditions (Matula et al. 2012; Konashova et al. 2018; Sultanova et al. 2019). Our study showed that experimental small-scale forest cutting practices in linden tree forest stands did not ensure the nectar-producing continuity. The failure to ensure the continuity is due to the death of the seed trees (nectar-producing trees) and the lack of the linden tree undergrowth. Low economic outcomes after ten years resulted from some aspects related both to the cutting technology and cutting procedures. The selection of trees for cutting is based on

the economic, qualitative, and biological and ecological characteristics of the wood species (Li et al. 2017).

The study revealed that TC regenerates rapidly through coppice shoots. The number of shoots decreases with time due to competition and external factors. Similar findings have been obtained when characterizing the little leaf linden tree in a changing climate (De Jaegere et al. 2016). The study demonstrates that TC has an increased potential for vegetative reproduction. Therefore, the species can outnumber other tree species. About 90 % of mature and over-mature linden tree forest stands in the Białowieża National Park have a coppice shoot origin (De Jaegere et al. 2016).

As expected, we have found that the stump diameter has a significant effect on the shoot growth and its characteristics. Similar studies were conducted in Central Europe (Matula et al. 2012). The studies found that the stump diameter had a diverse effect on the initial shoot growth in different tree species. The number of shoots grown from the stump increased significantly with the stump diameter in oak trees. The stump diameter in the linden tree caused changes in the number of shoots, shoot height, and diameter.

Cutting practices have a considerable effect on the stand structure, but changes in the horizontal distribution are quite slow. More notable changes might be found in the vertical structure with the intensive natural regeneration (Vacek et al. 2018).

Several studies on the natural forest regeneration deal with the vegetative structure and specific composition, and some are concerned with environmental factors (Fayolle et al. 2015; Gilman et al. 2016; Poorter et al. 2016). We have studied the natural regeneration as related to the season when the cutting practice is performed. The experimental study has established that cutting operations in TC forest stands should be regulated by the seasons, taking into account the higher efficiency of winter cuttings for regeneration processes. Our findings demonstrate that there is rapid height growth observed in linden trees during the first years after cutting. For instance, two years after cutting, the linden tree reached 2.3 m in height

in the winter cut areas. The findings obtained in Lower Saxony show that the height and volume growth rate in linden trees after winter cutting is higher than in other commercial trees (Bréda & Badeau 2008).

5. Conclusions

In terms of multifunctional forest use, TC is the most promising tree species. It serves not only as a source of wood (the share of the commercial linden tree in RB is about 67% of the total area linden tree stands) but also as the most productive basis for beekeeping (the area of the nectar-producing linden tree stands is about 33%). Also, TC stands are of significant environmental and social importance; the share of linden tree forest stands in various protection forests is 243.5 thousand hectares or 21.9%.

The study assessed the efficiency of cutting practices in mature TC stands. The practices ensure the growth of continuous productive linden tree forest stands and improve their production indices.

The study confirmed the need to perform small-scale cutting operations in nectar-producing linden tree forest stands bearing in mind the age limit and decay potential in linden trees. However, it is essential to ensure pre-generation undergrowth and subsequent linden coppice shoot regeneration in the cut areas to provide continuous growth of the nectar-producing trees. It is essential to prevent the parent forest stand aged 85–88 years old from over-maturing. The cutting area should not exceed 2 hectares.

No seed trees of the undergrowth were observed in the linden tree forest stands. Support for natural regeneration included cutting down the forest understorey and undergrowth of *Ulmus laevis*, *Ulmus glabra*, soil mineralization, retention of seed trees. However, the measures failed to ensure linden tree seed regeneration in all of the cut areas. Compared to other tree species, the linden trees possess an excellent potential for coppice shoot regeneration. So the linden tree are capable of growing in forests disturbed by various cutting practices.

Summer cuttings did not show any regeneration efficiency unless reliable pre-generated undergrowth was obtained. In terms of forest management, winter cuttings of linden trees (36.6 thousand trees/ha) had the best regeneration effect showing good biometric and quantitative indices. The season for the strip cutting (summer, winter) in linden tree forest stands affects the composition of the subsequent regeneration. In essence, summer cutting produces mainly regeneration of secondary tree species such as *Ulmus laevis* and *Ulmus glabra*. The process indicates the replacement of the main tree species. As a result, winter cutting practices produce regenerated linden trees of the coppice shoot origin, preserving the parent species in the forest stand.

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