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The effect of commercial thinning in Scots pine stands on the growth of black cherry

Robert Korzeniewicz[a], Bartłomiej Rutkowski, Wojciech Kowalkowski[b], Marlena Baranowska[c] ✉

Poznań University of Life Sciences, Faculty of Forestry, Department of Silviculture, Wojska Polskiego 71A, 60-625 Poznań, e-mail: marlena.baranowska@up.poznan.pl

a – https://orcid.org/0000-0002-4653-9154; b – https://orcid.org/0000-0002-5801-9818; c –https://orcid.org/0000-0001-9915-3776

Abstract

Black cherry (*Prunus serotina* Ehrh.) is one of the most abundant invasive species found in Polish forests. The mass occurrence of this species in pine stands is one of the main problems of silviculture. Therefore, the paper addresses the problem of the effect of commercial thinning, which increases the access of light to the lower layers of the stand, on the annual growth of rings and the development of black cherry. The study attempted to determine the strength of the progression of the black cherry threat as expressed by increased diameter increment. It was assumed that the thickness increment of mature black cherry individuals after thinning would be significantly greater compared to the average thickness increment before thinning. Over time after the treatment, the average growth of sprouts of black cherry will decrease.

Six pine stands differing in age and timing of the silvicultural treatment in the Golub–Dobrzyn Forest District (N 57°81’42” E 50°20’19”) were analysed. A positive effect of commercial thinning on the thickness increment of black cherry was found in all the studied plots. Over time, the average increment of black cherries resulting from the clearance decreased.

Conducting late thinning, in pine stands where black cherry occurs, results in an increased threat of its expansion. To limit the development of black cherry at this stage of pine stand management, two solutions are possible. The first is to abandon late thinning or reduce the intensity of the treatment, which will inhibit its rapid expansion. The second scenario is to limit the occurrence of black cherry a few years before thinning, perform thinning and introduce understorey or underplanting from native competitive tree species.

Key words

invasive species, understorey, underplanting under forest canopy, intermediate cutting

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Introduction

Black cherry (*Prunus serotina* Ehrh.) is one of the most abundant invasive species found in European forests (Starfinger 1997). However, as recently as the end of the 20th century in Poland, it was recommended to plant it as an admixture and phytomelioration species (Zasady Hodowli Lasu 1988). *Prunus serotina* rapidly colonizes new habitats, displaces native tree species and reduces the diversity of forest ecosystems (Starfinger 1997; Danielewicz and Wiatrowska 2012). The dominance of black cherry in the undergrowth restricts access to light for plants in the ground cover and ground layer and limits their occurrence (Chabrerie et al. 2010), which reduces the biodiversity of forest ecosystems (Vitousek 1990; Danielewicz 1994). The mass occurrence of this species in pine stands is one of the main problems of silviculture (Korzeniewicz et al. 2022). It is extremely troublesome and difficult to control (Danielewicz and Wiatrowska 2012; Bijak 2014; Baranowska et al. 2019; Korzeniewicz et al. 2022). It develops intensively primarily in pine stands in boreal habitats and in more fertile mixed forest habitats (Danielewicz and Maliński 1997; Rutkowski et al. 2002; Halarewicz 2011; Korzeniewicz et al. 2022). It has also been recorded in alder and riparian forests (Danielewicz and Maliński 1997; Dyderski and Jagodzinski 2015).

The most effective chemical methods used to control of black cherry are controversial (Namura-Ochalska 2012; Baranowska et al. 2019; Korzeniewicz et al. 2020; Wrońska-Pilarek et al. 2021; Korzeniewicz et al. 2022). Therefore, other methods of controlling this species are being sought (Van den Meersschaut and Lust 1997; Roy et al. 2010; Namura-Ochalska 2012; Korzeniewicz et al. 2022). Particularly noteworthy are silvicultural methods, which are based, among others, on stand reconstruction (Oosterbaan and Olsthoorn 2005; Nyssen et al. 2016; Baranowska et al. 2020) or on controlling the timing and intensity of forest stand improvement (Korzeniewicz et al. 2022). Therefore, the paper addresses the problem of the effect of commercial thinning (CT), which increases light access to the lower layers of the stand, on the annual growth of rings (the so-called growth from clear-cutting) and the development of black cherry. The study attempted to determine the strength of the progression of the black cherry threat as expressed by the increased diameter increment. It was assumed that the diameter increment of mature black cherry trees after CT would be significantly higher compared to the average diameter increment before CT. With time after the treatment, the average growth of black cherry will decrease.

Methods

The study was carried out in 2018 in the Golub-Dobrzyn Forest District in Paliwodzizna Forestry (N 5°81'42" E 50°20'19"). The experimental plots were established in six different-aged pine stands growing in the habitat conditions of fresh mixed coniferous forest, which represented three age classes (III–V). In the selected stands, CT was performed 2 and 5 years before the measurements. Details of the study areas are included in Table 1.

Table 1. Age, age class and timing of commercial thinning on experimental plots in Paliwodzizna Forestry

Area identificator	Division	Age [years] (age class)	Time (T) after commercial thinning (CT) [years] and experiments variants
D1	314 i	93 (V)	2 (Post_CT2)
D2	317 i	98 (V)	5 (Post_CT5)
D3	299 a	70 (IV)	2 (Post_CT2)
D4	308 h	65 (IV)	5 (Post_CT5)
D5	314 c	43 (III)	5 (Post_CT5)
D6	312 a	55 (III)	2 (Post_CT2)

Five 0.025 ha square-shaped sample plots were established in each subdivision and located at randomly selected sites spaced 50 meters apart. A total of 30 sample plots were surveyed. The quantity and abundance of black cherry, divided into height classes, were examined. Subsequently, an inventory of trees and shrubs was carried out, i.e., the species composition was determined for the first and second storeys of the stand [%], the density in the tree and the second storey [pcs/ha], and the height of black cherry was determined by classifying it into one of three height classes: H1 – up to 0.5 m, H2 – from 0.5 to 1.5 m and H3 – above 1.5 m in height. The adopted simplified height classification resulted from the assumption, which considered the

conducted evaluation of the studied stands in terms of the possibility of carrying out control of black cherry shrubs, using spot spraying of herbicide. In practice, spot spraying is possible for shrubs up to the height not exceeding 1.5 m. The best results of this control are achieved by carrying out spraying of black cherry individuals whose dimensions did not exceed 1 m in height (Korzeniewicz et al. 2022).

In addition, black cherries were classified in terms of their origin into two groups: stump sprout (F.ss.) – specimens grown from stems after attempted mechanical control, and natural forms (F.nr.) – specimens without damage caused by its previous felling. For dendrochronological analyses, cherry tree specimens characterized by the largest trunk diameter (= 96.37 mm, SD = 25.0 mm) were selected. In each studied stand, 10 specimens of black cherry were selected (60 samples in total), from which discs were cut from the butt for dendrochronological analysis (caliper, measurement accuracy 0.1 mm). Based on the samples obtained, the age of the study sample (black cherry) and the average width of annual growth of black cherry rings before (CT) and after thinning were determined for two variants: 2 years (Post_CT2) and 5 years (Post_CT5) after the thinning. Using Statistica version 13. program, the obtained results were subjected to statistical analysis to determine the relationship between the width of annual growth of rings and the time of carrying out CT.

Results

In each surveyed stand, the dominant species in the first storey was Scots pine (*Pinus sylvestris* L.), the proportion of which was ranged from nearly 67% to over 84%. The share of the admixture of the common birch (*Betula pendula* Roth) ranged from 10% to over 20%. The species composition of the studied stands also included larch (*Larix decidua* Mill.) and sessile oak (*Quercus petraea* (Matt.) Liebl.) (Fig. 1).

In the second storey (Fig. 2), hornbeam (*Carpinus betulus* L.) played a dominant role. The average density in the tree layer (total of the first and second storeys) was just over 790 pcs/ha (Fig. 3). In this respect, the stand in subdivision 314c stood out, where the highest density was recorded (nearly 1,100 pcs/ha, including pine 453 pcs/ha; Fig. 3).

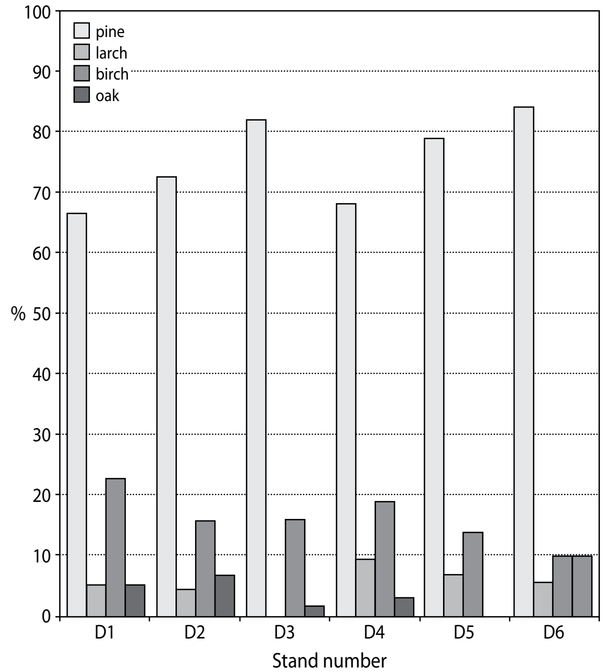

Figure 1. Species composition of the first storey of the studied stands in Paliwodzizna Forestry

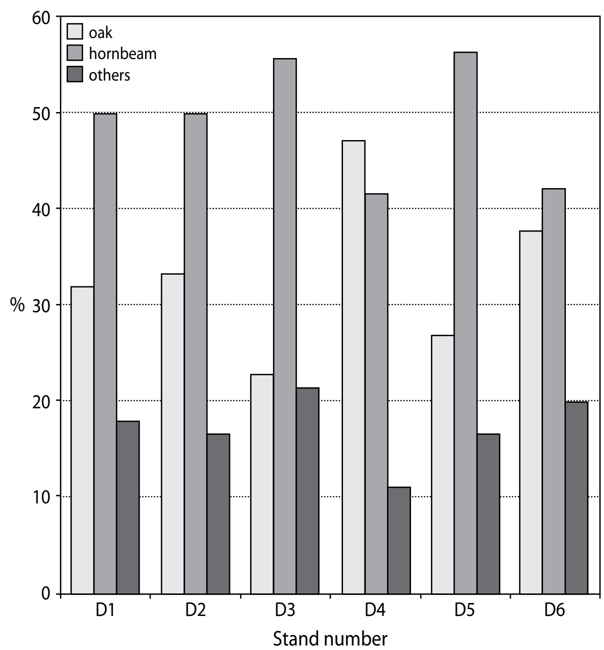

Figure 2. Species composition of the second storey of the studied stands in Paliwodzizna Forestry

The density of black cherry was characterized by a high coefficient of variation. The average density of this species was more than 3,800 pcs/ha and fluctuated within wide limits (from 1,280 to 7,680 pcs/ha), that is, the stands statistically significantly differed in the density of black cherry ($F=21.1249$; $p=0.0000$) and also statistically significantly differed ($F=6.9214$; $p=0.0002$) in the proportion of forms offshoot stump sprout (F.ss.) and natural forms (F.nr.) (Fig. 4, Suppl. 1).

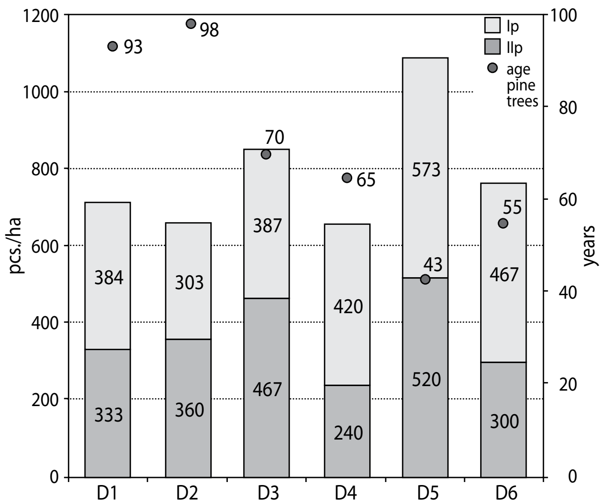

Figure 3. Comparison of the density of the studied stands in Paliwodzizna Forestry in the first storey (Is) and the second storey (IIs) and the age of the pine trees, D1–D6 – stand number

The average age of the individuals selected for analysis was 17 years (*Me* = 17 years; SD = 4 years).

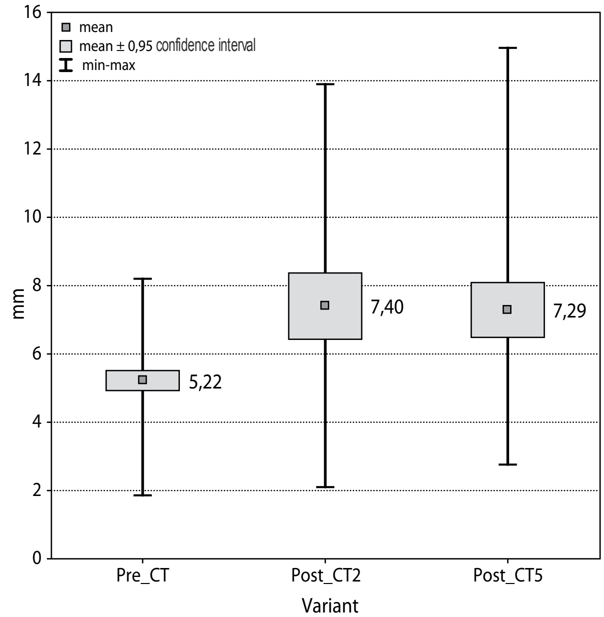

Figure 5. Comparison of average annual ring increment $\overline{Z}$ of black cherry [mm] before thinning (Pre_CT) with average annual increment [mm] 2 years (Post_CT2) and 5 years (Post_CT5) after thinning (letters indicate statistically homogeneous groups)

It was found that the average width of the annual wood ring of black cherry was $\overline{Z}$ = 5.68 mm, and in the period before CT, $\overline{Z}_{Pre\_CT}$ = 5,22 mm (Fig. 5, Suppl. 2). In contrast, it increased after CT and averaged $\overline{Z}_{Post\_CT2}$ = 7,40 mm (variant Post_CT2 variant) and $\overline{Z}_{Post\_CT5}$ = 7,29 mm in the Post_CT5 variant, i.e.,

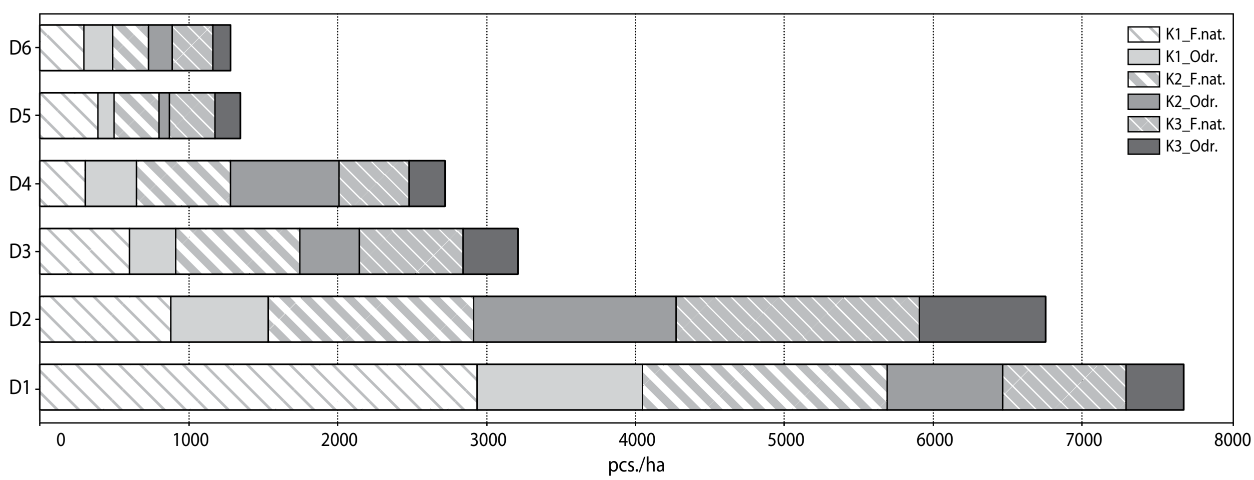

Figure 4. Comparison of the average density of black cherry by height class (H1–H3) and origin (F.nr. – natural form, F.ss. – stump sprout), D1–D6 – stand number

5 years after commercial thinning. Analysis of variance confirmed a statistically significant difference of more than 40% between the growth before and after thinning (F = 19.543; p = 0.0000). In contrast, there were no statistically significant differences between the increments two and five years after the commercial thinning, although it was observed that the increment decreases with the passage of time after the treatment – CT5. A characteristic feature was a similar increase in the width of black cherry tree rings before commercial thinning. On the other hand, after thinning, a weak, inversely proportional relationship was observed between increment and stand density (first and second storeys). Detailed data on the results of breast height and age measurements are included in Supplement 2.

Discussion

The growth rate of *P. serotina* increases significantly with increased access to sunlight (Bellon et al. 1977; Marquis 1990; Starfinger 1997; Closset-Kopp et al. 2007, Vanhellemont 2009; Closset-Kopp et al. 2011; Bielinis et al. 2012; Robakowski et al. 2012; Robakowski et al. 2016). The commercial thinning that was carried out in the pine stand relaxed the compactness of the second storey of the stand, increasing light access to the forest storey. The treatment was a stimulus for the cherry trees to respond with an increased growth in diameter (the so-called growth from clear-cutting). It should be noted, however, that with time, the average growth from overexposure of the cherries decreased. Carrying out maintenance operations, because of which more light reaches the bottom of the stand, also poses a threat to activating the seed bank of cherries lying in the soil (Namura-Ochalska 2012). Black cherry seeds lying in the soil retain their germination capacity only for two years outside the natural range in full-light conditions (Baranowska 2023). From the seed bank under the forest canopy can form a long-living sapling bank ("Oscar syndrome"). Suppressed saplings are "waiting" for their growing conditions to improve ("sit-and-wait" strategy). By increasing the access of light to the forest floor, we activate the suppressed sapling bank which grows rapidly (Closset-Kopp et al. 2007). Clear-cutting in monocultures promotes the reproduction and expansion of black cherry (Rutkowski et al. 2002; Starfinger et al. 2003). This may also be facilitated by commercial thinning carried out in tree stands, especially those of high intensity.

Many study results show the synergistic effect of combined methods in the control of black cherry (for example, Muys et al. 1992; Starfinger 1997; Starfinger et al. 2003; Oosterbaan and Olsthoorn 2005; Namura-Ochalska 2012; Demeter and Lesku 2015). Our results confirm the validity of the methods proposed by Korzeniewicz for reducing the occurrence of black cherry in pine stands (Korzeniewicz et al. 2022). In pine stands of the third age class, thinning should be planned with caution. Merely removing black cherry from a stand has a temporary effect and generates costs, while combining tree felling with chemical control of regrowth and shrubs briefly perpetuates the effect. Control of black cherry in maturing stands should be combined with the introduction of understorey species or understorey plantings under the canopy of a pine stand (species that compete with black cherry, such as common maple or sycamore) (Korzeniewicz et al. 2022). Such activities were undertaken in Polish forests, among others in the Spychowo Forest District, where after cutting down the black cherry, it was treated with chemical sprays, and then, competitive species were introduced – linden and hornbeam (Ligocki et al. 2021). However in the Kampinoski National Park, after limiting the occurrence of this invasive species, native species spontaneously appeared in the undergrowth plants (Namura-Ochalska 2012). The correctness of the decision to rebuild is confirmed by the results of Rutkowski and others (2002). According to Rutkowski and all (2002), stands in which hornbeam, oak or beech dominate in at least one of the layers, the first and second storeys or the undergrowth oppose the encroachment of black cherry (Rutkowski et al. 2002). The significant proportion of hornbeam in the second storey of the studied stands provides an opportunity to reduce the occurrence of black cherry in the study plots.

It is estimated that 80% of *P. serotina* populations in North America tend to form spontaneous regrowths from trunk and roots (Auclair 1975), with half of the cherry populations in Europe affected by this phenomenon (Closset-Kopp 2007). Research carried out by Namura-Ochalska (2012) showed that the black cherry did not regrow from roots. The phenomenon of black cherry creating regrowths from root in Poland is marginal (Marciszewska et al. 2021). Regrowths from trunks form most often among the youngest generation of the species (Del Tredici 2001). This is a mechanism affecting the invasiveness of the cherry tree. This tree, when mechanically damaged, begins to form offshoots at a rapid rate (Auclair 1975; Oosterbaan and Olsthoorn 2005; Halarewicz 2011; Otręba et al. 2017; Marciszewska et al. 2018; Baranowska et al. 2019; Marciszewska et al. 2024). The results of our inventory showed a significant proportion of cherry tree regrowth in pine stands. Under conditions of full access to light, cherry tree regrowth develops even faster (Marquis 1990), which in the study area was facilitated by the cuts made to relax the canopy of the stand. Hence, mechanical removal of black cherry alone is counterproductive, and other methods of limiting its expansion should be sought (Marquis 1990; Starfinger et al. 2003; Oosterbaan and Olsthoorn 2005; Annighöfer et al. 2012; Namura-Ochalska 2012; Baranowska et al. 2019; Korzeniewicz et al. 2022), which is confirmed by our research results.

Conclusions

Conducting commercial thinning, in pine stands where black cherry occurs, results in an increased threat to its expansion. Increased access to light has a positive effect on its growth. Three scenarios for the management of pine stands with black cherry undergrowth are possible. The first scenario is to carry out thinning without controlling black cherry. The second scenario is to abandon thinning or reduce the intensity of the treatment, which will inhibit the rapid growth of black cherry. The third scenario is to limit occurrence of black cherry a few years (e.g., 5) before thinning, perform thinning and introduce undergrowth or understorey plantings of native competitive species (sycamore, common maple, hornbeam or linden).

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Supplement 1. Density of black cherry in height classes (K1-K3) in all sample plots (D1-D6), F.nat. – natural form, F.odr. – offshoot stump sprout

Area	K1 [pcs./ha]		K2 [pcs./ha]		K3 [pcs./ha]		Σ [pcs./ha]
	F.nat. [$h_{0-0,5m}$]	F.odr. [$h_{0-0,5m}$]	F.nat. [$h_{0,5-1,0m}$]	F.odr. [$h_{0,5-1,0m}$]	F.nat. [$h_{>1,0m}$]	F.odr. [$h_{>1,0m}$]	
1	2	3	4	5	6	7	8
D1							
1.	4600	1920	2720	880	2120	320	12,560
2.	3560	840	720	280	0	280	5,680
3.	1160	760	2320	360	480	840	5,920
4.	3560	760	1000	1440	840	160	7,760
5.	1800	1280	1440	920	720	320	6,480
Average	2936	1112	1640	776	832	384	7,680
D2							
1.	440	760	1120	800	1520	360	5,000
2.	1720	360	560	1440	1680	720	6,480
3.	1040	360	3160	2320	1920	1240	10,040
4.	1040	1440	1280	1160	1280	1080	7,280
5.	160	360	760	1080	1760	840	4,960
Average	880	656	1376	1360	1632	848	6,752
D3							
1.	360	560	600	360	1240	320	3,440
2.	1160	320	720	880	800	240	4,120
3.	680	320	840	360	440	760	3,400
4.	440	240	1040	200	440	160	2,520
5.	360	120	960	200	560	360	2,560
Average	600	312	832	400	696	368	3,208
D4							
1.	120	0	360	1400	320	80	2,280
2.	240	200	920	280	520	240	2,400
3.	0	280	560	280	720	240	2,080
4.	720	240	1000	1360	120	360	3,800
5.	440	1000	320	320	680	280	3,040
Average	304	344	632	728	472	240	2,720
D5							
1.	280	0	280	80	360	160	1,160
2.	840	80	160	200	120	0	1,400
3.	280	0	440	0	200	280	1,200
4.	120	200	280	80	640	280	1,600
5.	440	240	360	0	200	120	1,360
Average	392	104	304	72	304	168	1,344

1	2	3	4	5	6	7	8
D6							
1.	200	440	160	80	240	0	1,120
2.	200	280	240	160	80	40	1,000
3.	360	160	280	80	320	320	1,520
4.	440	80	360	160	440	160	1,640
5.	280	0	160	320	280	80	1,120
Average	296	192	240	160	272	120	1,280

Supplement 2. Characteristics of annual increments [mm] of black cherry, D1–D6 – sample plots

Area	Age [years]	After CT [years]	Post CT [years]	Diameter of stumps [mm]	∑z total increment after CT [mm]	∑z total increment post CT [mm]	$\bar{Z}$ mean increment [mm]	$\bar{Z}$ mean increment after CT [mm]	$\bar{Z}$ mean increment post CT [mm]
1	2	3	4	5	6	7	8	9	10
D1	22	20	2	41,4	37,2	4,2	1,88	1,86	2,10
D1	23	21	2	54,8	50,6	4,2	2,38	2,41	2,10
D1	17	15	2	61,8	51,0	10,8	3,64	3,40	5,40
D1	21	19	2	97,8	92,2	5,6	4,66	4,85	2,80
D1	16	14	2	104,2	87,0	17,2	6,51	6,21	8,60
D1	13	11	2	71,2	52,8	18,4	5,48	4,80	9,20
D1	17	15	2	80,0	66,6	13,4	4,71	4,44	6,70
D1	19	17	2	100,6	80,4	20,2	5,29	4,73	10,10
D1	20	18	2	136,8	115,0	21,8	6,84	6,39	10,90
D1	18	16	2	111,6	92,0	19,6	6,20	5,75	9,80
D2	18	13	5	60,2	46,4	13,8	3,34	3,57	2,76
D2	11	6	5	85,0	49,2	35,8	7,73	8,20	7,16
D2	16	11	5	144,8	70,0	74,8	9,05	6,36	14,96
D2	19	14	5	95,6	57,0	38,6	5,03	4,07	7,72
D2	16	11	5	94,8	45,2	49,6	5,93	4,11	9,92
D2	12	7	5	57,4	27,8	29,6	4,78	3,97	5,92
D2	20	15	5	104,2	79,4	24,8	5,21	5,29	4,96
D2	11	6	5	65,6	27,8	37,8	5,96	4,63	7,56
D2	13	8	5	74,2	41,0	33,2	5,71	5,13	6,64
D2	17	12	5	90,6	53,6	37,0	5,33	4,47	7,40
D3	17	12	5	104,0	66,0	38,0	6,12	5,50	7,60
D3	16	11	5	104,2	61,6	42,6	6,51	5,60	8,52
D3	25	20	5	137,8	94,6	43,2	5,51	4,73	8,64
D3	14	9	5	75,0	52,0	23,0	5,36	5,78	4,60
D3	20	15	5	131,0	98,2	32,8	6,55	6,55	6,56
D3	11	6	5	69,6	32,4	37,2	6,33	5,40	7,44
D3	16	11	5	112,2	69,0	43,2	7,01	6,27	8,64

1	2	3	4	5	6	7	8	9	10
D3	14	9	5	103,2	56,8	46,4	7,37	6,31	9,28
D3	19	14	5	126,6	90,4	36,2	6,66	6,46	7,24
D3	15	10	5	81,2	47,8	33,4	5,41	4,78	6,68
D4	15	13	2	83,2	68,4	14,8	5,55	5,26	7,40
D4	19	17	2	92,0	77,0	15,0	4,84	4,53	7,50
D4	19	17	2	107,8	90,4	17,4	5,67	5,32	8,70
D4	17	15	2	118,4	109,8	8,6	6,96	7,32	4,30
D4	24	22	2	135,6	115,6	20,0	5,65	5,25	10,00
D4	14	12	2	107,2	79,4	27,8	7,66	6,62	13,90
D4	15	13	2	89,0	71,0	18,0	5,93	5,46	9,00
D4	17	15	2	91,2	75,0	16,2	5,36	5,00	8,10
D4	22	20	2	111,8	92,8	19,0	5,08	4,64	9,50
D4	18	16	2	128,0	110,8	17,2	7,11	6,93	8,60
D5	19	14	5	86,0	53,4	32,6	4,53	3,81	6,52
D5	13	8	5	83,8	35,2	48,6	6,45	4,40	9,72
D5	22	17	5	108,0	75,8	32,2	4,91	4,46	6,44
D5	23	18	5	113,2	80,8	32,4	4,92	4,49	6,48
D5	24	19	5	126,0	101,8	24,2	5,25	5,36	4,84
D5	11	6	5	68,4	25,0	43,4	6,22	4,17	8,68
D5	21	16	5	130,2	98,8	31,4	6,20	6,18	6,28
D5	17	12	5	91,4	64,4	27,0	5,38	5,37	5,40
D5	12	7	5	75,0	44,8	30,2	6,25	6,40	6,04
D5	13	8	5	91,2	51,2	40,0	7,02	6,40	8,00
D6	24	22	2	126,4	112,4	14,0	5,27	5,11	7,00
D6	8	6	2	51,6	40,4	11,2	6,45	6,73	5,60
D6	13	11	2	67,2	57,0	10,2	5,17	5,18	5,10
D6	26	24	2	155,0	143,6	11,4	5,96	5,98	5,70
D6	19	17	2	110,0	94,2	15,8	5,79	5,54	7,90
D6	13	11	2	83,8	70,4	13,4	6,45	6,40	6,70
D6	17	15	2	87,4	70,4	17,0	5,14	4,69	8,50
D6	17	15	2	85,0	70,6	14,4	5,00	4,71	7,20
D6	19	17	2	104,6	90,4	14,2	5,51	5,32	7,10
D6	22	20	2	96,6	83,6	13,0	4,39	4,18	6,50