ORIGINAL RESEARCH ARTICLE

The influence of initial spacing on growth and survival of Scots pine in 40 years period of cultivation in varied habitat conditions

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Abstract. The aim of the research was to determine the effect of initial spacing on the survival and growth of pine trees in dry coniferous and fresh coniferous forest habitats after nearly 40 years from the establishment of plantation.

The study presents an analysis of seven spacing variants in square, rectangular and triangular spacing patterns with the initial density ranging from 6 944 seedlings/ha to 15 625 seedlings/ha. The studies were conducted on two study sites. No tending treatments (selective thinning) were performed in the examined stands throughout the growing season.

It was shown that habitat conditions had a significant effect on the survival, diameter and height growth of trees in pine stands. In the less productive forest habitat, where the competition of trees is smaller, the survival was 1.5 to 2-fold higher compared to the more productive habitat. Pine trees growing in the fresh coniferous forest had substantially larger diameters at breast height (dbh) compared to the dry coniferous forest. The spacing effect depended on the habitat conditions. This influence was stronger in the less productive habitat compared to the more productive forest habitat which was reflected in the greater differences in the discussed parameters. The average dbh value of all trees on the Płock site increased with the increase of tree growing space (*i.e.* lower initial planting density) and ranged from 8.24 cm in variant A (15 625 seedlings/ha) to 9.79 cm in variant C (6 944 seedlings/ha). On the Łąck site, the trees growing at a low density (variants C and E) had significantly larger diameters compared to the trees growing at a density from 10 000 plants/ha to 15 625 plants/ha (spacing variants A, B, F, G). The studies also showed a significant effect of the habitat conditions and initial spacing on the diameter of pine trees in biosocial class I.

Triangular spacing in the fresh coniferous forest was found to have more positive effect on tree diameter growth. It is consistent with the findings of other authors that trees planted in triangular spacing make better use of space which is positively reflected in their growth. The results obtained from the research allow to formulate the conclusion that habitat conditions have a significant effect on the survival, diameter and height growth of trees in pine stands. The research also showed a significant effect of initial spacing on the diameter at breast height of pines at the end of age class II. No dependence was found of the initial planting density on the height growth rate of trees. In both forest habitats under consideration, trees planted at a density of approximately 11.5 thousand plants per hectare were the highest. The triangular initial spacing pattern had a positive effect on this characteristic.

Key words: Scots pine, initial spacing, initial density, survival of trees, trees' growth, habitat conditions

1. Introduction

The majority of previous polish experiments on the influence of initial spacing on growth and development of pines forest stands deal with earlier growth phases of forest stand (Ceitel 1989; Burzyński, Zajączkowski 1975; Zajączkowski, Kopryk 1990). There are no reports however about biometric parameter differentiation of pines of older age planted in various spacings. The main reason is the lack of proper empirical material. In the Department of Silviculture of Forest Research Institute, research on spacing has been conducted from 1960s. Within this research, permanent experimental plots were established in a system of random blocks on various habitats, allowing for pine development course comparison. It also allowed following of the natural processes of forest stand's structure differentiation and formation of biometric features in the growth of trees that grow in various densities. Some of them exist until today, and their scientific value is underlined by the fact that no tending interventions of selective character were performed on them, and the currently shaped spatial structure is a result of natural processes of tree differentiation in forest stands.

The aim of the current research was to determine the influence of initial spacing on survival differentiation and tree growth parameters in a period of the first 40 years of life of a not-nursed pine forest stand growing on dry coniferous forest and fresh coniferous forest habitats.

2. Methodology and research object

The objects of research involve two experimental areas:
1. Surface in Płock Forest Inspectorate, Forest District Sierpc, Comp. 117 and 122, established in 1965 on a dry coniferous forest habitat. Soil on experimental area was prepared by full cultivation. Planting material was 1-year-old Scots pine. The last measurement, which is a factor of the following analysis, was taken in 2002, when the pine reached 38 years. The size of one measurement plot (repetition) was 5 acres. In the 1980s, in the forest stand one sanitation cutting was performed in order to remove declining and dead trees.

2. Experimental area in Łąck Forest Inspectorate, Korzeń Forest District, Comp. 290c, 290h and 286c. The surface was established in 1965 on a habitat of fresh coniferous forest. Soil on the experimental area was prepared by full cultivation. Planting material was 1-year-old Scots pine. The last measurement, results of which are the subject of this analysis, was also taken in 2002 when the pine reached 38 years. The size of one measurement plot was 16 acres, whereas only a part of the plot's surface was covered with measurement – 7 acres. On the surface, at one time sanitation cutting was also performed that removed trees declining and dead.

Objects, in which the research was conducted, were located in Middle-Poland Lowlands. Growing seasons lasts 200–210 days. Average annual rainfall is around 450–700 mm, and average annual temperature 7–9°C.

In the following thesis, seven spacing variants (A–G) were analysed. Each variant was measured in three repetitions.
• square spacing:
A – 0.80×0.80 m – initial density 15 625 seedlings/ha
B – 1.00×1.00 m – 10 000 seedlings/ha
C – 1.20×1.20 m – 6 944 seedlings/ha
• triangular spacing:
D – 1.00×1.00×1.00 m – 11 547 seedlings/ha
E – 1.20×1.20×1.20 m – 8 019 seedlings/ha
• rectangular spacing:
F – 0.55×1.20 m – 15 152 seedlings/ha
G – 0.80×1.20 m – 10 417 seedlings/ha.

On each measurement plot, the following were performed:
• measurement of the diameter breast height (dbh) ($D_{1.3}$) [cm] and height (H) [m] of all trees
• biosocial classification of trees.

The dbh of trees was measured by calliper with an accuracy of up to 1 mm. Measurements were taken in two perpendicular directions (alongside and crosswise of planting row). Measurement of tree heights was taken by Vertex electronic hypsometer with an accuracy of up to 0.1 m.

Survival of trees was expressed in percentage relation of trees growing on surface to the initial number of trees in the year of measurement.

Biosocial position was defined by the scale: 1 – dominant trees, 2 – co-dominant trees, 3 – lower trees (undercrop) and 4 – suppressed and declining trees.

The trees of 1st class should be treated as trees of 1st and 2nd class of Kraft's biological classification, trees of 2nd class as 3rd Kraft's class, trees of 3rd class as 4th Kraft's class, and trees of 4th class as trees of 5th Kraft's class.

The range of measurements in experimental areas was much larger. In following publication are results presented concerning the influence of initial spacing and habitat fertility on tree survival, and their growth in thickness and in height.

Statistical analysis of forest stand measurement results conducted was for whole forest stand and for trees from 1st biosocial class. The aim was to assess the pos-

sibility of selection after about 40 years of forest stand's growth in various spacings and on various habitats. The descriptive statistics used were average, standard deviation and variation ratio.

For new calculations, Statistica 10 (2011) program was used. To define relations between features (stating the significance of differences between averages), multi-factor ANOVA variance analysis was used with significance level p=0.05 and Tukey's multiple comparison test (the so-called post-hoc).

3. Research results

3.1. Trees number change depending on initial spacing

Tree survival after 38 years of growth is shown in Table 1 (Płock area) and 2 (Łąck area). To better illustrate the influence of spacing on tree survival, this dependence was also shown in a graph (Fig. 1).
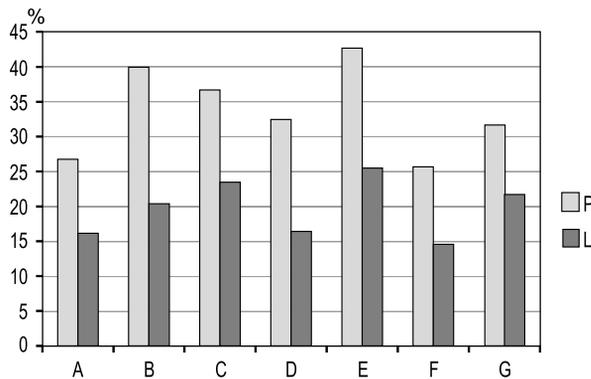
Figure 1. Survival of trees after 38 years of growth depending on spacing variant on experimental plots Płock (P) and Łąck (L).

The smallest survival of trees on Płock surface was stated in the densest spacing variants – F (25.8%) and A (26.8%), and the biggest in variant E corresponding to initial density – 8 019 seedlings/ha. Generally, survival increased with initial spacing loosening, whereas in the smallest of analysed initial densities (variants E and C), an influence of spacing shape on tree survival was observed: in triangular spacing at initial density 8 019 seedlings/ha, few more trees survived than in case of square spacing at initial density 6 944 seedlings/ha. A similar trend was observed on an area in Łąck where the smallest survival

after 38 years noted was in variant F (15 152 seedlings/ha) – 14.7%, and the biggest in variant E – 25.6%. Also on this surface, in case of trees planted in loose triangular spacing (E) few more trees survived than in variant of loosest square-shaped spacing – C.

After 38 years on poorer habitat, around 1.5–2 times more trees survived than on more fertile habitat. Because of this fact that on both surfaces one sanitation cutting was performed, the result achieved was an effect of trees' slower growth on dry coniferous forest habitat and smaller competition processes pace, and then consequently tree secretion.

3.2. Influence of initial spacing on trees dbh

Average dbh of trees in spacing variants, calculated on the base of all trees and on the base of trees representing 1st biosocial class, is presented in Tables 1 (Płock) and 2 (Łąck). In tables, information is also included about actual tree number, standard deviation and variability ratio of measured parameters.

The research showed a relevant influence of habitat conditions and initial spacing on pine's thickness formation after 38 years of growth (p=0.00002). Multifactor variance analysis performed for average dbh of all trees in particular variants distinguished six homogenous groups, whereas trees growing on habitat of dry coniferous forest (Płock) had, as could be expected, substantially smaller dbh than trees growing on habitat of fresh coniferous forest (Łąck).

Average value of all trees dbh on Płock surface increased with expansion of tree living space (decrease of initial density) and ranged from 8.24 cm in variant A (15 625 seedlings/ha) to 9.79 cm in C (6 944 seedlings/ha). Thickness of trees planted in loosest spacing – variant C with initial density 6 944 seedlings/ha and E with density 8 019 seedlings/ha – was significantly greater than thickness of trees in the remaining spacing variants (Fig. 2).

A similar tendency was observed on experimental surface in Łąck. Average value of all trees ranged from 11.37 cm in variant F (15 125 seedlings/ha) to 12.76 cm in D (11 547 seedlings/ha). Trees growing in small density (variants C and E) were significantly thicker from trees growing in density from 10 000 seedlings/ha to 15 625 seedlings/ha (spacing variants A, B, F and G) with the exception of variant D triangular spacing, which created a homogenous group with variants C and E (Fig. 2).

On both surfaces, the influence of spacing on trees thickness developed in a similar way, except for triangular spacing D (11 547 seedlings/ha). In this variant, on a more

**Table 1.** Trees characteristics (all and from 1st biosocial class) depending on initial spacing on Płock surface

Features		Variants*						
		A	B	C	D	E	F	G
		all trees						
Trees per 1 ha		4114	4001	2546	3763	3406	3915	3294
DBH $D_{1.3}$	average [cm]	8.24	8.66	9.79	8.58	9.36	8.31	8.59
	std. dev. [cm]	2.39	2.60	2.76	2.61	2.82	2.62	2.81
	variability [%]	28.97	30.02	28.19	30.42	30.13	31.53	32.64
Height H	average [m]	9.48	9.47	9.53	9.75	9.93	9.34	9.47
	std. dev. [m]	1.58	1.73	1.81	2.11	1.50	1.85	4.06
	variability [%]	16.67	18.27	18.99	21.64	15.11	19.81	42.78
		1st biosocial class						
Trees per 1 ha		1892	1931	1343	1832	1673	1607	1435
DBH $D_{1.3}$	average [cm]	9.98	10.52	11.41	10.48	11.22	10.53	10.77
	std. dev. [cm]	1.99	2.19	2.44	2.11	2.48	2.27	2.36
	variability [%]	19.94	20.82	21.38	20.13	22.10	21.56	21.91
Height H	average [m]	10.46	10.53	10.42	11.14	10.93	10.76	10.76
	std. dev. [m]	1.16	1.36	1.56	1.48	1.05	1.28	1.40
	variability [%]	11.09	12.92	14.97	13.29	9.61	11.90	13.01

* Initial spacing square: A – 0.8 × 0.8 m (15 625 trees ha-1), B – 1.0 × 1.0 m (10 000 trees ha-1), C – 1.2 × 1.2 m (6944 trees ha-1); triangular: D – 1.0 × 1.0 × 1.0 m (11 547 trees ha-1), E – 1.2 × 1.2 × 1.2 m (8019 trees ha-1); rectangular: F – 0.55 × 1.2 m (15 152 trees ha-1), G – 0.8 × 1.2 m (10 417 trees ha-1)

Table 2. Characteristic of trees (all and from 1st biosocial class) depending on initial spacing on Łąck surface

Features		Variants*						
		A	B	C	D	E	F	G
		all trees						
Trees per 1 ha		2508	2050	1642	1896	2050	2225	2271
DBH $D_{1.3}$	average [cm]	11.56	11.80	12.47	12.76	12.21	11.37	11.85
	std. dev. [cm]	2.44	2.77	2.9	2.65	2.52	2.6	2.79
	variability [%]	21.29	23.26	23.89	21.29	21.16	23.07	23.68
Height H	average [m]	13.13	13.45	13.70	14.00	13.35	13.18	13.76
	std. dev. [m]	1.30	1.31	1.17	1.14	1.13	1.26	1.21
	variability [%]	9.90	9.73	8.54	8.14	8.46	9.56	8.79
		1st biosocial class						
Trees per 1 ha		1825	1500	1158	1417	1571	1529	1679
DBH $D_{1.3}$	average [cm]	12.43	12.71	13.54	13.67	12.84	12.44	12.97
	std. dev. [cm]	2.17	2.53	2.51	2.38	2.32	2.24	2.37
	variability [%]	17.60	19.70	18.83	17.88	18.33	18.01	18.47
Height H	average [m]	13.61	13.80	14.15	14.36	13.59	13.69	14.25
	std. dev. [m]	1.09	1.16	0.89	0.97	1.03	0.94	0.82
	variability [%]	8.01	8.41	6.29	6.75	7.58	6.87	5.75

*As in Table 1
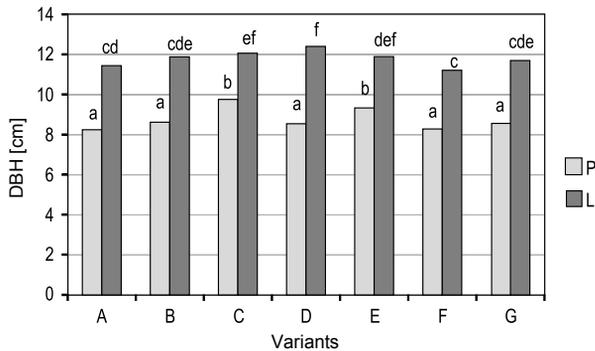
Figure 2. DBH of pines in spacing variants and in varied habitat conditions (P – Płock, dry coniferous forest, L – Łąck, fresh coniferous forest). Average values of feature marked with the same letter do not differ significantly with p=0.05. Variants as in Table 1.
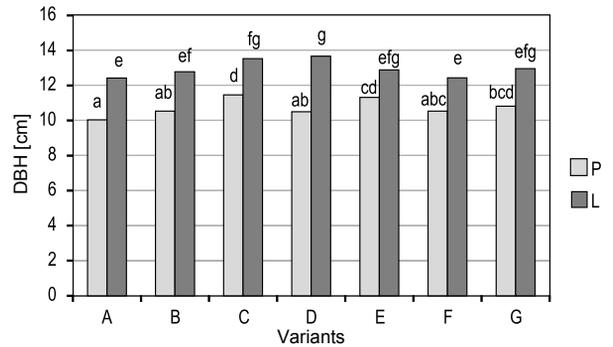

Figure 3. DBH of pines from 1st biosocial class in spacing variants and in varied habitat conditions (P – Płock, dry coniferous forest, L – Łąck, fresh coniferous forest). Average values of feature marked with the same letter don't differ significantly with p=0.05. Variants as in Table 1.

fertile habitat, trees were thicker than in remaining variants while on dry coniferous forest average dbh was smaller than dbh of trees growing in the smallest initial density.

Variability ratio of all trees' dbh on Płock area developed from 28.19% (C) to 32.64% (G) (Table 1). In Łąck, where survival of trees was smaller than on an area in Płock, changeability of the feature analysed was vividly smaller. Variability ratio of dbh in case of all trees developed from 21.16% (E) to 23.89% (C) (Table 2).

3.3. The influence of initial spacing on dbh of trees from 1st biosocial class

Research showed a relevant influence of habitat conditions and initial spacing on forming the thickness of pines belonging to 1st biosocial class (p=0.00005). Variance analysis performed for average dbh of all trees on surfaces distinguished seven homogenous groups. Trees growing on a habitat of dry coniferous forest (Płock), both all and from 1st class, had significantly lower dbh in comparison with pines growing on a fresh coniferous forest habitat (Fig. 3).

Average dbh of trees in 1st biosocial class on Płock area was, depending on the spacing variant, around 17–27% higher than average of all trees in forest stand. The smallest dbh in this class of trees, as in the case of all trees, was stated in variant A (9.98 cm), and the biggest in C (11.41 cm). In variants of loosest spacing – C and E – trees from 1st biosocial class, as in the case of all trees, had significantly bigger dbh than trees from the majority of remaining variants (except variant G, 10 417 seedlings/ha).

On Łąck surface, average dbh of trees in 1st biosocial class was 5–9% more than average dbh of all trees in forest stand. The smallest dbh was stated in variant A (12.43 cm), and the biggest in C and D (13.54 and 13.67 cm). These values were significantly higher from dbh values of trees growing in variants A, F and B; however, they did not differ significantly from the average dbh values of trees from 1st biosocial class in spacing variants E and G (Fig. 5).

In variant D (triangular spacing), both dbh of dominant trees and dbh of all trees belonged to the biggest on more fertile habitat, while on poor habitat to average.

Dbh variability ratio of trees belonging to 1st biosocial class on Płock surface ranged from 19.94% (A) to 22.10% (E), which means that diversity of potential crop trees in terms of dbh was smaller than diversity of all trees. On Łąck surface, the value of dbh variability ratio of this group of trees was slightly lower than in Płock and ranged from 17.60% (A) to 19.70% (B). Diversity of potential crop trees in terms of dbh was also smaller than diversity of all trees.

3.4. Influence of initial spacing on trees height

Habitat conditions and initial spacing had a significant influence on pine's height forming (p=0.00005). Analysis of variance performed for average height of all trees on surface distinguished six homogenous groups. Trees growing on dry coniferous forest habitat (Płock) had, regardless of group affiliation, significantly lower value than pines growing on fresh coniferous forest habitat (Fig. 4).

Average height of all trees on Płock surface ranged from 9.34 m in variant F (15 152 seedlings/ha) to 9.93 m in E (8 019 seedlings/ha). The influence of initial density on height was irrelevant; however, spacing shape turned out to be an important factor, especially in variant E, where trees growing in density 8 019 seedlings/ ha were relevantly higher than trees growing in spacing: A, B, F and G (Fig. 4).

Average height of all trees on Łąck surface developed in a similar way as on Płock surface and ranged from 13.13 m in densest variant A (15 625 seedlings/ha) to 14.00 m in D (11 547 seedlings/ha). Trees planted in variants D and G were relevantly higher than trees growing in densest spacing – A and F; however, they did not differ significantly in height from trees in variants C and B.

Variability ratio of height of all trees on Płock surface was in most cases lower than variability ratio of trees dbh and ranged from 15.11% (E) to 42.78% (G). The high variability ratio of tree height in variant G (10 417 seedlings/ha) is surprising in this case. It is over two times higher than in variant B with similar initial density, which indicates greater share of low trees in lower biosocial layers in variant G. On surface in Łąck, height variability ratio ranged from 8.14% (D) to 9.9% (A) and was much smaller than on Płock surface located on a poorer habitat.

## 3.5. Influence of initial spacing on height of trees from 1st biosocial class

Initial spacing, similar to habitat conditions, had a significant influence on formation of pines height,

both in case of all trees and in case of trees belonging to 1st social class (p=0.00000). Variance analysis performed for this average height of this class trees growing on both surfaces distinguished six homogenous groups, wherein dominant trees growing on dry coniferous forest (Płock) had a significantly lower height than dominant pines growing on fresh coniferous forest habitat (Fig. 5).

On Płock surface, average height of trees belonging to 1st biosocial class was higher than values of average height for all trees by 9–15%. The smallest average height had dominant trees in variant C (10.42 m), and the biggest in D (11.40 m). Influence of spacing on tree height was similar both in case of 1st biosocial class and all trees. Trees of 1st biosocial class planted in triangular spacing (variants D and E) were significantly higher than trees from variants A, B, C and F (Fig. 5).

Average height of trees from 1st biosocial class on Łąck surface was also equalised and higher from average height of all trees only by 2–4%. The highest average had trees from variant D (14.36 m) and the smallest from E (13.59 m). Average height of trees from 1st biosocial class in particular variants was significantly different (p=0.00000). Variance analysis divided trees of this class into two homogenous groups. Trees from variants G and D were significantly higher than trees from remaining spacing variants, except for C (Fig. 5).

Variability ratio of examined feature on Płock surface ranged from 9.61% (E) to 14.97% (C), whereas on Łąck surface these values ranged from 5.75% (G) to 8.41% (B) (Table 2).
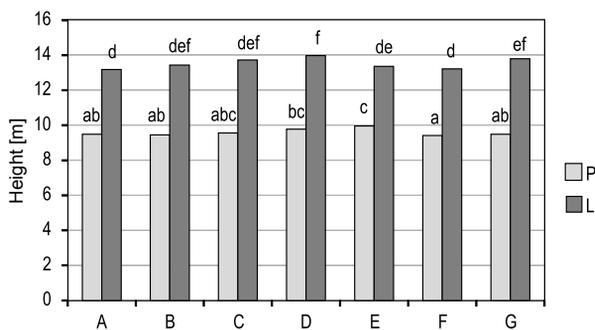
Figure 4. Height of spacing variants and in varied habitat conditions (P – Płock, dry coniferous forest, L – Łąck, fresh coniferous forest). Average values of feature marked with the same letter do not differ significantly with p=0.05. Variants as in Table 1.
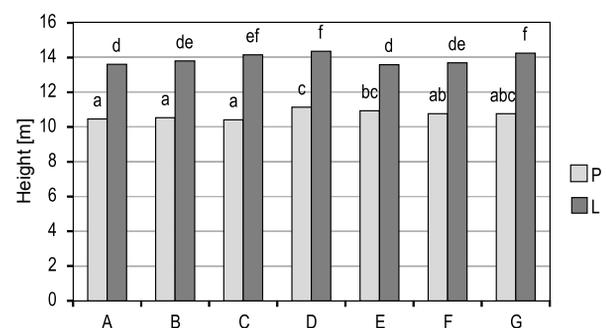
Figure 5. Height of pines from 1st biosocial class in spacing variants and in varied habitat conditions (P – Płock, dry coniferous forest, L – Łąck, fresh coniferous forest). Average values of feature marked with the same letter do not differ significantly with p=0.05. Variants as in Table 1.

4. Results discussion

In this research, seven initial spacing variants were analysed: square-, rectangular- and triangular-shaped, with initial density from 6 944 seedlings/ha to 15 625 seedlings/ha. Experimental plots were established in 1965. In both objects, after around 20 years of growth, dead and declining trees (once) were removed.

In this research, the influence of initial density and habitat on tree survival was shown. After 38 years of growth, more trees survived in wider spacing (with lower initial density) and on poorer habitat where the pace of tree growth and therefore the secretion was smaller. Smaller survival had an influence on smaller diversity of tree size on a more fertile habitat.

Similar results concerning initial spacing influence and habitat fertility on secretion process were also seen in the studies by Kramer (1988), Rjabokin' (1991), Spellmann and Nagel (1992), and Zajączkowski and Kopryk (1990). Significant loss in denser spacing is a main argument of loose spacing supporters who believe that there is no need to invest in expensive planting material (Kramer 1988). Yet, analysis in isolation of only survival from the remaining features that characterise height and quality of forest stand does not support the correctness of inference.

Initial spacing and habitat type influenced thickness of all trees in forest stand, and thickness of trees from 1st biosocial class. Trees on more fertile habitat were significantly thicker than trees on a poorer habitat. After 38 years of growth, dbh of all trees was significantly bigger in variants of lower initial density (6 944 seedlings/ha and 8 019 seedlings/ha), irrespective of habitat conditions. A similar tendency was observed in case of trees from 1st biosocial class, whereas on a poorer habitat the difference between dominant trees dbh and dbh of all trees was far bigger than on a more fertile habitat. Smaller tree survival on a more fertile habitat had an influence on such a state.

The variant D case is interesting: triangular spacing, 11 547 seedlings/ha, in which on a more fertile habitat, dbh – of all and dominant trees – had the highest value, while on a poorer habitat dbh did not differ much from average for whole forest stand. For such a result, the quite low survival of trees in this type of spacing on fresh coniferous forest habitat had an influence. It should be noticed, however, that trees growing in a different variant of triangular spacing – E, of lower density, on both surfaces (Płock and Łąck) – also belonged to the thickest. It is possible that on a more fertile habitat,

negative effect of trees high density is slightly eliminated by positive characteristics of spacing shape. It would be consistent with the statement of Assmann (1968) that with triangular spacing, trees make better use of the space, which is positively reflected in their growth. This relation was observed in the following research also in terms of influence of spacing shape on tree height. Šutov (1984) also considers, in terms of breeding, triangular spacing the best, but this spacing causes considerable difficulties in work mechanisation.

Hamilton and Christie (1971) in youngest Scots pine development phases (cultivation, thicket) stated the increase of dbh growth pace of all and dominant trees (in smaller degree) along with decrease of initial density. Strong, directly proportional dependence of pines dbh in young age (11 years) on the spacing planting was confirmed by Ceitel (1989) in his research. The results of the following study also confirm the research results of other authors (Kramer 1988; Dittmar 1992; Kenk 1998; Lockow 1998; Buzykin, Pšeničnikova 1999; Huss 1999 a, b).

The presented research shows that on a poor habitat after around 40 years of growth, dbh of trees growing in various densities still differs, and is bigger in case of trees growing in looser spacing. Difference between average dbh of trees planted in different spacings occurs in early stages of forest stand's development and is maintained in the following years. This regularity is characteristic of coniferous species (Braathe 1952; Sjolte-Jørgensen 1967; Zajączkowski, Kopryk 1981).

After 38 years of growth, trees growing on a fresh coniferous forest habitat were significantly higher (all and dominant) than trees growing on a dry coniferous forest. Initial density had smaller influence on height than on dbh of trees. Even though on a more fertile habitat the lowest trees were observed in variants of greater initial density over 15 thousands seedlings per 1 hectare, these relations were not significant. By contrast, the highest trees – both all and from 1st biosocial class – were in variants with density 10.5–11.5 thousands seedlings/ha.

In case of a poorer habitat, a positive influence of triangular-shaped spacing (variants D and E) on the height of all trees and trees of 1st biosocial class was observed. Trees of this group planted in density 11 547 seedlings/ha (variant D) were, as on a fresh coniferous forest habitat, the highest.

In other research on coniferous forest stands, average forest stand height increased with planting density increase (Evert 1971; Kramer 1988; Ceitel 1989; Moberg 1999). The research by Elfving (1975) in not-nursed 22-year-old pine forest stands in Sweden confirms this

conclusion with reference to average forest stand height, but not to dominant trees: average height of a hundred thicker trees increased with initial density increase.

5. Conclusions

On the basis of this research, the following results may be formulated:

1. Habitat conditions have an influence on tree survival in pine forest stands and on their growth in thickness and height. On a less fertile habitat, lesser competition between trees occurs, especially in younger age, which results in increased survival of trees. On a fresh coniferous forest habitat, however, pines have significantly bigger dbh and height than on a dry coniferous forest habitat. At the same time, habitat conditions affect the strength of spacing impact on analysed features. On a poorer habitat, this impact is stronger, which is expressed by greater differentiation of analysed parameters, than on a more fertile habitat.

2. The research showed a significant influence of initial spacing on pine dbh at the end of 2nd age class. Tree dbh increased with initial spacing loosening. This relation regarded all trees and trees from 1st biosocial class. A positive influence of triangular-shaped spacing on this feature was also stated, but only on a fresh coniferous forest habitat.

3. No height increase of trees was stated with decrease of initial density. On both examined habitats, the highest were trees planted in a density of around 11.5 thousands per hectare. Triangular initial spacing shape had also a positive influence on this feature.

Acknowledgements

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