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Analyses of spatial structure and selected measures of growth of *Sorbus torminalis* in Forest District Jamy (northern Poland)

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Abstract: The subject of the study was a dynamic population of *Sorbus torminalis* resulting from spontaneous regeneration from seeds in northern Poland. The population, occupying a fenced plot of 1.72 ha in Forest District Jamy, amounted to 579 individuals. The spatial structure of population and some basic individual traits of trees were recorded, then the growing space of individual trees was examined. The following measures of tree growing space were investigated: crown diameter and projection area, and tree volume. The spatial structure of population was non-random, and there was evidence for effects of population density on tree performance. The observations have to be continued in order to describe optimal growing space of wild service tree; the results could be used to improve *in situ* conservation of this rare and valuable species.

Additional key words: wild service tree, growing space, tree crown, *in situ* conservation, competition

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Introduction

The wild service tree *Sorbus torminalis* (L.) Crantz is a typical forest companion species with a scattered distribution (Rasmussen and Kollmann 2004a). It is distributed across western, central and southern Europe, but also occurs in south-western Asia and north-western Africa. The species is a component of various oak, sometimes beech or pine-dominated forests, where it is usually found at low density <30 trees per hectare (Demesure-Musch and Oddou-Muratorio 2004). Wild service tree forms fleshy, brown fruits, dispersed by birds and small mammals (Rasmussen and Kollmann 2004b). It reproduces by seeds and by root suckers, the latter especially at the distribution border in northeastern Europe (Rasmussen and Kollmann 2007). *Sorbus torminalis* is a light-demanding species, often out-competed by other hardwood species (Demesure-Musch and Oddou-Muratorio 2004). In Poland, the species reaches north-eastern limit of its distribution range and occurs at present on 84 natural localities, with only eight populations including more than 100 individuals (Bednorz 2010).

In a stand, which is a collection of individual trees, different processes occur (Assman 1970; Pretzsch 2010). First of all, there are processes of growth and competition which are most important for stand structure and species composition. The essence of competition is to meet the demands of individual trees. Biotic, abiotic and anthropogenic factors are affecting many population processes occurring in a stand. In commercial forests, planning is based on an assessment of growth dynamics of individual trees. However, the site conditions which a tree has at its disposal in a stand, change over time. Initially, trees have fairly specific regeneration niches (Grubb 1977), depending on habitat type, method of soil cultivation and the purpose of production. In case of protected species, such as *Sorbus torminalis* in Poland, tree growing space are not changed through breeding. Therefore, there is significant to know which site conditions, including growing space, allow optimal growth and increment of individual this species, so that the trees develop the right shape without deformation or other effects of suppression. Studies on crown size and different measures of growth have been mainly done in commercially important species as pine, spruce, oak and larch (e.g. Lemke 1966; Miś and Sugiero 2004; Hemery et al. 2005; Kaźmierczak and Stosik 2008; Kaźmierczak 2009, 2010; Kaźmierczak et al. 2010).

The presented study investigates a young population of wild service tree resulting from spontaneous regeneration from seeds in early 90. of the last century. This numerous population of almost 600 individuals, occupying the fenced plot of 1.72 ha, gives a unique opportunity of carrying out research on the biology of the species as well as the observation of processes of tree growth and shape development of trees growing at different densities.

The aims of the study were to examine the spatial structure of several years old natural regeneration of *Sorbus torminalis*, and to carry on an analysis of the selected traits of a single tree growing space in a fenced experimental plot. Some research on stand structure with *S. torminalis* are known but they concern mature stands (e.g. Müller et al. 2000; Hochbichler 2003; Rasmussen and Kollmann 2007). The studies of a single tree growing space for wild service tree were carried out for the first time.

Materials and methods

Study site

The study plot is located in the area of Forest District Jamy (RDLP Toruń) about 10 km N–E from Grudziądz (18°51'31" E, 53°35'28" N). The annual precipitation in this region amounts to a long-year average of approximately 522 mm and the annual average temperature amounts to 7.9°C (Woś 2010). The fenced plot of an area of 1.72 ha makes the compartment 84 f of Forest District Jamy. This undulating terrain located at an altitude of 80–92 m above sea level and slightly (3%) inclined to the south-west, is a part of the edge of moraine upland. The type of soil is podzolized rusty soil, which has been formed from sander sands lying on medium loams. The type of habitat is fresh mixed deciduous forest. At present the site is covered by impoverished oak-hornbeam forest (*Tilio-Carpinetum*) with low dense stand. The tree layer is mainly formed out of pine (*Pinus sylvestris*) 28–30 m height and of diameter 31–39 cm, with slight admixture of oak (*Quercus petraea*), lime (*Tilia cordata*), spruce (*Picea abies*) and birch (*Betula pendula*). In the sapling layer apart from predominated wild service (*Sorbus torminalis*) also oak, birch and hornbeam (*Carpinus betulus*) are present. The plot was fenced in 1995 to protect *S. torminalis* seedlings from browsing. The only mature wild service tree growing on the plot has died a few years later. The inventory of *S. torminalis* regeneration made in 2000 by Forest District Jamy showed the occurrence of 360 individuals of 0.5–3 m height (Tarnawski 2001).

Methods

All *Sorbus torminalis* individuals in the experimental plot were mapped using electronic tachymeter Topcon GTS-229, and were provided with labels with subsequent numbers.

For each individual the following was measured:

1. Diameter at breast height $d_{1.3}$ in bark in two directions (N–S and W–E) with an accuracy of up to 0.1 cm; the arithmetic mean of these measurements was assumed as tree dbh.
2. Tree height h with an accuracy of up to 0.1 m.
3. The base of tree crown height with an accuracy of up to 0.1 m.
4. Crown diameter in two directions (N–S and W–E) with an accuracy of up to 0.1 m.

Although totally 579 trees were measured only 506 of them were used in further analyses – trees strongly bended or with distinctly deformed crowns were excluded (Lemke 1968).

The following measures of the growing space of a single tree were selected and determined:

1. Crown diameter d_k (m).
2. Crown projection area p_k (m^2).
3. Single tree space ppd (m^3).

Crown projection area was calculated as a circle area with a radius equal to the average crown diameter. Space of a single tree was calculated as the volume of a cylinder with a height equal to the height of a tree, while the base area was based on the average crown radius. The growing space, described by the simplest two-dimensional (d_k, p_k) and three-dimensional (ppd) characteristics, well defines the space of a single tree, which it has at its disposal. Crown length l_k (m) was also calculated as the difference between the tree height and the height of its crown base. Relative crown length l_k/h was additionally calculated as the percentage of crown length in tree height. The strength of the relationship between seven traits of trees (dbh, height, crown length, relative crown length, crown diameter, crown projection area and single tree space) was also estimated. All statistical computations were performed by using the software Statistica 7.1 (StatSoft), and the maps were prepared in ArcGIS ArcMap 9.3 (Esri) programme.

Results

The spatial structure of the population was non-random, with a few aggregations with higher density, some patches with more or less even distribution and some patches free of *Sorbus torminalis* individuals. Totally, 579 individuals up to 19 years old were mapped in the study area. The average density of population amounted to 336.6 individuals per 1 ha. The area covered by wild service tree crowns was estimated as about 50% of total area of the plot (Fig. 1).

Both individual and growing space traits of *S. torminalis* trees showed a high level of variation (Table 1 and 2). Diameter at breast height ranged from 0.5 to 15.5 cm (with mean 5.43 cm) and was the most variable individual trait (coefficient of variation CV=47.33%). Tree height varied between 1.3 and 9.5 m (with mean 4.47 m). The coefficient of variation of this feature was considerably lower and amounted to 27. 41%. Considering these two traits, trees with dbh 7 cm and height of 5 m, occurred most often within the study area. The crown length ranged from 0.55 to 7.9 m, with mean 3.51 m and coefficient of variation 32.50%. The relative crown length ranged from about 31% up to about 97%, with mean amounted to 77.61% of tree height.

The measures of growing space were significantly more variable than the basic individual traits of trees described earlier. Among the measures analysed, the width of the crown was the least variable (37.67%), while the space of a single tree showed the greatest variability at the level of 81.70% (Table 2). Tree crowns were characterized by a width ranging from 0.50 to 5.75 m, with an average value of 2.92 m. The crown projection area ranged widely from 0.20 to 25.97 m^2, with an average of 7.63 m^2. The volume of cylinder, describing the space of a single tree, ranged from 0.29 to 242.42 m^3, with an arithmetic mean of 38.81 m^3 (Table 2).

Considering differences in density and distribution of *S. torminalis* trees within the study area we distinguished five subplots (Fig. 2), and we tested the relevance of differences in seven previously calculated traits of trees growing in these subplots. The results of the analysis of variance showed that population density significantly ($p < 0.001$) affects the formation of the basic traits of trees (dbh, height, crown length and relative crown length) and measures of the growth space (crown diameter, crown projection area and single tree space).

The charts (Fig. 3) show the mean values of tree traits for individual subplots, along with 95% confidence interval. The subplot I, with the lowest population density, differed markedly from the others in respect to all tree measures. Trees growing in this subplot were characterized by good shape, larger size and greater single tree growth space, and had good prospects of future growth. The other parts highlighted did not significantly differ.

The correlation coefficients between seven traits of trees (dbh, height, crown length, relative crown length, crown diameter, crown projection area and single tree space) were significant at the level 0.05 (Table 3). A strong relationship between dbh and other tree measures was observed. Considering all measures, diameter of trees at breast height was strongest correlated with crown diameter (Table 3).

Table 1. Statistical description of basic traits of *Sorbus torminalis* trees: M – arithmetic mean, Min. – minimum, Max – maximum, SD – standard deviation, CV – coefficient of variation

Statistics	Diameter at breast height $d_{1.3}$ (cm)	Height h (m)	Crown length l_k (m)	Relative crown length l_k/h (%)
M	5.43	4.47	3.51	77.61
Min.	0.50	1.30	0.55	31.43
Max	15.50	9.50	7.90	97.50
SD	2.57	1.23	1.14	8.82
CV [%)]	47.33	27.41	32.50	11.36

Table 2. Description of the growing space traits of *Sorbus torminalis* trees: M – arithmetic mean, Min. – minimum, Max – maximum, SD – standard deviation, CV – coefficient of variation

Statistics	Crown diameter d_k (m)	Crown projection area p_k (m^2)	Space of a single tree ppd (m^3)
M	2.92	7.63	38.81
Min.	0.50	0.20	0.29
Max	5.75	25.97	242.42
SD	1.10	4.97	31.71
CV [%)]	37.67	65.13	81.70

Table 3. Correlation coefficients of seven trait values of *Sorbus torminalis* trees (all significant at the level 0.05)

Trait	$d_{1.3}$	h	l_k	l_k/h	d_k	p_k
h	0.830					
l_k	0.814	0.953				
l_k/h	0.406	0.414	0.652			
d_k	0.896	0.824	0.815	0.427		
p_k	0.880	0.771	0.772	0.401	0.972	
ppd	0.860	0.810	0.805	0.385	0.912	0.967

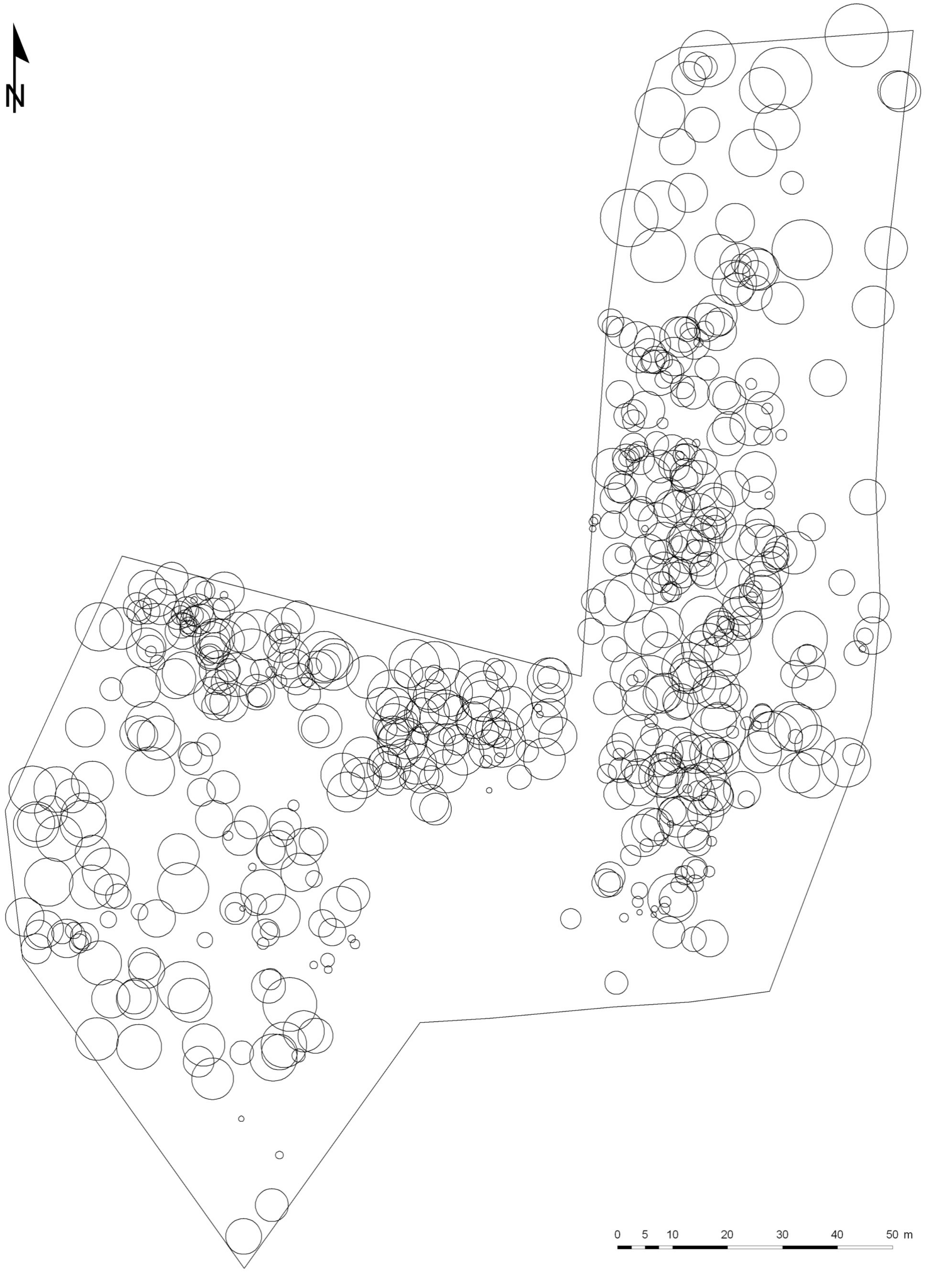

Fig. 1. Spatial structure of *Sorbus torminalis* population; circles show crown projections

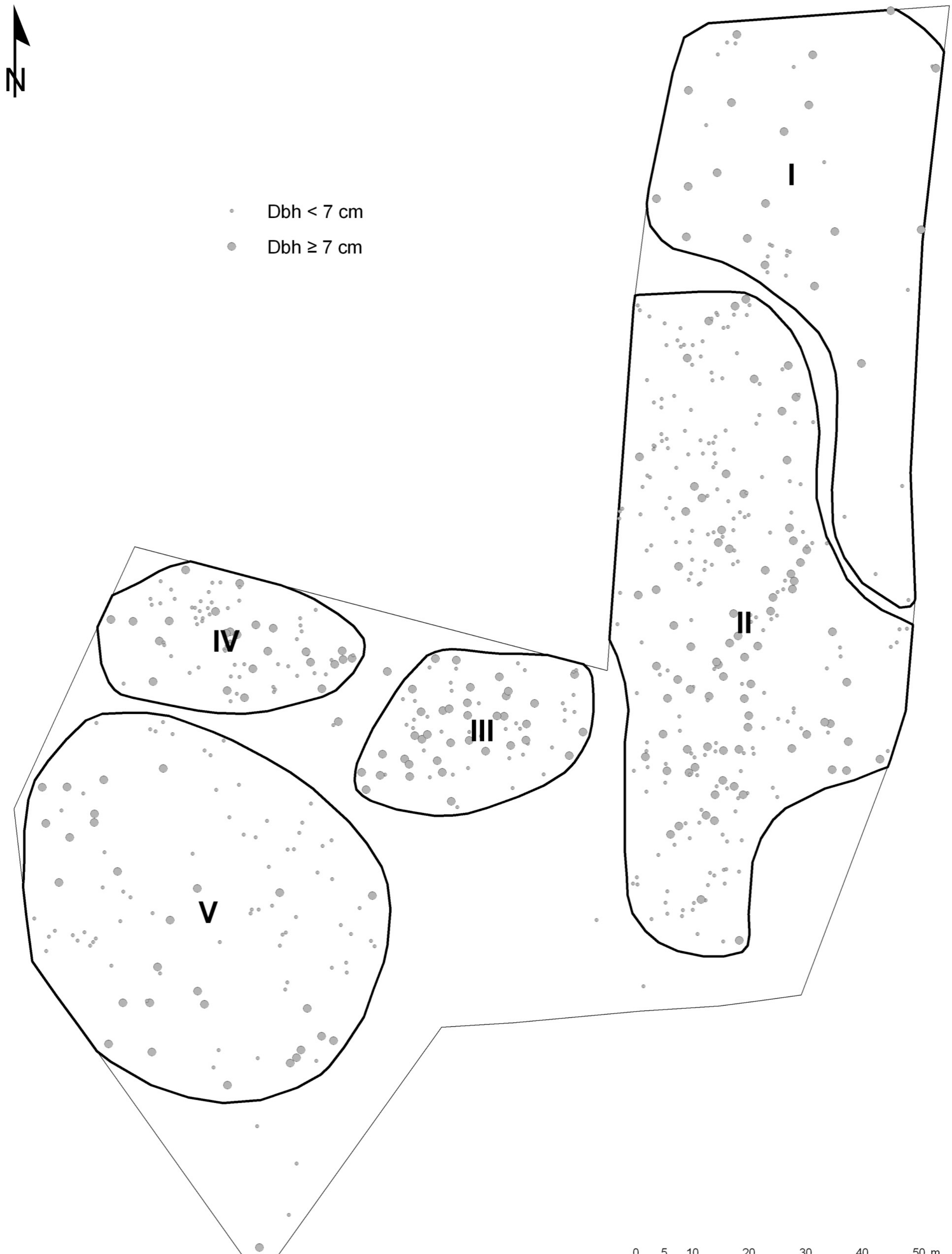

Fig. 2. Spatial structure of *Sorbus torminalis* population with five subplots of different densities set apart (dbh also shown)

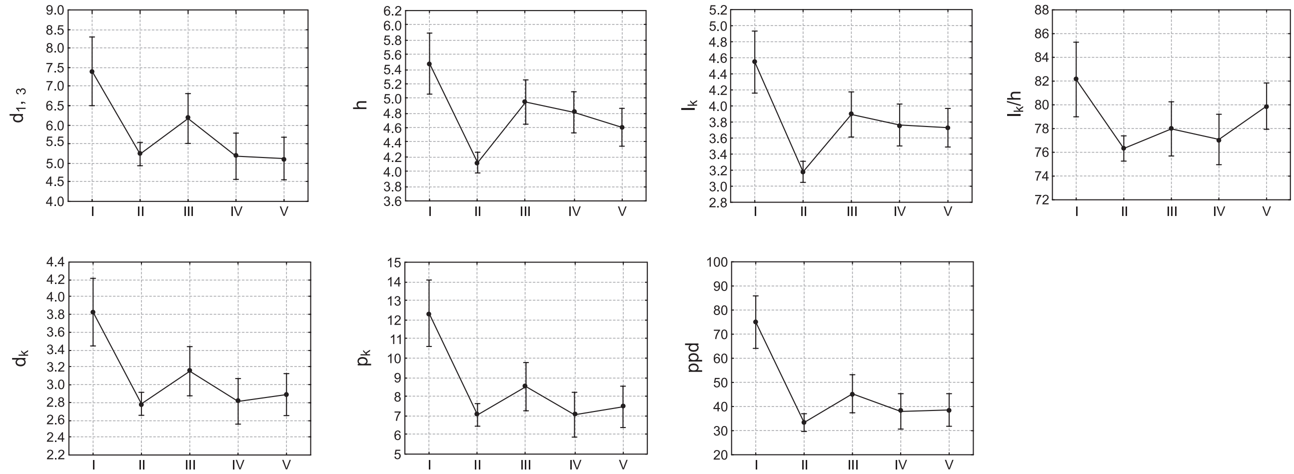

Fig. 3. Differences in mean values of tree traits and selected measures of the growing space of *Sorbus torminalis* in subplots (I–V) with different population densities

Discussion

Sorbus torminalis as a typical companion species never forms pure stands and only exceptionally rarely occurs in considerable densities (Demesure-Musch and Oddou-Muratorio 2004; Nicolescu et al. 2009). Hochbichler (2003), counted up to 812 trees (height > 130 cm) per hectare in the forests of northern Austria. In the study plot in Forest District Jamy the density of *S. torminalis* population was also considerable and amounted to 337 young trees per 1 ha. The spatial structure of population was non-random with a few aggregations with considerable higher density. This clearly corresponds to non-random seed shadows which are well known in plant species dispersed by animals, in particular by birds (e.g. Hoppes 1988; Wilson 1993; Kollmann 2000; McEuen and Curran 2004). We have found a clear relationship between population density and both individual features of trees and single tree growing space measures. We can expect that in the future, competition processes within dense aggregations, will significantly influence the crown architecture (self pruning) and fate of individual trees including their self thinning (Pretzsch 2010).

It is peculiar that we observed expansion of the *S. torminalis* population occurring on the north-eastern limit of the distribution range of the species, while in Danish populations on distribution limit, poor sexual reproduction and/or seed dispersal was revealed (Rasmussen and Kollmann 2004b). According to Hemmery et al. (2010) the range of *S. torminalis* may shift slowly north to north-eastwards in a changing climate. It is possible that our example confirms this theory.

Both individual and growing space traits of *S. torminalis* trees showed a high level of variation, what is natural, considering young and uneven age of trees within study plot. According to Nicolescu et al. (2009; after Hochbichler et al. 2001 and Nicolescu 2007) diameter at breast height is strongly correlated with crown diameter (R^2 = 0.7687) on plantations with free-grown trees of *S. torminalis*. It gives important support for the choice of planting design, for tending interventions and for controlling the growing space of future crop trees (Nicolescu et al. 2009). In our study we analysed the young population of wild service tree resulting from spontaneous regeneration from seeds, characterized with uneven age of individuals and population density. And like in case of plantations, in our population, the relation between diameter at breast height and crown diameter was comparably strong (R^2=0.8019). Our study presents the growing space of young *S. torminalis* trees up to 19 years old. It seems appropriate to continue these research to describe optimal growth space of wild service tree, which would be suitable for individual trees until the end of their life. It is important both in case of introducing the species to forests as admixture and its cultivation on plantations as a crop tree.

There is also conservation context of the study. The fenced experimental plot in Forest District Jamy can serve as an excellent example of effective, active *in situ* conservation of the species, consisting in protection of natural regeneration from browsing and ensuring optimal condition of growth in the first few years of seedlings life.

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