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Some characteristics of the stagnation stage in the development of silver fir (*Abies alba* Mill.) trees in selection forests in Serbia

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Abstract: A period of stagnation in silver fir development has been recorded in all felled trees in selection forests of Serbia (233 trees on Mt. Goč and 451 trees on Mt. Tara). In the selection forests on Mt. Goč, the stagnation stage ranges between 40 and 330 years, but on Mt. Tara, it ranges from 15 to 185 years. It was concluded that the duration was caused not by the ecological and productivity potential (site class) of the soil for fir development, but primarily by the growth space, resulting from the application of single-tree selection or group selection systems. It was also found that the duration of latent state and tree sizes attained over that phase (except for height, and that was to a lesser extent) did not affect the silver fir tree development in the post-stagnation period.

Key words: Selection forest, Serbia, silver fir, stagnation stage

Introduction

Uneven-aged forest management has a significant role in forestry in central Europe (Mitscherlich 1961; Mlinšek 1968; Schütz 1989; Klepac 1995) and parts of southeastern Europe. Over the last few decades, higher public awareness of the forest ecosystem multifunctionality has made it a significant option (Schütz 1997) in the integration of forest protection, social production, and other aspects of forest management. However, the management of selection forests in these areas of Europe has recently encountered numerous problems, which are reflected in the structural changes (Schütz 1975, 1992; Korpel 1982; Boncina et al. 2002), the death of silver fir (Larsen 1986; Ell and Luhmann 1996; Oliva and Colinas 2007; Elling et al. 2009), the change in dominant tree species compared to beech, the decrease in silver fir percentage in the mixture as the carrier of the selection structure (Boncina et al. 2003), and in the difficulties in achieving natural regeneration (Korpel 1985; Andrzejzyk et al. 1987). The individual, and, much more often, the synergic effects of these problems at some sites, throw into question the capacity of selection forests to fulfill the numerous functions in the group of the assigned protection, social and production functions. The starting point in the identification of adequate management procedures to address these problems is the study of biological potential (Bagnaresi et al. 2002) and the development regularities and dynamics (Banković 1981) of the species incorporated in selection forests. This is especially relevant to silver fir, as the tree species is narrowly related to selection management, the method which has always been and

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will remain one of the most significant systems of silver fir management.

The study of the dynamics of silver fir and its characteristic development on Mt. Goč and Mt. Tara, the mountains with the most important complexes of selection forests in Serbia, which have already been managed for 50 years by the principles of the control method (Biolley 1920; Schaeffer et al. 1930; Miletić 1951; Milojković 1962; Obradović 2008), emphasizes the growth stagnation in fir development as the general characteristic. Latent state occurs as a consequence of the specific structure of selection forests, and in this sense, of the lack of growing space (primarily the lack of light from above) in the earliest phases of tree development (in the seedling stage), and biological features and capacities of tree species to survive in such conditions. This means that after a long period of suppression, silver fir, which falls in the category of an extremely shade tolerant tree species (Šafar 1963; Stanescu et al. 1997), is capable of reforming full growth after favorable light conditions have been created by felling, snow break, uprooting, etc., and the morphological traces of the time spent in deep shade disappear gradually with advancing age (Stojanović and Krstić 2008).

The opinion that each tree in a selection forest has special laws of development (Biolley 1920), i.e. that this stand form offers hundreds of very favorable laws governing the tree development (Badoux 1949), indicates that the period of growth stagnation depends primarily on the silver fir's biological characters, such as the maximal possible period of shade tolerance with the continuation of normal development in favorable environmental conditions and on management procedures, such as regeneration felling of suppressed trees. In this sense, the first objective of this research was to identify the maximal possible length of stagnation period after which silver fir can continue its normal development.

The development of individual trees of a species depends primarily on the site and stand conditions. Taking into account this general assumption and the biological characters of silver fir trees, it can be presumed that the length of tree stagnation is more dependent on stand conditions (growth space of individual trees) than on site conditions. For this reason, the second objective of this research was to assess the effect of site conditions on the length of the silver fir stagnation stage.

Given that silver fir trees are subject to growth stagnation, the question is whether the stagnation has a major effect on fir tree development in the post-stagnation period. Magin (1959) concludes that the length of stagnation stage does not have a significant effect on the subsequent development of silver fir trees. However, after studying the development trends of silver fir to assess the productivity of ecological units in the selection forest on Mt. Goč, Banković (1981) reported that the stagnation stage and the tree sizes attained over that period influenced the development of silver fir trees in the post-stagnation period. Therefore, the third objective of this research was to analyze the effect of the stagnation stage (its length and the tree sizes attained over that period) on the later development, specifically on the development of silver fir trees in the post-stagnation period.

Beginning with the above statements and tasks, the following are the initial hypotheses of this research:

- Silver fir falls in the category of an extremely shade tolerant tree species;
- Site conditions do not have a major effect on the analyzed elements of the stagnation stage (its length and tree sizes attained over that period);
- There is no statistically significant correlation between silver fir development over post-stagnation and stagnation periods.

Materials and methods

Study area

Mt. Goč forests are located between latitudes 43°30′ and 43°35′N and longitudes 18°15′ and 18°30′E (Figure 1). The parent rock consists of old Palaeozoic schists with a low degree of metamorphism, contact metamorphic rocks, marble, granodiorites, andesites, dacites, and serpentinitized dunites. The soils are classified as sierozem, black soils, brown soils, leached brown soils and podzols. A humid climate prevails in the region. The average annual air temperature is 7.3 °C, relative air humidity is 81%, precipitation is 1010 mm, and duration of sunny periods is 1938 h (Banković 1981; Jović et al. 1999).

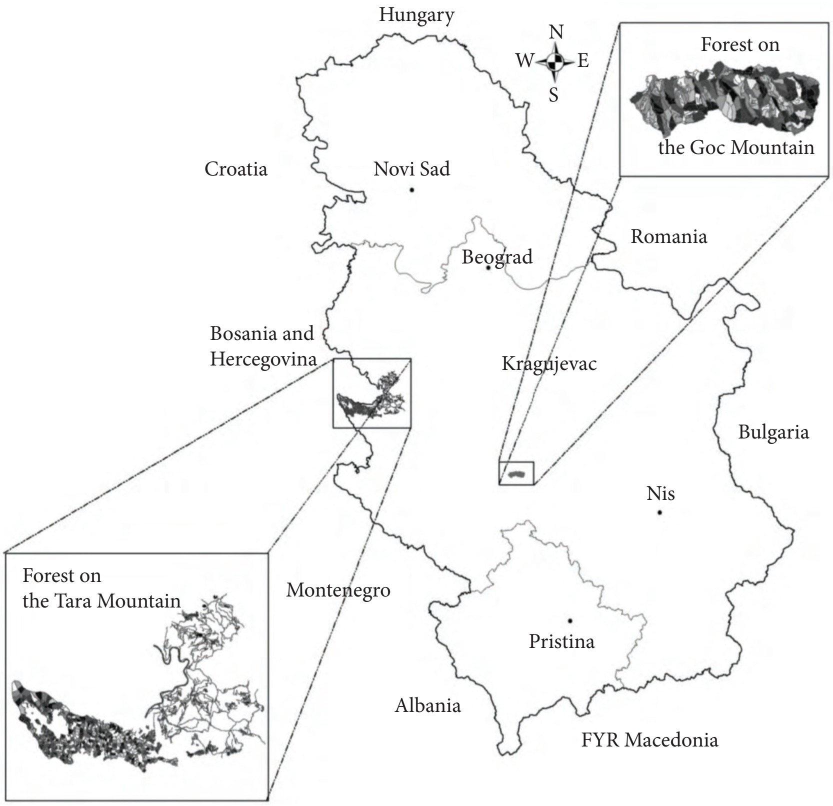

Figure 1. Location of the study areas. The most significant complexes of selection forests in Serbia (Mt. Goč and Mt. Tara).

Based on the research of site-class potentials for silver fir development, the following forest types were defined in silver fir and beech selection forests on Mt. Goč (Banković 1981):

- Forest of silver fir and beech (*Abieti-Fagetum typicum*) on deep (81-120 cm) and very deep (> 120 cm) acid brown soils on granodiorites and quartz-diorites (I site class);
- Forest of silver fir and beech (*Abieti-Fagetum drymetosum*) on shallow (16-40 cm) and medium deep (41-80 cm) acid brown soils on granodiorites and quartz-diorites (II site class);
- Forest of silver fir and beech (*Abieti-Fagetum drymetosum*) on shallow (16-40 cm) and medium deep (41-80 cm) acid brown soils on schists and contact metamorphic rocks (III site class);
- Forest of silver fir and beech (*Abieti-Fagetum serpentinicum typicum*) on skeletal brown soils to leached brown soils on serpentinite (IV site class).

Mt. Tara forests are located in the far west of Serbia, between latitudes 43°52′ and 44°02′N and longitudes 19°15′ and 19°38′E (Figure 1). The basic parent rocks consist of serpentinitized peridotites, Middle and Upper Triassic limestones, amphibolites and Tertiary sediments. The most represented soils occur on limestone (calcareous black soil, rendzina, brown soils on limestone, terra fusca, illimerized soils, and leached terra fusca), on serpentinite (humus-siliceous soils, ranker, and eutric brown soils), and less on siliceous rocks (dystric humus-siliceous soil, dystric ranker, and acid brown soils). A continental mountainous climate approximating the more humid variant of a subalpine climate prevails in the area. The average annual air temperature is 7.9 °C, relative air humidity is 83%, precipitation (with a substantial percentage of snow) is 977 mm, and duration of sunny periods is about 1700 h (Medarević et al. 2002, 2005; Obradović 2008).

The following forest types were defined based on the study of soil, phytocoenology, and the productivity development of silver fir, spruce, and beech selection forests on Mt. Tara (Medarević et al. 2005):

- Forest of silver fir, spruce, and beech (*Piceo-Abieti-Fagetum typicum*) on medium deep (41-80 cm) and deep (81-120 cm) brown soils on limestone (I site class);
- Forest of silver fir, spruce, and beech (*Piceo-Abieti-Fagetum drymetosum*) on very shallow (< 15 cm) and shallow (16-40 cm) brown soils on limestone (II site class);
- Forest of silver fir, spruce, and beech (*Piceo-Abieti-Fagetum*) on skeletal-karst soil on limestone (III site class).

As already stated, the Mt. Goč and Mt. Tara forests are the most significant and the most valuable complexes of selection forests in Serbia, and for that reason, among others, they were selected for this research.

Data collection and processing

Satellite images of Mt. Goč and Mt. Tara show a square form grid network, the sides of which are 400 m. The centers of circular plots of a 10 m radius are in the intersection points of the cluster network. A circular plot which, based on the imagery data and additional information from the Forest Information System data base in Serbia, is classified as a selection stand of silver fir and beech (silver fir, spruce, and beech, are assigned identification numbers and the coordinates of its center are identified). If a sample plot is in a clearing, in even-aged stands or stands of other tree species, etc., it is excluded from the sample. This procedure ensures that the sample covers all forest types (site classes) in which silver fir occurs in the study sites, as well as the selection stands in different development phases within each forest type (selection forest in construction, in the optimal phase, and in degradation). This method ensures the representative sample as a necessary prerequisite for valid conclusions.

In the field, circular plots were detected using a GPS receiver, after which the center of the sample plot was temporarily marked. The distances of the trees in the circle to the nearest neighbors were measured using a Vertex III hypsometer with transponder-by ultrasonic distance meter. Diameters at breast height (DBH) were measured for each silver fir tree in the circle, as was the length, i.e. height (H), after tree felling and debranching. The felled trees were cut into disks: on the stump (0.3 m), at breast height (1.3 m), and then at lengths of 2 m (3.3 m, 5.3 m, 7.3 m, etc.).

The stem disks were analyzed using LINTAB 4 tree-ring measuring, with TSAP software. Tree age was calculated by counting growth rings on the disk taken at the stump. Ages ranged between 130 and 380 years on Mt. Goč and between 49 to 305 years on Mt. Tara. Based on the diameters at the end of the ten-year periods which were marked on each disk from the periphery towards the center, on the height (length) at which the disks were taken, and on the number of growth rings, the calculated data made it possible to draw the lines of development and diameter, height and volume increments of each felled silver fir tree, using Tree Analysis software (Banković and Pantić 2006). Silver fir development at different sites will be the subject of a special analysis. This paper focuses on only 1 phase in the development-the stagnation stage. Thus, the stagnation stage was differentiated from the post-stagnation period. The criteria for the differentiation of these two phases in silver fir development were growth ring width on disks at breast height, i.e. current diameter increment (Ferlin 2002), and current height increment (Banković 1981). Growth ring width above 1 mm, that is, the current diameter increment above 2 mm and the current height increment above 0.125 m, were the indicators that the tree was out of the stagnation stage. The tree sizes in the latent state (dbh and h) were calculated based on the duration of the stagnation stage (t) from the lines of diameter and height growth. Therefore, the data for 233 fir trees were calculated on Mt. Goč, and for 451 fir trees on Mt. Tara, with the forest type structure (site classes) presented in Tables 1 and 2.

Table 1. Duration of the stagnation stage, average sizes of silver fir trees in the stagnation stage and average sizes of silver fir trees in the post-stagnation period (at felling) in the Mt. Goč selection forests.

Site class	Number of analyzed trees	Duration of stagnation stage t (years)			Average tree sizes in stagnation stage		Average tree sizes in post-stagnation period	
		Min	Max	Average	dbh (mm)	h (m)	DBH (mm)	H (m)
I	68	60	260	150	153.1	10.1	705.0	36.1
II	46	40	330	148	155.7	10.7	652.0	32.4
III	59	50	210	151	160.2	10.3	597.0	29.7
IV	60	60	310	154	159.7	10.4	501.0	26.1
In general for Mt. Goč	233	40	330	151	157.2	10.4	613.8	31.1

Table 2. Duration of the stagnation stage, average sizes of silver fir trees in the stagnation stage and average sizes of silver fir trees in the post-stagnation period (at felling) in the Mt. Tara selection forests.

Site class	Number of analyzed trees	Duration of stagnation stage t (years)			Average tree sizes in stagnation stage		Average tree sizes in post-stagnation period	
		Min	Max	Average	dbh (mm)	h (m)	DBH (mm)	H (m)
I	219	15	122	55	71.4	6.1	536.0	31.5
II	189	16	185	53	72.6	6.5	490.0	27.2
III	43	18	102	54	74.1	6.2	375.0	23.9
In general for Mt. Tara	451	15	185	54	72.7	6.3	467.0	27.5

The trees in the Mt. Goč stands are distributed by the single-tree selection system and on Mt. Tara by group selection. To confirm the visual assessments, the information in the Forest Information System data base in Serbia, and the results of previous research at these localities (Stajić and Vučković 2006), the spatial distribution of trees in the study stands (random, group, or uniform) and the structure in the nearest neighborhood were calculated using the Clark-Evans index. The average empirical distance to the nearest neighbor was compared to the average theoretical distance to the nearest neighbor in random distribution. The ratio of these 2 values is the Clark-Evans index (CEI). The deviation of CEI from 1 was verified by the value of c (c is the standard variance of the normal curve) at the 95% confidence level (Clark and Evans 1954).

The differences in average lengths of the stagnation stage between site classes and average tree sizes attained over that period in the study areas were tested by one-way ANOVA and LSD tests at the 95% confidence level. The forms and intensities of simple relation between tree sizes in the post-stagnation period (DBH and H), the duration of the stagnation stage (t), and tree sizes attained over the latent state (dbh and h) were determined using correlation analysis (Correlation Matrix and its graphical equivalent Scatterplot Matrix) and regression analysis. The value of the correlation coefficient was ranked using the very precise Roemer-Orphal scale (0.0-0.10, no correlation; 0.10-0.25, very weak; 0.25-0.40, weak; 0.40-0.50, modest; 0.50-0.75, strong; 0.75-0.90, very strong; 0.90-1.0, full correlation) at the 95% confidence level. The above statistical analyses were performed using STATGRAPHICS Plus 5.1 software for Windows.

Results

Length of stagnation stage

Previous studies of different silver fir aspects (ecology, biology, growth dynamics, productivity, stand structure, etc.) reported different maximal durations of the stagnation stage, either as a conclusion or as a secondary result. Our research shows that the length of growth stagnation in silver fir development in the single-tree selection system on Mt. Goč ranges between 40 and 330 years and between 15 and 185 years in the group selection system on Mt. Tara.

The average stagnation stage of silver fir on Mt. Goč is 151 years and during that period the trees attained 157.2 mm in diameter and 10.4 m in height on average. So the average diameter increment is 1.04 mm, and the average height increment is 0.069 m (Table 1). In selection forests on Mt. Tara, the silver fir latent state is 54 years on average. During that period, the trees reach a diameter at breast height of 72.7 mm and a height of 6.3 m. Therefore, the average diameter increment is 1.35 mm, and the average height increment 0.117 m (Table 2).

The above values of diameter and height increments across the stagnation period point to the extraordinary capacity of silver fir both to survive in the conditions of full shade, drastically reducing its growth, and to preserve its capacity to continue normal development after 330 years, when a more favorable light regime has been released. These characters make silver fir an extremely favorable species for the application of single-tree selection or small-group selection systems.

Effect of site conditions on the length of stagnation stage

The results of one-way ANOVA show that there are no statistically significant differences in the average lengths of silver fir stagnation in different forest types (site classes) on Mt. Goč ($F_{3,229}$ = 0.97, P = 0.4332). This leads to the conclusion that site conditions in selection forests on Mt. Goč do not have a major effect on the duration of the latent state in silver fir development, and that it mostly depends on stand conditions, namely, growth space. The same could also be concluded for the average values of tree diameter ($F_{3,229}$ = 1.74, P = 0.1013) and height ($F_{3,229}$ = 0.12, P = 0.9439) attained during the stagnation.

The differences between the sites in selection forests on Mt. Tara also do not have a statistically significant effect on the average length of the silver fir stagnation stage ($F_{2,448}$ = 0.70, P = 0.5168), or on the average tree diameter ($F_{2,448}$ = 0.82, P = 0.4621) and height ($F_{2,448}$ = 0.33, P = 0.7221) attained in that period.

The comparative analysis of the values in Table 1 (Mt. Goč) and Table 2 (Mt. Tara) shows that there are significant differences between these 2 localities in all the analyzed parameters of stagnation stages. As the site potential for silver fir development on Mt. Goč is significantly higher than that on Mt. Tara, it could be supposed that it is the cause of the above differences between the 2 localities. However, it was confirmed that site conditions in the localities do not have a statistically significant effect on the analyzed values of the stagnation stage, and so it is more logical to conclude that the differences between Mt. Goč and Mt. Tara result from the activities of other factors with a strong effect on tree development. The 2 factors which affect the growth space are primarily the stand origin and the applied selection system. On Mt. Goč, significant harvesting of silver fir and beech selection forests started 65 years ago, and so the forests still have a primeval forest character. In selection forests of silver fir, spruce, and beech on Mt. Tara, significant harvesting started 230 years ago, and so these forests can be considered "regular" selection forests. Furthermore, the system applied in Mt. Goč selection forests is single-tree selection (random distribution of trees CEI = 0.94; c = -0.44) and the system applied on Mt Tara is group selection (group distribution of trees CEI = 0.83; c = -2.97). These 2 systems create unequal conditions for the development of silver fir trees; the former creates a lesser amount of growth space, and the latter creates a much larger space for the development of suppressed trees, which are subject to growth stagnation due to the absence of light. In the selection forests on Mt. Goč, the virgin-forest character and the applied single-tree selection system are most probably the 2 basic causes of the substantially higher values of growth stagnation parameters, compared to selection forests on Mt. Tara.

Effect of the stagnation stage on silver fir development in the post-stagnation period

The high variability of the study elements (DBH, H, t, dbh, h) in the Mt. Goč selection forests (Figure 2) makes the linear correlation between them practically non-existent. This conclusion is also confirmed by the correlation matrix (Table 3), which shows the correlation coefficient in the linear correlation type DBH = f (t) 0.0261 (P = 0.8105), in DBH = f (dbh) 0.0767 (P = 0.4800), and in H = f (t) -0.0264 (P = 0.8085), whereas in H = f (h), it amounts to 0.0607 (P = 0.5764). As for the nonlinear forms of these correlations (Table 4), the values of correlation coefficient indicate the absence or presence of very weak correlation between the analyzed variables. An exception is the correlation type H = f (h) which is weak in the second order polynomial and amounts to 0.3146 (P = 0.0125). The above facts lead to a conclusion that the length of the stagnation stage and the tree sizes attained over that period (except for height) do not have a statistically significant effect on the development of silver fir trees in the post-stagnation period.

The Mt. Tara selection forests are also characterized by a high variability of data (Figure 3), and so there is practically no linear correlation between the study

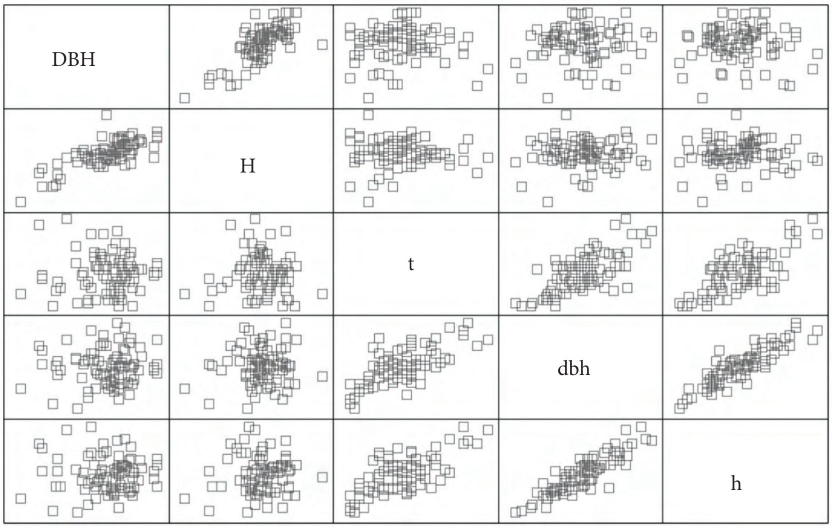

Figure 2. Scatterplot matrix of the variables in the Mt. Goč selection forests.

Table 3. Correlation matrix of the variables in the Mt. Goč selection forests.

	DBH	H	t	dbh	h
DBH		0.7336 (0.0000)	0.0261 (0.8105)	0.0767 (0.4800)	-0.0118 (0.9136)
H	0.7336 (0.0000)		-0.0264 (0.8085)	0.0599 (0.5813)	0.0607 (0.5764)
t	0.0261 (0.8105)	-0.0264 (0.8085)		0.7077 (0.0000)	0.6939 (0.0000)
dbh	0.0767 (0.4800)	0.0599 (0.5813)	0.7077 (0.0000)		0.8803 (0.0000)
h	-0.0118 (0.9136)	0.0607 (0.5764)	0.6939 (0.0000)	0.8803 (0.0000)	

Correlation Coefficient (P-Value)

Table 4. Test results of nonlinear correlation between the variables in the Mt. Goč selection forests.

	DBH = f (t)		DBH = f (dbh)		H = f (t)		H = f (h)	
	R	P	R	P	R	P	R	P
Exponential	0.0308	0.7769	0.0739	0.4965	0.0038	0.9721	0.0757	0.4856
Reciprocal - y	-0.0371	0.7330	-0.0726	0.5041	-0.0346	0.7501	-0.0919	0.3972
Reciprocal - x	-0.1265	0.2430	-0.1694	0.1168	-0.0016	0.9883	-0.1780	0.0993
Double Reciprocal	0.1209	0.2648	0.1446	0.1815	0.0619	0.5688	0.2000	0.0632
Logarithmic - x	0.0947	0.3827	0.1437	0.1841	-0.0080	0.9417	0.1287	0.2347
Multiplicative	0.0960	0.3765	0.1374	0.2045	0.0240	0.8251	0.1433	0.1854
Square Root - x	0.0639	0.5567	0.1063	0.3273	-0.0163	0.8810	0.0947	0.3830
Square Root - y	0.0283	0.7950	0.0752	0.4890	-0.0115	0.9161	0.0680	0.5312
S-Curve	-0.1244	0.2510	-0.1598	0.1392	-0.0319	0.7690	-0.1898	0.0783
Polynomial - order 2	0.2388	0.0849	0.1348	0.4632	0.0910	0.7052	0.3146	0.0125

R - Correlation Coefficient
P - P-value from the ANOVA

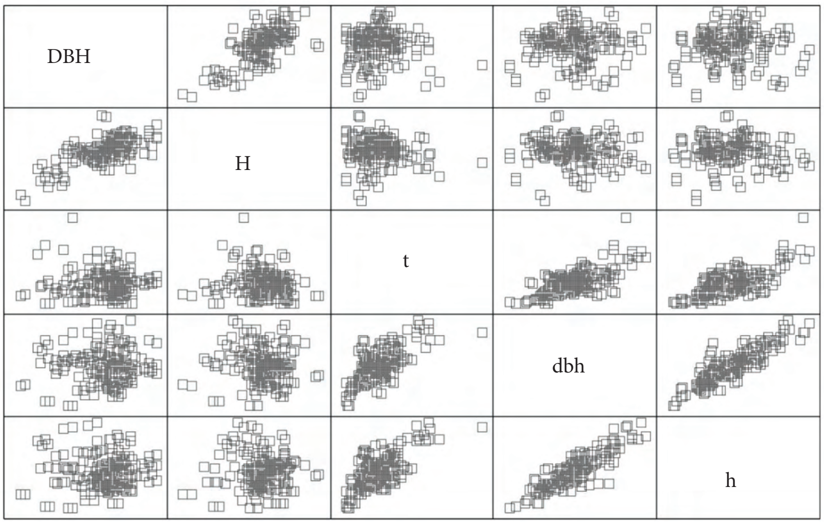

Figure 3. Scatterplot matrix of the variables in the Mt. Tara selection forests.

variables, which is also evident from the correlation coefficients and their statistical significance presented in the correlation matrix (Table 5). In other tested functions (Table 6), correlation coefficients range within the Roemer-Orphal scale indicating the absence or presence of a very weak correlation between the analyzed variables. Just as in the case of Mt. Goč, the exception to the general assessment is the correlation H = f (h), which is weak in the second order polynomial (R = 0.3359) and is statistically significant at the significance level above 95% (P = 0.0118). Consequently, in the conditions of Mt. Tara, the stagnation stage and the tree sizes attained over that period (except height) do not have a statistically significant effect on the later development of silver fir trees.

Table 5. Correlation matrix of the variables in the Mt. Tara selection forests.

	DBH	H	t	dbh	h
DBH		0.6990 (0.0000)	0.0125 (0.8698)	0.0591 (0.4384)	0.0160 (0.8345)
H	0.6990 (0.0000)		-0.0988 (0.1531)	-0.0491 (0.5199)	0.0005 (0.9948)
t	0.0125 (0.8698)	-0.0988 (0.1531)		0.7090 (0.0000)	0.7068 (0.0000)
dbh	0.0591 (0.4384)	-0.0491 (0.5199)	0.7090 (0.0000)		0.8790 (0.0000)
h	0.0160 (0.8345)	0.0005 (0.9948)	0.7068 (0.0000)	0.8790 (0.0000)	

Table 6. Test results of nonlinear correlation between the variables in the Mt. Tara selection forests.

	DBH = f (t)		DBH = f (dbh)		H = f (t)		H = f (h)	
	R	P	R	P	R	P	R	P
Exponential	0.0165	0.8293	0.0584	0.4442	-0.0824	0.2797	0.0127	0.8676
Reciprocal - y	-0.0233	0.7700	-0.0594	0.4362	0.0535	0.4834	-0.0277	0.7167
Reciprocal - x	-0.1257	0.0984	-0.1861	0.0139	0.0502	0.5110	-0.1211	0.1113
Double Reciprocal	0.1231	0.1055	0.1711	0.0240	-0.0030	0.9691	0.1333	0.0795
Logarithmic - x	0.0889	0.2432	0.1391	0.0672	-0.0761	0.3186	0.0713	0.3497
Multiplicative	0.0902	0.2363	0.1368	0.0719	-0.0492	0.5193	0.0817	0.2848
Square Root - x	0.0544	0.4756	0.0931	0.2219	-0.0923	0.2256	0.0360	0.6371
Square Root - y	0.0143	0.8519	0.0586	0.4427	-0.0960	0.2078	0.0062	0.9348
S-Curve	-0.1251	0.1001	-0.1817	0.0164	0.0267	0.7261	-0.1276	0.0934
Polynomial - order 2	0.2407	0.0061	0.1314	0.2254	0.1399	0.1843	0.3359	0.0118

Discussion

The study of biological potential, dynamics and laws of development of tree species is one of the necessary instruments for addressing numerous problems occurring in European selection forests. A modest contribution to this task is the study of some characteristics of stagnation stage in the development of silver fir trees in selection forests in Serbia.

This research shows that silver fir can survive in deep shade for as long as 330 years, retaining its strong capacity for normal development in the conditions of a more favorable light regime. Assman (1961) reported a period of only a few decades, while Milojković and Mirković (1955) reported more than 100 years in Mt. Tara conditions, and the same duration was reported also by Schütz (1969, 2001, 2002) and Jaworski and Zarzycki (1983). The upper limit of the silver fir latent state is 140 years in Gorski Kotar (Frančišković 1938), 189 years in selection forests of Slovenia (Ferlin 2002), and Šafar (1963) reports as many as 200 years. Compared to the stagnation stages reported by the above authors for European selection forests, a latent stage duration of 330 years is a considerably longer period and it additionally confirms the conclusions drawn by Kobe et al. (1995), Parent and Messier (1996), and Kobe and Coates (1997) that silver fir falls in the category of an extremely shade tolerant tree species. This characteristic makes silver fir an exceptionally favorable species for single-tree or group selection (small group) systems, i.e. the protagonist of a specific structure of selection forests.

Site conditions have almost no effect on the length of stagnation stage, or on the sizes attained by trees in that period. The size of tree growth space and, in this sense, the light regime in the stand as the consequence of the applied systems of selection management (single-tree or group selection) are the most effective factors influencing the duration of the stagnation period and the tree sizes attained in that period. The selection system, among other things, also affects the size of the tree growth space, more precisely, the light regime in selection forests. For this reason, selection cutting is an instrument by which foresters can influence the dynamics of different processes in selection forests (length of stagnation stage, recruitment, transition time, etc.). By increasing the tree growth space, the length of stagnation stage can be shortened, but this simultaneously also increases and accelerates the recruitment and shortens the transition time between diameter classes, which can finally lead to the disturbance of the typical selection structure. Consequently, the conservation of the selection structure should be the limiting factor in the process of speeding up the dynamics of selection forest development, and therefore also in the procedure of shortening the period of stagnation stage.

It was also found that the duration of stagnation stage and the tree sizes attained over that period (except for height, and that to a lesser extent) did not have a statistically significant effect on the silver fir development in the post-stagnation period, which agrees with Magin (1959), and is in contrast to the conclusions drawn by Banković (1981). The absence of correlation between these two stages in silver fir development is a logical consequence of the fact that the first stage (stagnation stage) depends exclusively on the light regime in the forest, while the second stage (post-stagnation period) depends on a series of ecological factors contained in the site class.

Based on the study results and their in-depth analysis, it can be concluded that the initial hypotheses of this research are confirmed. They are as follows:

- Taking into account the time which silver fir in selection forests can survive in the latent stage (in the concrete conditions as much as 330 years), this species falls in the category of an extremely shade tolerant tree species;
- The analyzed elements of stagnation stage (its length and tree sizes attained over that period) do not depend on site conditions, but primarily on stand conditions, i.e. light regime, as the consequence of the applied selection management system;
- There is no statistically significant correlation between silver fir development in post-stagnation period and that in stagnation period.

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