ECOLOGIA BALKANICA
2019, Vol. 11, Issue 1 June 2019 pp. 35-50

Growth Characteristics of Robinia pseudoacacia (Linnaeus, 1753) Plantations After Applying of Agroforestry

Vania G. Kachova*[*], *Angel A. Ferezliev, Yonko D. Dodev

Forest Research Institute – Bulgarian Academy of Sciences,
Bulvd. Kliment Ohridski 132, Sofia 1756, BULGARIA
[*]Corresponding author: vania_kachova@abv.bg

Abstract. Forest plantations with and without agroforestry practice are being analyzed. Biometric characteristics (mean height, stem volume, volume of construction timber and total volume) are better in the case of agroforestry with 2.11 m, 0.789 m³, 0.787 m³ and 0.878 m³ respectively. Concerning the biometric parameters of the crowns (length and width) the advantages are on the side of the plantations without agroforestry practice, which is explained by the lower planting density of the tree vegetation. In the comparative studies carried out on the variation curves of distribution of the diameters the majority of trees are in the thinner part of the mean tree diameter in both cases (60.8% for agroforestry and 54.7% without agroforestry). The comparative studies carried out on the variation curves of distribution of the heights show that the curves of height have approximately the same form and depend in certain degree of management activities. It is observed advantage of the plot with agroforestry in relation with the higher values of natural degrees of height and in much wider interval of natural degrees of thickness.The horizontal structure is also presented through the Stand Visualization System (SVS) program, which visualizes the graphical distribution of the plantations according to a previously made model in Microsoft Excel. Improvement of the soil quality in the plantation where agroforestry has been practiced is ascertained. The content of more resistant humic acids in the humus composition is higher for sample plot with agroforestry (1.45% against 1.02%), while the content of the more mobile and unstable fulvic acids is lower (0.65% against 0.92%). The results are a reason to recommend the application of agroforestry in the early stages of cultivation of acacia plantations, which is a highlighted advantage in relation with wood production in the future.

Key words: agroforestry, variation curves of diameters, curves of height, Stand Visualization system(SVS), soil humus composition, forest practices.

Introduction

Black Locust (*Robinia pseudoacacia* L.) is a fast-growing tree species, widely used in afforestation of Bulgaria, as one of the most cultivated alien species. It participates in the forest, protective, alley and anti-erosion tree belts composition. It is characterized by high productivity, quality of medium and small timber and adaptability to the soil and climatic conditions of the country (Donchev, 1968; Tsanov *et al.*, 1992). The species was conveyed from North America to Europe in 1601 (Yurukov, 2003). In Bulgaria it is grown widely and has been naturalized in many places (Donchev, 1968). In Northern Bulgaria, the purpose of afforestation with Black

Union of Scientists in Bulgaria – Plovdiv
University of Plovdiv Publishing House

Locust is mainly the establishment of wood-producing plantations, as well as such with anti-erosion and fortification purposes on eroded terrains with degraded, poor and dry soils. The annual increment of Black Locust reaches 6.73 m^3/ha and it is an alternative substitute of beech and oak wood vegetation (Alexandrova *et al.*, 1994). It is breeded easily, has rapid growth and valuable wood. It can grow on poor, polluted and dry soils, but the most suitable are Fluvisol and Chernozems (WRB, 2006). It produces productive and sustainable pure and mixed plantations with seed and coppice origin (Kostov *et al.*, 1992). It quickly accumulates biomass in young ages about which many biometric models have been made in Bulgaria (Stankova *et al.*, 2016). Many plantations have been established, especially in Northeastern Bulgaria, where many strong winds blow and soil erosion is available. But many species of these plantations remain still not sufficiently studied in biological, ecological and forestry aspect.

Black Locust successfully participates in the establishment of a number of agroforestry systems. These practices are a sustainable way of land management, in which both agricultural and forest practices are integrated simultaneously on the same unit of land (Mosquera-Losada *et al.*, 2009). Current conditions for agroforestry practices are favorable in Bulgaria due to the socio-ecological incentives available in the country such as wide popularization, comprehensive research programs and preparation and education of specialists, and also due to environmental necessities such as soil fertility improvement for example (Stancheva *et al.*, 2007). Integration of woody vegetation leads to optimization of the use of natural resources (nutrients, water, sunlight, and etc.). Woody perennials facilitate stability of the local temperatures, reducing extreme heats and ammonia and nitrogen volatilization, improve nutrient cycle in the ecosystem, and prevent nutrient leaching through ground water (Nair *et al*, 2009; Carvalho *et al.*, 2016; Pardon *et al.*, 2017). In these ways a food security, environmental protection and climate change mitigation at local level can be achieved (Mosquera-Losada *et al.*, 2012; Nair, 2013; Mosquera-Losada *et al.*, 2017; Santiago-Freijanes *et al.*, 2018). The opposite questions concerning the introducing the agricultural crops into tree rows of forest plantations and the role of the crops on trees growth still remain not well examined. This is an old practice which is applying mainly in the first few years of the growing of the young forest saplings. What are the benefits of this practice? What are the advantages of this combination for the trees and the other components of the ecosystems? Undoubtedly, there are such benefits, because growing of agricultural crops between rows of saplings is one practice that is widely applied in forest enterprises. Unfortunately, studies on the growth of tree species in agroforestry systems are limited in literature (Huber *et al.*, 2018). The questions related to their productivity, their creation and management are still poorly studied.

For the productivity of woods are important their structure according their thickness and height. Studies in this direction in the world scientific literature have been numerous and have long been known, with the first comprehensive summary of the accumulated material in terms of regularities in the thickness was made by Thyurin in 1931 (Krastanov, 1968; Ferezliev *et al.*, 2018). More important studies on the structure of the woods according height were carried out by Thyurin, Shifel, Tretyakov, Davidov, Levin (Anuchin, 1982; Mihov, 2005).

The aim of the study is to make a comparative characteristic and to show the advantage in the application of agroforestry systems by clarifying the benefits for the growth of trees after the application of agroforestry practices in which in the initial years of the life of the young plantations together with the saplings are grown agricultural crops.

Materials and Methods

The object of the study is a plantations of 2.6 ha of Black Locust (*Robinia pseudoacacia* L.), established in 2000, in which have been set areas with a size of 20 m x 25 m (0.05 ha). The first sample plot (SP1) was made up in a plantation afforested at density sheme 1.30 x 2.00 m. In this plot of 1 ha has been practiced agroforestry: in the first and second year of planting the plantations between tree rows were grown watermelons and melons. Fertilization with nitrogen fertilizer (ammonium nitrate) and care for Black Locust and agricultural crops were applied. The second sample plot (SP2) was created in a plantation (0.8ha) where the Black Locust was planted at scheme 1.30 x 2.50 without application of agroforestry. This sample plot was tested for comparison (control) and is located in close proximity to SP1. Both experimental plantations are located on a northern exposure, in the forested part of the slope at an altitude of 150 m in the boundaries of the Governmental Hunting Estate (GHE) Seslav-Kubrat – North-Eastern Bulgaria near the river Danube (Table 1). The saplings used for afforestation in two SPs had been produced in the tree nursery of the GHE and represent Bulgarian species. The measurements were carried out in the autumn of 2018.

Volumes and timber assortment structure was made by program FET 1.11 (Demo) (Evangelov, 2012), which mathematical model in relation with acacia plantations is based on the tables of Krastanov *et al.*, (2004a; b).

Comparative studies of the shape of the curves according the height and thickness were made, and average curves of arrangement were calculated for sets of plantations (Thyurin, 1931; Krastanov *et al.*, 1965; Tsakov, 1998; Ferezliev *et al.*, 2017; 2018). The distribution of the number of trees by absolute degrees of thickness for the studied experimental plots and curves for normal distribution was obtained through the Statistica program (Six Sigma, 7).

To investigate the regularities in the height structure, the so-called method of relative heights was applied. Its essence is that trees heights are determined as relative according to average height (so-called natural degrees of height - NDH) (Davidov, 1949), and the number of trees in different heights is presented as a percentage of total number of the growing stock (Krastanov, 1969).

The horizontal spatial structure is illustrated by the software Stand Visualization system (SVS), presenting graphically the tree stands according previously made model in Microsoft Excel (McGaughey, 1997).

Stand quality class is determined by interpolating and using the tables for determining the quality of Black Locust plantations according Georgiev (Krastanov & Raykov, 2004).

We studied the composition of humus in soils using the method by Kononova & Belchikova (1961) following the necessary steps: determination of the total content of humic and fulvic acids with a mixed solution of 0.1N $Na_4P_2O_7$ and 0.1M NaOH; determination of aggressive fulvic acids with 0.05M H_2SO_4. The total N is analyzed by the method of Keldal. These analyses were made in the autumn of 2018, 15 years after establishing of plantations.

Table 1. Location and characteristics of the sample plots.

Location	Sample Plot (SP)	Coordinates	Altitude a.s.l. m	Orientation of SP Exposure	Slope °	Age years
GHE Seslav	SP1	N43.90052° E 26.44102°	150	Eastern-Western	2	18
GHE Seslav	SP2	N43.90052° E 26.44018°	150	Eastern-Western	2	18

Dendrometrical indicators were determined by *in situ* measurements. Tree height (H), the height at the beginning of the crown (with altimeter SUNTO PM *-5/1520 PS* , with accuracy of 0.5 m) and diameters at breast height (DBH) (with accuracy of 0.1 cm) of all trees in SPs were measured.

The mean DBH was determined by the arithmetic basal area – formula (1):

(1) $DBH=SQRT(1.274*\sum G$(cm)

where:

$G=\sum g_i/ n$ - is arithmetic basal area in sample plot (m^2);

$\sum g_i$ – is the sum of the basal areas of all the trees in the sample plot (m^2);

n - is number of trees in sample plot;

The average height (*H*av.) was calculated after the formula of Lorey:

(2) $Hav. = (h_1g_1 + h_2g_2 + \ldots\ldots.+h_ng_n)/(g_1 + g_2 + \ldots\ldots\ldots+g_{n)}$(m)

where:

h (1,2…n) – is a mean (arithmetic) height of each degree of thickness (1,2, ….n) (m); g (1,2…n)– is a basal area for each degree of thickness(1,2, ….n) (m^2).

The mean width of the crown (Dcr(m)) and mean length of the crown (Lcr(m)) are the arithmetic mean of crowns' diameters of all trees.

Results and Discussion

Dendrometric characteristics

Calculation of the dendrometric indicators (average diameter DBH (cm), average height- Hav (m)) and parameters of tree crowns (mean crown width Dcr (m) and mean length of crowns Lcr (m)), cubing and assortmenting of the studied Black Locust plantations were made. The results are presented in Table 2.

In SP1, where agroforestry was practiced, the meanings of most dendrometric indicators are better than in SP2 (control). Despite the virtually identical values of average diameter DBH, the other dendrometric indicators as stem volumes, volume of construction timber and entire trees are better in SP1 with 16.10 m^3 / ha (7.8%), 15.74 m^3 / ha (8.0%) and 17.56 m^3 / ha (7.0%) respectively. In the area with applied agroforestry (SP1) particularly indicative is the diffrence of a mean height: the mean height is 2.11 m higher than in control (17.27 m against 15.16m) and due to that fact is the difference in the timber volume. This happens despite the relatively denser scheme of planting in plantation with agroforestry practiced. According to local foresters, the difference in height was accumulated during the first 2 years after the establishment of the plantation, i.e. during the agroforestry practicing and when the care of the agricultural crops was applied (hoeing, fertilizing, weeding) which have contributed to the better growth of the tree stands. The less rare planting scheme in plantation without agroforestry (SP2) reflects the biometric parameters (mean length and mean width) of crowns which logically have higher values. For a more objective comparison and demonstration of the advantage of the agroforestry, the regularities in the structure according diameter and height were ascertained and compared by using the variation curves of distribution of these dendrometric indicators in the studied plantations.

The distribution of the number of Black Locust trees by absolute degrees of thickness for the studied SPs and curves for normal distribution is illustrated in Fig. 1 and Fig. 2.

When tested, the density of the normal distribution, i.e. the closeness of the distribution of diameters to the normal type according to the criteria of Kolmogorov-Smirnov, (Lilliefors (BOROVINKOV, 1998)) it shows that the smaller value of the coefficient K-S (0.08525) is in SP2 - here the distribution of the random variables (diameters) is relatively closer to normal. The probability of zero hypothesis in both SPs (p) is less than 0.01, so the hypothesis of normality in the distribution of the trees in them can not be rejected.

Study of the variation curves for arrangement of trees according to the degrees of thickness and to the degrees of height

The here used method of variation curves of arrangement of stems through natural degrees of thickness (NDT) allows comparison of the curves of arrangement by calculation the number of trees in separated degrees as a percent of total number trees.

In Fig. 3 (a and b) is showed the respective variation curves of arrangement of the number of trees according to the natural degrees of thickness obtained as parts of the mean diameter (Table 2), which is accepted as a unit.

It is interesting to compare the variation curves of plantations managed differently. In the present study, such a comparison is made by comparing the shape of the variation curves presented as a percentage arrangement of the trees according to the natural degrees of thickness to their total number in the respective sample plot (Fig. 4) and by analytical comparison of the analysed arrangements according to the diameter.

The variation curves of the trees arrangement according to the thickness in the studied plots have a typical asymmetric course (Fig. 4), with clearly discernible maximums of curves. In SP1 the arrangement of the Black Locust trees is closer to the normal one (NDT from 0.4 to 1.7) and it is observed the maximum in NDT 0.6 (13.1%), which is also maintained for NDT 0.7 - to the left of the average diameter. In SP2 saturation of trees is observed in a wider range (NDT from 0.4 to 1.8), as the maximum here is lower (11.3%) and again to the left of the average diameter (in NDT 0.6).

In both cases, most of the trees are located in the thinner part of the average tree diameter (60.8% for SP1 and 54.7% for SP2), so the right–hand part of the curve has a smoother move and the leftpart – steeper move.

In the central degrees of thickness are concentrated almost equal percentage of trees (average for the three central NDT - 9.8% for SP1 and 9.5% for SP2), which are close to the values (decrease by 0.5% and 0.8% respectively) of the number of stems (10.3%) determined by DUHOVNIKOV & ILIEV (1957). The average degrees of thickness, represented by the largest number of stems, increase the quantity of the large and medium sorting in the plantation (LOGVINOV, 1956; FEREZLIEV *et al.,* 2018). In this case, the small percentage of participation confirms the established assorting structure, where the sortings are from III to VI class (middle and small construction timber) - Table 2.

The calculated parameters of Skewness and Kurtosis of distributions the number of trees according to the degrees of thickness and their standard errors are presented in Table 3.

The values of skewness in the SPs is greater than 0, which confirms that the distributions are mostly displaced to the right-hand part (the curve is tilted to the left). Such abnormalities are often found in natural forests and plantations with one and the same ages (FEREZLIEV *et al.,* 2018; TSAKOV *et al.,* 2018). In both areas, the values obtained by dividing coefficients of skewness to their standard errors are greater than the limit of 1.96.

The arrangements of the diameters is carried out on curves which diminish the normal distribution curves to a small degreein their uppermost parts . Criteria for this are the Kurtosis of the arrangements according to diameter in both plots which are negative (-0.265 and -0.581 respectively) and small by values. It can be assumed that the reason for the deviations from the normality of the tree arrangements according to the degrees of thickness is their right-hand skewness.

In general, the graphs of the variation curves and the analysis of the statistical indicators and Kurtosis show that the distributions according to the diameter in both cases are displaced mainly to the right-hand of the mode (the curves have a characteristic asymmetric move and are inclined to the left in both cases). In SP1 with applied agroforestry the peaks are higher and cover a wider range with respect to natural degrees of thickness.

In Fig. 4, a comparison also of the variation curves of percentage distribution of the number of trees in the investigated sample plots according to natural degrees of thickness with the uniform variation distribution curve (after THYURIN, 1931) was made. Both experimental plots have significant deviations from the course of the uniformvariation curve (which is situated almost symmetrically towards average diameter). In both cases the curves of the SPs show lower peaks and more prolonged intervals. The variation curve of SP2 differs from that of SP1 and Thyurin as far as the right-hand move is concerned, where it exceeds with one NDT, reaching 1.8.

In order to examine the peculiarities of in the height structure, the so-called method of relative heights was applied. Its essence lies in the fact that tree heights are defined as relative in terms of the mean height (i.e. natural degrees of height - NDH) (DAVIDOV, 1949) and the number of trees at different heights is given as a percentage of the total number of trees (KRASTANOV, 1969). Curves of percentage arrangement of the number of Black Locust trees according to the NDH in both SPs are obtained (Fig. 5). In the height structure the attention is directed mainly to curves of heights and mean heights, using the well-known correlation between diameter of trees and their height. Fig. 6 shows the height curves for the two SPs according to NDH and NDT (in relative numbers), as well as the equal curve for each one of them.The equal curves of heights give the opportunity to compare the height curves for SPs with the unified height curve of Thyurin (Fig. 7). Fig. 7 clearly shows that the move of the mean curves in both SPs in the range of NDT from 0.4 to 1.8 is identical but differs substantially from the unified curve of Thurin (for NDT from 0.5 to 1.7).

The range of variation of relative heights according to natural degrees of thickness is approximately the same and is determined from 0.3 (for NDT 0.4) to 1.4 (for NDT 1.8) for SP1 and in a slightly shorter interval for SP2 (from 0.3 (for NDT 0.4) to 1.2 (for NDT 1.8)) and is more significant than for Thyurin (from 0.8 (for NDT 0.5) to 1.15 (for NDT 1.7).

A study of the height structure confirmes the published by Thurin that the curves of heights of the trees have approximately the same shape and depend to a certain extent on the forestry activity (MIHOV, 2005). An advantage of the SP with agroforestry is observed in relation to the higher values of natural degrees of height and in a broader range of natural degrees of thickness. Unlike Thyurin's claims, due to observed differences in relation with his unified curve (wider ranges of variation and better natural values of NDH and NDT) probably along with age and made management activity on the curves of heights do an affect also the tree species, as well as the site conditions.

The availability of information on the overall move of curves of thickness and height is useful for forestry science as it can be used to develop a forest simulation model for comparing of plantations with and without applied agroforestry.

Spatial structure of the stands

Spatial structure of the tree stands is a driving factor for growth processes and competition in them. Every impact on tree stands is primarily a change in their spatial structure (ALEXANDROV, 2015, pers. comm.). The location of the trees in space is illustrated by the software Stand Visualization System (MCGAUGHEY, 1997), which is a relatively modern approach in forest science (ALEXANDROV, 2015, pers. comm.). For the purpose, a local coordinate system has been developed within each SPs, where the co-ordinates of all trees are determined as well as the coordinates of the horizontal projection of their crowns in the four directions. In this way is illustrated the spatial horizontal structure that presents graphically the plantations. This computer product makes it possible to create a visual image of the forest section through the mentioned available and measurable on the terrain data. In the United States, for example, the software is most commonly used by forest owners and designers to display a representative area of forests (BARRETT *et al.*, 2007).

On the basis of the measurements made in the SPs and on the created on this basis incoming files with data, the following graphic images were produced, presenting the spatial structure of the SPs (Fig. 8 and Fig. 9). As the SPs are of the same form and size, a visual assessment of the differences in the structure of the studied forest plantations can be made in the two selected cases (with and without applied agroforestry). The profile diagrams obtained with the program can not be used for direct analysis but they show the location of the trees in the space (ALEXANDROV, 2015, pers. comm.) and the result of the application of the agroforestry in SP1, which is resulted in a more visible horizontal structure in this plot.

Improving the soil environment after applying agroforestry practices

The site conditions have influence on the tree growth. From special importance is the soil environment. The results of soil analyses are presented in Table 3. The soils in both SPs have slightly acid reaction. The total carbon in soil surface layers is with high content with weakly higher value in SP1 (4.58%). The total nitrogen is also higher in SP1 where agroforestry was applied. The C/N ratio is an important factor in assessing the degree of humification of the organic matter in the soil. If the ratio is less, the mineralization is faster and the humus system is more mature. At C/N < 14 the humus system is defined as Mull, between 14 ÷ 25 as Moder, and > 25 as More. SP1 (with agroforestry) has ratio much close to 25 and this shows that the conditions of organic substances decomposition are much better in comparison with SP2 (without agroforestry) where the ratio has very high value. Especially better data has the SP1 in relation with soil humus composition. According the method of Kononova-Balchikova soil humus in relation with the solvent in which soils substances are dissolved, is divided into humic acids, fulvic acids and humin. The humic acids are dissolved in NaOH but do not dissolve in HCl. They are basicly carboxylic acids containing benzene nuclei in their molecule. This is the stable part of soil humus (KONONOVA & BALCHIKOVA, 1961). The more humic acids, the more organic matter is more stable in the soil. In contrast, fulvic acids are the mobile and more unstable part of the humus in the soil and dissolve in both NaOH and HCl. The insoluble part of the humus substances is the humin in the soil. The data shows that a better composition has the humus in SP1 - the humic acids are more in comparison to SP2, and the fulvic acids are less. It is particularly indicative that the amount of the most mobile and unstable part of the soil - that of "aggressive fulvic acids" - is higher in soils of SP1 than in SP2 (with 0.01%).

Therefore, agroforestry practices have played a positive role in improving the conditions of the soil environment, contributing to the better development of the existing tree vegetation. These results support the opinion of other authors regarding agroforestry as an opportunity to improve the soil properties (NEUPANE, & THAPA, 2001; GUO *et al.*, 2018; CHEN *et al.*, 2019).

Guidelines for the management of black locust plantations

The scheme of afforestation in the two SPs is different - in SP1 it is denser (with 70% of the originally afforested saplings is presented, and SP2 is less common (with significantly more surviving trees - 87%) This is explained by agricultural activities in SP1, which is also related to the thinning of the tree plantation. In planting and hoeing the watermelons during the first two years after the establishment of the plantation, workers unintentionally destroyed nearly 20% of the Black Locust saplings.

If the goal is to produce firewood at rotation ages 15-20, then both SPs have reached these ages, and logging can occur. The total stock in SP1 is bigger than in SP2

Table 2. Dendrometruc characteristics of sample plots.

Sample plot (SP)	Average Diameter DBH	Average height Hav	Mean length of the crown Lcr	Mean diameter of the crown Dcr	Stand quality class	Stem volume V stem	ASSORTMENT STRUCTURE OF STEMS: Medium construction timber (MCT) Class III	Class IV	Class V	Total MCT	Small constriction timber class VI	Total constriction timber	Volume of the branches	Volume of the whole trees
	cm	m	m	m		m³ m³/ha	m³	m³	m³	m³	m³	m³ m³/ha	m³	m³ m³/ha
SP1	10.9	17.27	7.98	3.04	I	10.323 206.46	0.074	1.349	4.979	6.402	3.430	9.832 196.64	2.168	12.491 249.82
SP2	11	15.16	8.01	3.55	II	9.518 190.36	0.075	1.447	4.646	6.168	2.877	9.045 180.90	2.094	11.612 232.24

Table 3. Descriptive statistics of the trees in the sample plots.

SP	Valid number of trees (N)	Skewness	Std. Err. Skewness	Skewness÷ Std. Err. Skewness	Kurtosis	Std. Err. Kurtosis	Kurtosis÷ Std. Err. Kurtosis
SP1	135	0.677	0.208	3.25	-0.265	0.414	-0.64
SP2	134	0.445	0.209	2.13	-0.581	0.415	-1.40

Table 4. Soil properties in sample plots.

SP	pH	C%	N%	C/N	C in humic acids (%)	C in fulvic acids (%)	C in aggressive fulvic acids (%)	C in residue (humin)
SP1	6.01	4.58	0.16	29	1.45	0.65	0.05	2.86
SP2	6.09	4.36	0.10	44	1.02	0.92	0.06	3.17

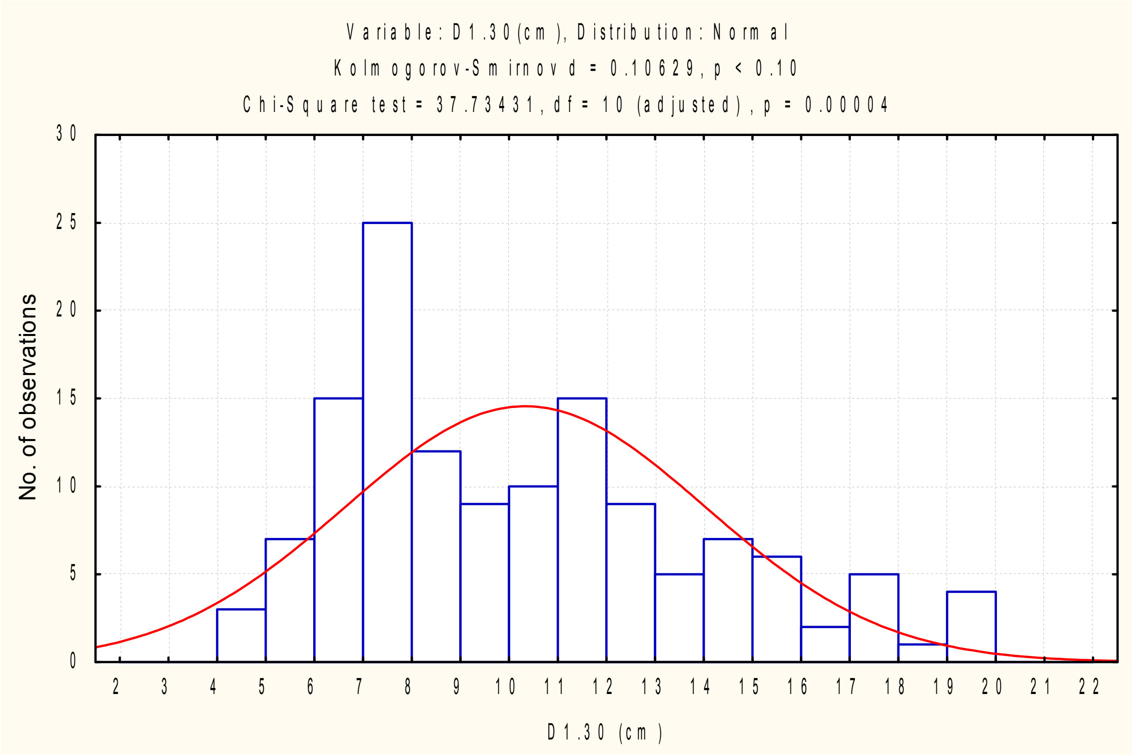


Fig. 1. Distribution of the number of trees in SP1 (a),
by degrees of thickness and curve of the normal distribution.

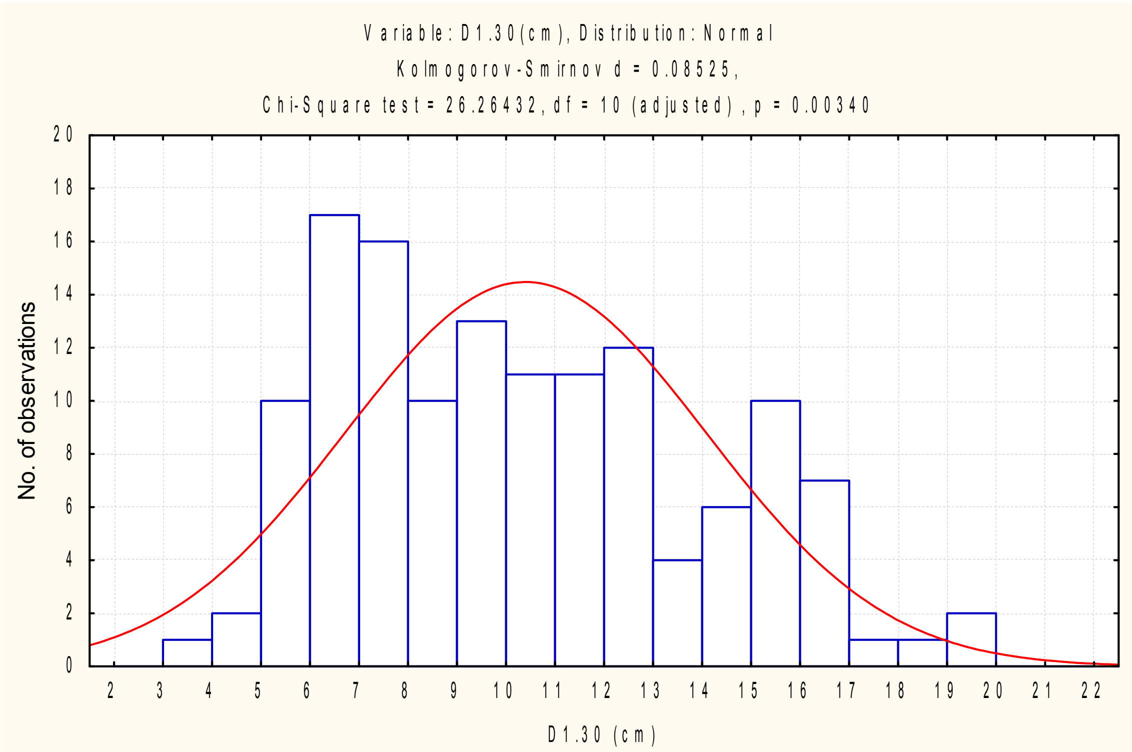
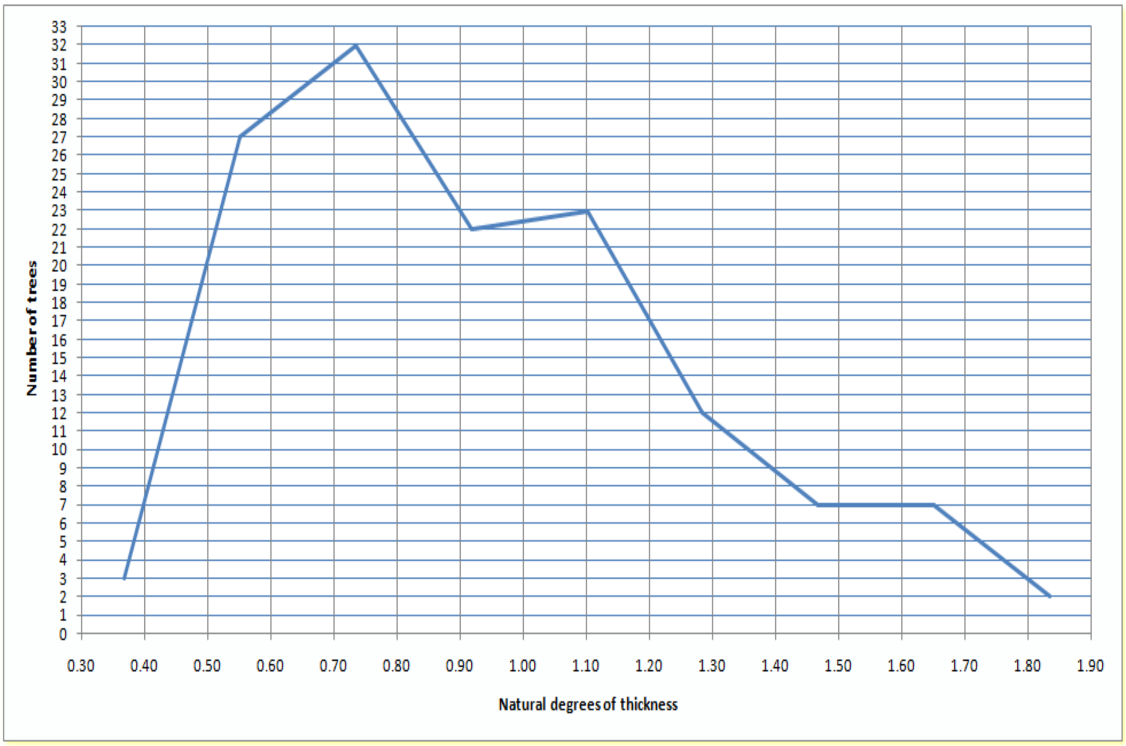
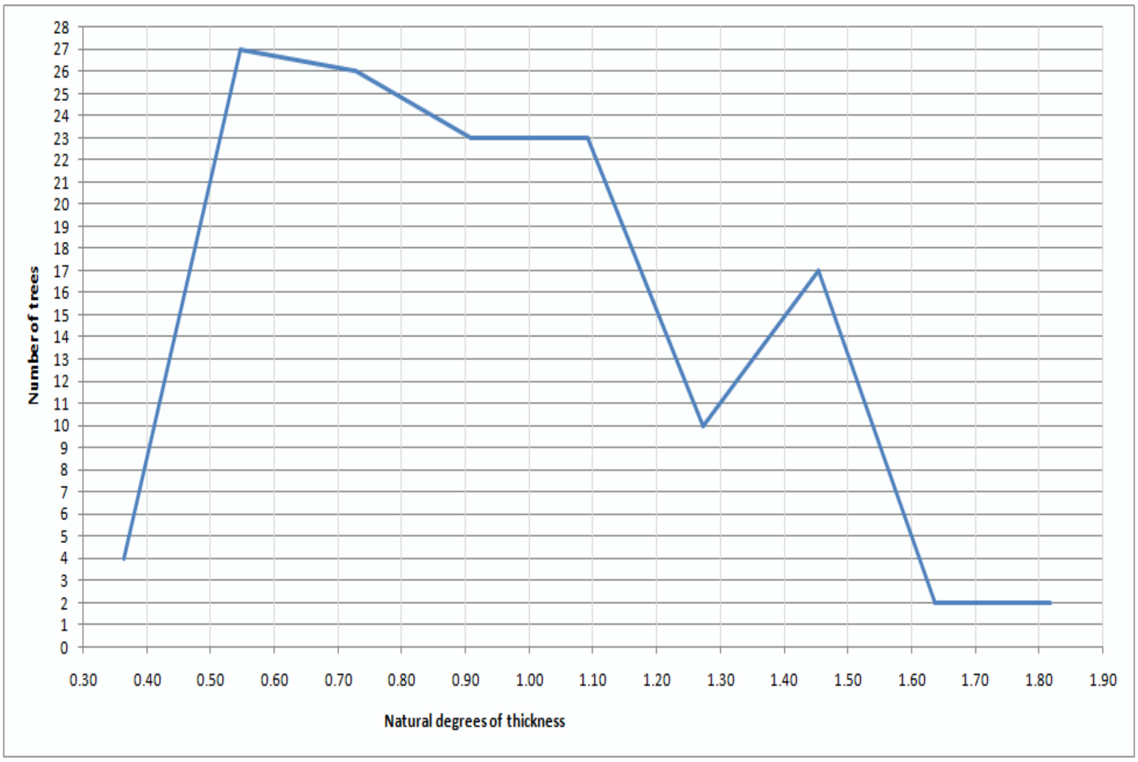


Fig. 2. Distribution of the number of trees in SP2 by degrees of thickness and curve of the normal distribution.



a



b

Fig. 3. Variation curves of distribution of the number of trees in SP1(a) and SP2 (b) by natural degrees of thickness.

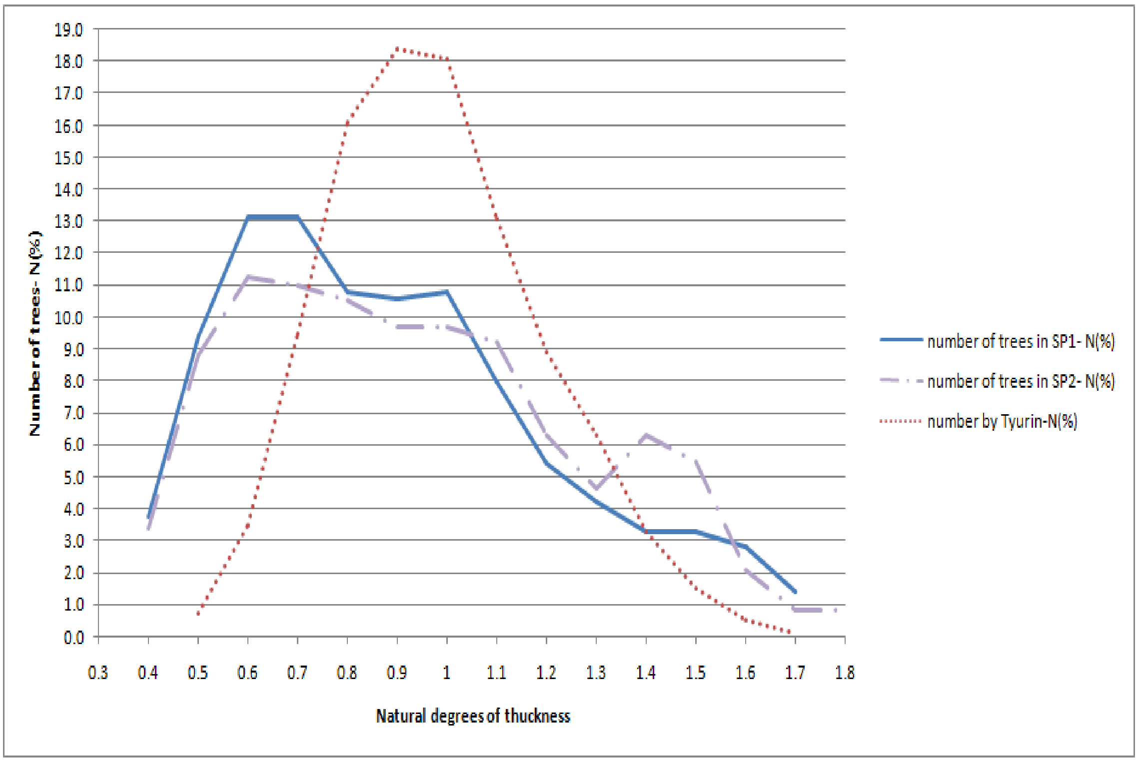


Fig. 4. Comparison of the obtained variation curves of the number of trees in SP1 and SP2 with the uniform variation distribution curve of Thyurin.

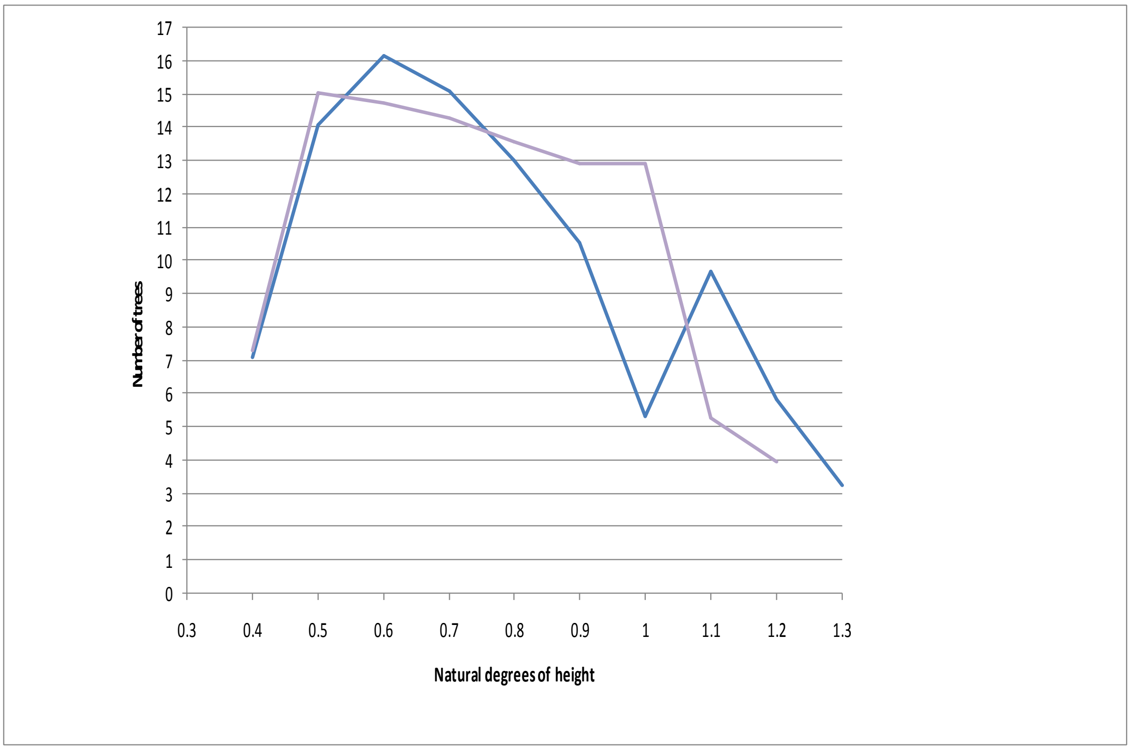
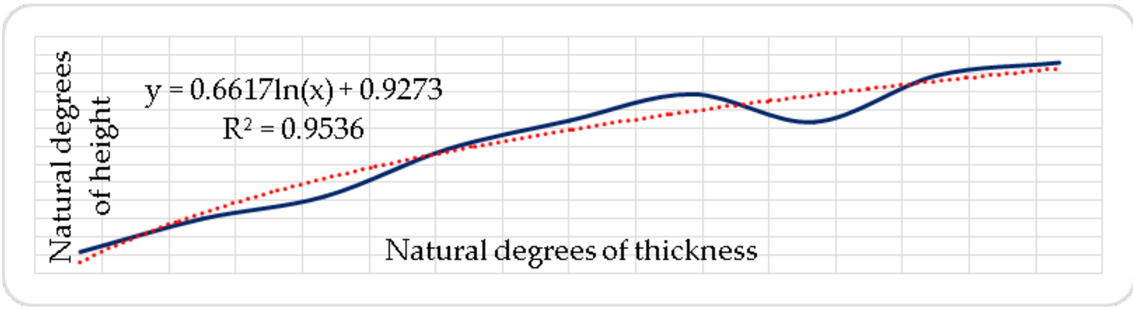
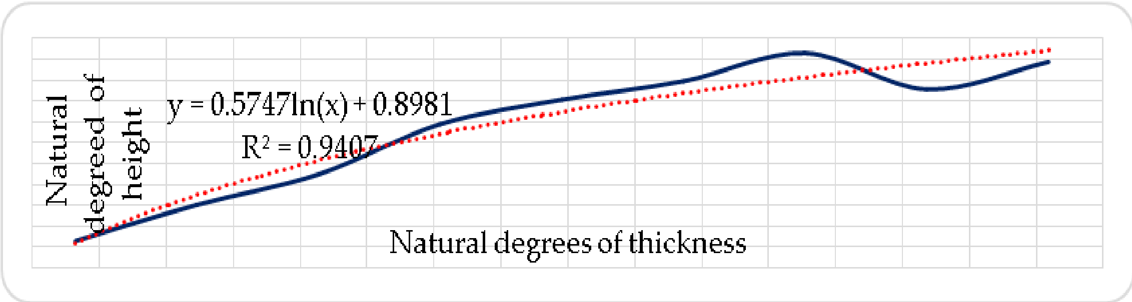


Fig. 5. Variation curves of percentage distributions of the number of trees in sample plots by natural degrees of height.



a



b

Fig. 6. Curves of heights in relative numbers for SP1 (a) and SP2 (b).

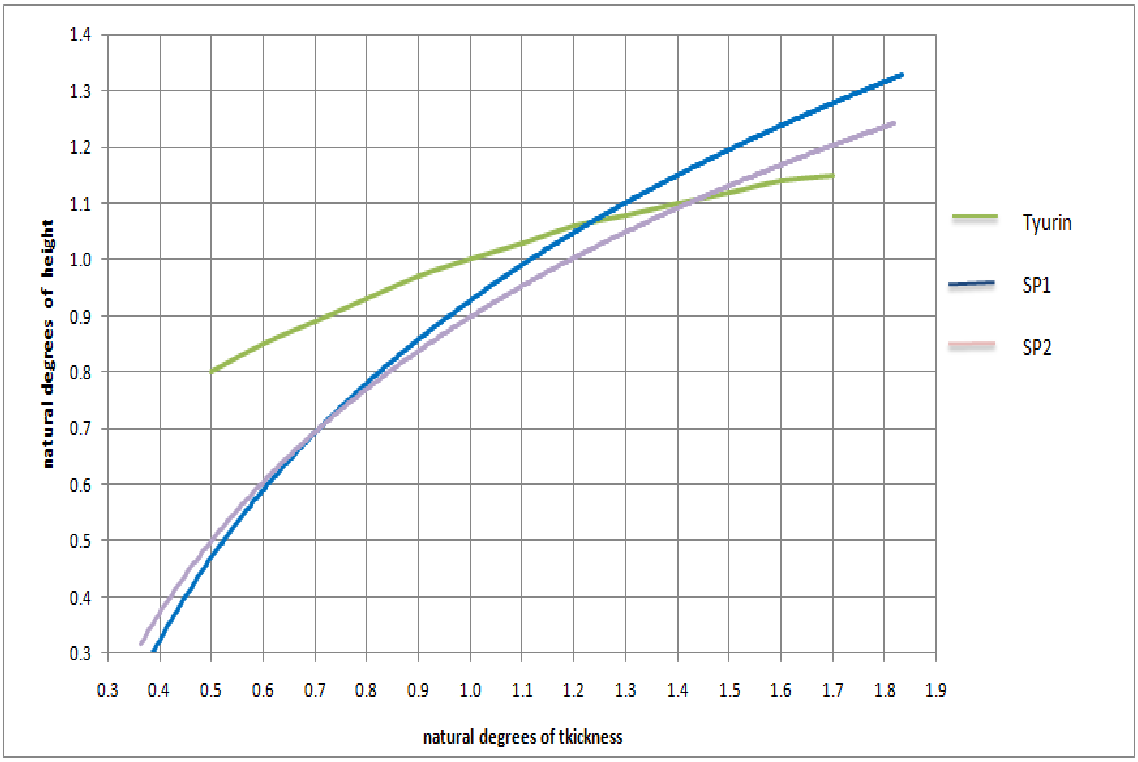


Fig. 7. Comparison of the mean curves of the heights in the investigated sample plots with the mean unified curve of the heights of the Tyurin.

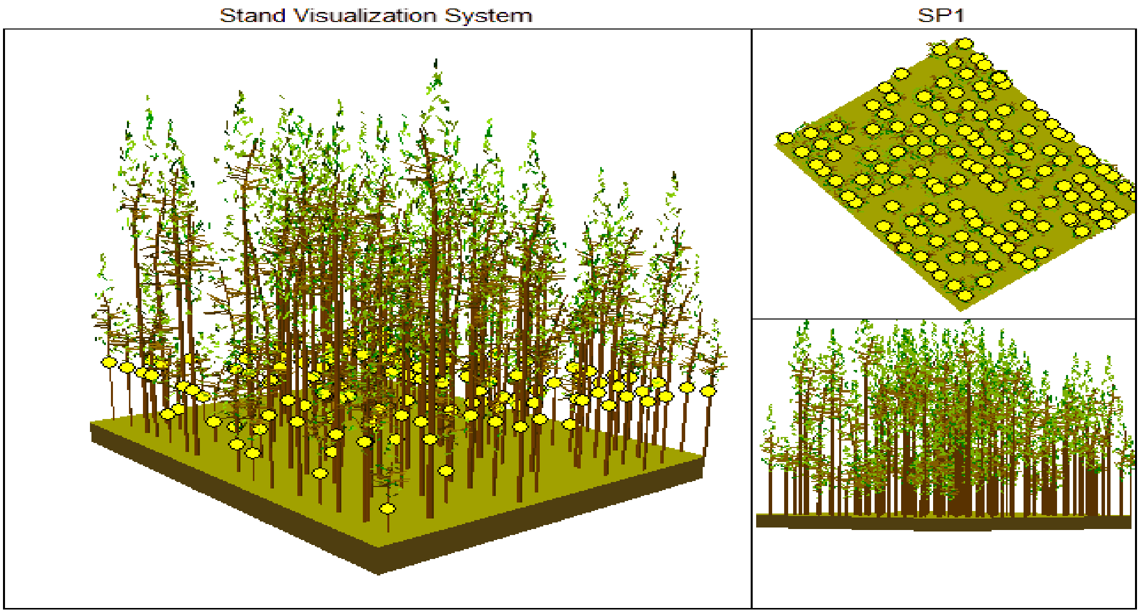


Fig. 8. Spatial Structure of SP1 – in perspective, in profile and from above.

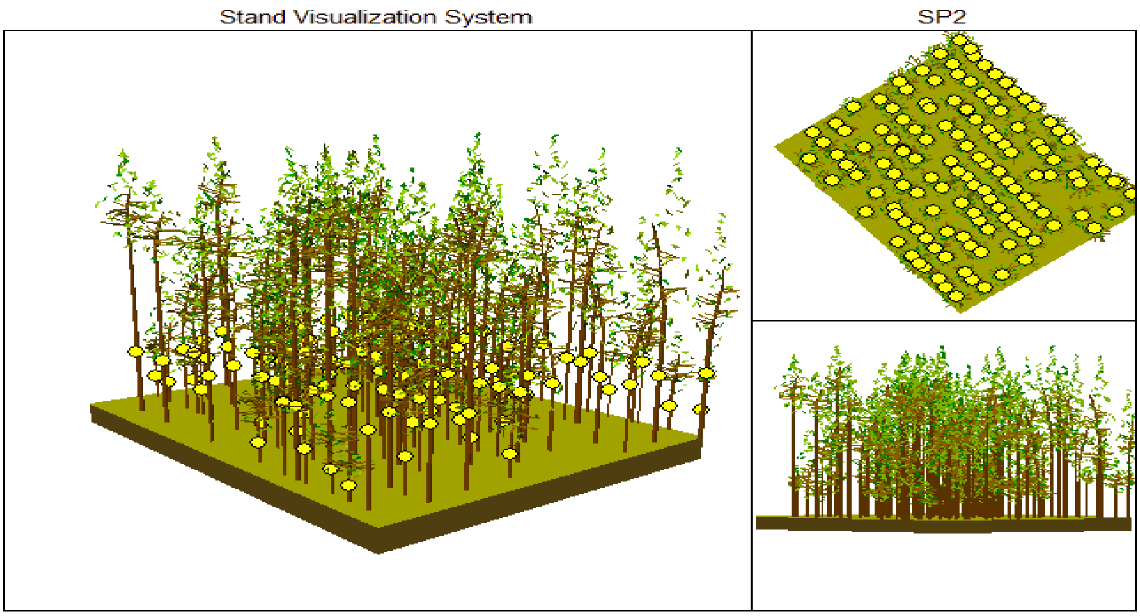


Fig. 9. Spatial Structure of SP2 – in perspective, in profile and from above.

(Table 2) and, besides the fact that in this SP, a certain amount of agricultural output has been obtained in the first two years, also a higher amount of wood will be harvested.

If it is intended to produce large construction wood in rotation period 30 years, it is necessary to be done a single selecting thinning at the moment. Its intensity should be up to 35% of the total volume and the stocking rate should be reduced to the 0.6 - 0.7. The trees of the future are chosen and grown, and the inferior specimens that compete with them are removed. The degree of distortion of the stem the Black Locust is dependent on the hierarchy of the individuals in the tree stand, which is most pronounced in the case of the oppressed specimens, but is also genetically depending. In this case, SP1 again has priority over SP2. On the one hand, a slightly larger yield in SP1 will be obtained due to its larger total volume. What is more important, however, is that growth in height in SP1 is significantly more advanced and woodland is already entering the growth stage in diameter, while in SP2 it is still in the growth stage in height. In SP1 the process of differentiation is more pronounced and the trees of the future are more clearly outlined. In their cultivation they will react more quickly and will begin to accumulate a growth in diameter, what is the forestry goal. In this case, in both SPs are recommended periodically performing a pruning to form a stem section with a length of 4-6 m. The crown should not be reduced by more than 1/3 of the total height. Overall, it can be concluded that the application of agroforestry practices facilitates and improves the production of wood.

Conclusions

Agroforestry is an economically efficient combination of forestry with plant and / or livestock breeding. And while the agricultural part of it can change every year or even a few months (depending on the life cycle of the crop used), the management of its wood component has a much longer and more complex character. With wood components can also achieve a broad range of goals: industrial, environmental, social, landscaping, etc. Particularly suitable for agroforestry systems is white Black Locust (*Robinia pseudoacacia* L.). With applied agroforestry system, the significance of the dendrometric indicators, which are criteria for qualitative and quantitative productivity, are greater in the area with agroforestry where there is a concentration of larger volume (including construction) wood. The comparative characteristics done, the established features in the diameter and height structures and the established horizontal structure together with the improved soil conditions in the plantations where agroforestry is practiced show the advantages of practicing this form of land use, where in the cultivation of acacia saplings in the initial years of the development of plantation between tree rows can be grown appropriate agricultural crops.

References

ALEXANDROVA E., K. KALMUKOV, G. GEORGIEV, TS. TSANOV. 1994. Nitrogen-fixation in white acacia (*Robinia pseudoacacia* L.), black alder (*Alnus glutinosa* L.) and raknitka (*Hippophae rhamnoides* L.) in dependence of soil type. - *Nauka za gorata (Forest Science)*, 1: 22-37. (In Bulgarian).

ANUCHIN N. 1982. *Forest Estimation Records*. Moskva. (In Russian).

BARRETT T., ZUURING H.R., CHRISTOPHER T. 2007. Interpretation of forest characteristics from computer-generated images. – In: *Landscape and Urban Planning*, 2007, 80, pp. 398.

BOROVINKOV B. 1998. *Popular introduction in program Statistica*. Moskva. Kompiuter-Press. (In Russian).

CARVALHO G., I. CARDOSO, M. E. DE SÁ, F. ALVES, L. SCHIAVON, O. SENA. 2016. Trees modify the dynamics of soil CO_2 efflux in coffee agroforestry systems. - *Agricultural and Forest Meteorology*, 224: 30–39.

CHEN C., W. LIU, J. WU, X. JIANG, X. ZHU. 2019. Can intercropping with the cash crop help improve the soil physico-chemical properties of rubber plantations? - *Geoderma*, 335: 149–160.

DAVIDOV M. 1949. Studying the move of height of stands in western areas of USSR. - *Lesnoe hozaistva*, pp. 12 (In Russian).

DONCHEV G. 1968. For some basic moments in establishment of industrial plantations of white acacia (*Robinia pseudoacacia* L.). - *Scientific papers of Forest University*, XVI: 51-61. (In Bulgarian).

DUHOVNIKOV I., A. ILIEV. 1957. On the size of the degrees of thickness and the distance between the heights ranks and their significance for the precision of the cubing and the sorting of the coniferous trees. - *Scientific papers of Forest University*, V: 84-96. (In Bulgarian).

EVANGELOV E. 2012. *Forestry Estimation Tool* (FET 1.11 Demo). Programme for cubing and sorting, version 1.11 (demo).

FEREZLIEV A., H.TSAKOV, I. MIHAL, M.BARNA, A.CICAK. 2017. Peculiarities in structure according diameter in stands updet by the hurricane in the West Rhodopes. – *Nauka za Gorata* (*Forest Science*), 1: 53-63. (In Bulgarian).

FEREZLIEV A., N. ZAFIROV, K. KAROV. 2018. Comparative investigation on distribution by diameter variation curves in douglas-fir plantations in State Forestry Alabak. – *Nauka za Gorata (Forest Science)*, 1: 38-54. (In Bulgarian).

GUO J., BO WANG, G. WANG, Y. WU, F. CAO. 2018. Vertical and seasonal variations of soil carbon pools in ginkgo agroforestry systems in eastern China. – *Catena,* 171: 450-459.

HUBER J., M. MATIU, K.-J. HULSBERGEN. 2018. First-rotation growth andstand structure dynamics oftree species in organic andconventional short-rotationagroforestry systems. – *Heliyon,* 4(6): e00645. [DOI].

KONONOVA M., N. BELCHIKOVA. 1961. [Rapid method of mineral soil humus composition]. - *Pochvovedenie*, 10: 75-85. (In Russian).

KOSTOV K., M. BROSHTILOVA, K. BROSHTILOV. 1992. Aboveground phytomass of mono and mixt stands of white acacia (*Robinia pseudoacacia L.*) in the region of Biala Slatina. - *Nauka za gorata (Forest Science)*, 4: 13-23. (In Bulgarian).

KRASTANOV K., P. BELYAKOV, H. STOIKOV, D. STOYKOV, E.DIMITROV. 2004a. Table for determination of the height ranks of white Black Locust. - In: Krastanov, K., R. Raikov (Ed.), *Guide on dendrometry*. Sofia. Bulprophor, pp. 236. (In Bulgarian).

KRASTANOV K., H. TSAKOV, P. BELYAKOV, H.STOIKOV, D. STAIKOV, E. DIMITROV. 2004b. Volume and sorting table for white locust. - In: Krastanov, K., R. Raikov (Ed.): *Guide on dendrometry.* Sofia. Bulprophor, pp. 237-245. (In Bulgarian).

KRASTANOV K., R. RAYKOV, 2004. *Guide on dendrometry*. Sofia. Bulprophor, 552 p. (In Bulgarian).

KRASTANOV K. 1968. Regularities in the structure according to the thickness of mixed beech-oak plantations. – *Nauka za gorata (Forest Science)*, 5: 25-41. (In Bulgarian).

KRASTANOV K. 1969. Regularities of the structure according to the height. - *Nauka za gorata (Forest Science)*, 6: 37-49. (In Bulgarian).

KRASTANOV K., P. BELYAKOV, A. ANDONOV. 1965. On some regularities in the structure, growth and productivity of the stands in "Belka" Forest. – *Nauka za gorata (Forest Science)*, 5: 387-400. (In Bulgarian).

LOGVINOV I. 1956. Structure of the growth of pine - fir plantation in pine-mulberry tree forest type in Leningrad region and the organization of forestry in them. - *Records of Arboriculture Academy*, pp. 73. (In Russian).

MCGAUGHEY R. J. 1997.*Visualizing forest and stand dynamics using the stand visualization*. Available at: [fs.fed.us].

MIHOV I., 2005. *Forest Estimation Records*. Sofia. RIK "Litera", 103 p. (In Bulgarian).

MOSQUERA-LOSADA M. R., G. MORENO, A. PARDINI, J. H. MCADAM, V. PAPANASTASIS, P. BURGESS, N. LAMERSDORF, M. CASTRO, F. LIAGRE, A. RIGUEIRO-RODRÍGUEZ. 2012. Past, Present and Future of Agroforestry Systems in Europe. - In: P.K.R. Nair and D. Garrity (Ed.), *Agroforestry - The Future of Global Land Use*. Advances in Agroforestry 9. Springer Science + Business Media Dordrecht 2012. [DOI].

Mosquera-Losada M. R., J. McAdam, R. Romero-Franco, J. Santiago-Freijanes, A. Rigueiro-Rodigues. 2009. Definition and Components of Agroforestry practices in Europe. - In: Rigueiro-Rodigues A., J. McAdam, M. R. Mosquera-Losada (Ed.): Agroforestry in Europe. Current Status and Future Prospects. Springer Science + Business Media B. V., 2009.

Mosquera-Losada M. R., R. Borek, F. Balaguer, G. Mezarrala, M. E. Ramos-Font. 2017. Agroforestry as a mitigation and adaptation tools. - In: EPI-AGRI Focus Group (Ed.): *Agroforestry*. Minipaper, pp 1-9.

Nair R. 2013. *Agroforestry: Trees in Support of Sustainable Agriculture.*University of Florida. Gainesville, FL, USA2013 Elsevier Inc., pp. 15.

Nair R., V. D. Nair, E. Gama-Rodrigues, R. Garcia, S. Haile, D. Howlett, B. Mohan Kumar, M. R. Mosquera-Losada, S. Saha, A. Takimoto, R. Tonucci. 2009. *Soil Carbon in Agroforestry Systems: An Unexplored Treasure? - Nature Precedings*. Available at: [precedings.nature.com].

Neupane R., G. Thapa. 2001. Impact of agroforestry intervention on soil fertility andfarm income under the subsistence farming system of the middle hills, Nepal. - *Agriculture Ecosystems and Environment,* 84 (2): 157–167.

Pardon P., B. Reubens, D. Reheul, J. Mertens, P. De Frenne, T. Coussement, P. Janssens, K. Verheyen. 2017. Trees increase soil organic carbon and nutrient availability in temperate agroforestry systems. - *Agriculture, Ecosystems and Environment,* 247: 98–111.

Santiago-Freijanesa J., A. Pisanellic, M. Rois-Díaza, J. Aldrey-Vázquezb, A. Rigueiro-Rodrígueza, A. Panterae, A. Vityif, B. Lojkag, N. Ferreiro-Domígueza, M. R. Mosquera-Losada. 2018. Agroforestry development in Europe. – *Policy issues: Land Use Policy*, 76: 144–156.

Stancheva J., S. Bencheva, K. Petkova, V. Piralkov. 2007. Possibilities for agroforestry development in Bulgaria – outlook and limitations. – *Ecological Engineering*, 29 (4): 382-387.

Stankova T., V. Gyuleva, K. Kalmukov, P. Dimitrova, E. Velizarova, D. Dimitrov, H. Hristova, E. Andonova, I. Kalaydziev, K. Velinova. 2016. Biometric models for the above ground biomass of juvenile black locust trees. - *Silva Balcanica*, 17 (1): 21-30.

Tsakov H., A. Ferezliev, A. Delkov, H. Hristova. 2018. Thickness structure of Macedonian pine (*Pinus peuce* Griseb.) plantations growing in the Vitosha Mountain. – In: *Proceeding papers International Scientific Conference "90 Years Forest Research Institute - for the Society and Nature"*. 24-26.10.2018, Sofia, Bulgaria, pp. 83-90. (In Bulgarian).

Tsakov H. 1998. Studies on the thickness of natural plantations of *Pinus peuce Gris*. in North Pirin Mountain. – *Nauka za gorata (Forest Science)*, 3-4: 63-75. (In Bulgarian).

Tsanov T., I. Naydenov, K. Kalmukov, K. Broshtilov. 1992. Initial results from testing certain clones of false acacia (*Robinia pseudoacacia L.) - Nauka za gorata (Forest Science)*, 4: 24-30. (In Bulgarian).

Tyurin A. 1931. [*Normal productivity of forest plantations of pines, cutters and spruce*]. Moskva. (In Russian).

WRB (World reference base for soil resources, 2006. *A framework for international classification, correlation and communication*. World Soil Resources Report, 103. FAO, pp. 130.

Yurukov S. 2003. *Dendrology*. Sofia. Publishing House at Forest University, 158 p. (In Bulgarian).

Received: 11.02.2019
Accepted: 15.04.2019