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RESEARCH ARTICLE

Growth and productivity of half-sibs progenies of selected *Robinia pseudoacacia* L. clones in the region of Ruse

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Abstract

An assessment was made on the main growth and productivity indicators in half-sibs progeny plantations of 18 *Robinia pseudoacacia* L. clones in the region of Ruse, on (M-I-2 D1 (13)) site, on rich, dry and compacted (Haplic luvisols) grey forest soil, at planting scheme 3.0x1,5 m. The differences in the main inventory indicators, defining the growth and productivity of the progenies of 18 black locust clones, confirm good qualities of the progenies of the Bulgarian clones Pordim-10, Pordim-13, Obretenik-1, Obretenik-6 and Ryahovo-1 and of the Hungarian clones Szajki and Nyirségi. This should be taken into account in the selection of material for establishment of industrial plantations and plantations for biomass production, as well as in the choice and performance of tending activities.

Keywords

black locust, clone, half-sibs progeny, growth, productivityt

Introduction

Black locust (*Robinia pseudoacacia* L.), as a multipurpose species has an economic, environmental and social role for wood and biomass production, soil stabilization, erosion control and restoration of disturbed terrain, agroforestry, source of bio-oil, fodder, honey etc. The peak of growth in height, diameter and volume occurs before the age of 20, which ranks it third after eucalypts and hybrid poplars (Pišek et al. 2009).

In the last 10 years, there has been a decreased interest in Bulgaria regarding the Black locust, influenced by the fact that in the international database EUFORGEN *Robinia pseudoacacia* L. is on the list of the 100 invasive species for America and Europe, although in 13 European countries it is considered a formally invasive species (Brus et al. 2016). As the species' potential to adapt to projected climate changes is high, the importance of the Black locust as both "preferred and rejected" species in Europe is expected to increase in the future, despite its invasive potential (Vítková et al. 2017).

Studies on the growth and productivity of Black locust plantations are important as they provide the guidelines for their management (Dimitrova, 2017; Dimitrova & Kalmukov, 2019; Kalmukov et al., 1999; Kalmukov, 2009, 2010, 2013; Kraszkiewicz, 2013; Redei et al. al., 2010, Redei et al. 2011; Stolarski et al. 2013; Tsnov et al. 1992). In our country, volume-class and assortment-class tables for the Black locust have been developed, applicable to trees with a diameter of more than 4 cm and a height of more than 6 m (Krastanov et al., 2004). In recent years in Bulgaria and other countries, the Black locust has been evaluated as one of the promising species for the production of biomass and energy, in plantations established at a higher density and with a short rotation period (Gyuleva et al., 2013; Gyuleva, 2014; Redei et al. al., 2010, 2011). The influence of density, genotype and rotation period on biomass production was analyzed and biometric models were developed to calculate the aboveground biomass of single-stem and coppice Black locust saplings with both vegetative (Redei et al., 2010, 2011) and seed origin (Böhm et al., 2011; Gyuleva et al., 2013; Gyuleva, 2014; Stankova et al., 2016; 2018; 2020).

In the 1980s, with the development and improvement of technology for vegetative propagation of the species by root cuttings, the Black locust management was placed on a selection basis and a clonal framework was introduced in the breeding of *Robinia pseudoacacia* L. in Bulgaria (Naydenov et al., 1981; Broshtilov et al., 1998). To increase the productivity and wood qualities, plantations were already established with selected (seed and vegetative) material. The established clonal collections, seed production gardens, progeny and technological experiments are the basis for choosing a suitable clone and of technology for establishing plantations with an economic or an ecological function depending on the site conditions. This enables the rational use of the Black locust's biological potential, its management and the increase of its productivity (Kalmukov, 2014).

The aim of the present study is a comparative analysis of the growth and productivity of plantations from half-sib progenies of Bulgarian and foreign selected *Robinia pseudoacacia* L. clones on gray forest soils.

Materials and Methods

The object of investigation are half-sib progeny plantations from 18 branches of *Robinia pseudoacacia* L. established in 2003 by Assoc. Prof. Kancho Kalmukov on the territory of the Ruse State Forest Enterprise, site (M-I-2 D1 (13)), on a rich, dry and compacted (Haplic luvisols) gray forest soil (WRBSR, 2014). The total area of the plantations is 18 dka. The terrain has a slope of 1° and has a southeast exposure, at altitude of 200 m

(43°45'04.1"N 26°11'45.2"E). The plot for each progeny is 1 dka with a size of 100x10 m. 330 individuals of one-year seed saplings from each clone of *Robinia pseudoacacia* L. are planted at a scheme of 3x1.5 m. The seeds were collected from the autovegetative seed production garden at the Experimental station for fast-growing forest tree species near the village of Vardim, Svishtov region. The rows are oriented in an east-west direction. The plots are separated by a border row of *Gleditsia triacanthos* L. (Figure 1).

For the study of each progeny of the Black locust clones, in 2023 trial areas of 0.72 dka have been set, and only for the Nyirsegi and Pustavagso progenies, the areas are 0.54 dka.

The heights of a representative sample of at least 50% of the trees in each sample plot were measured with a Vertex IV altimeter with accuracy to 10 cm.

Total caliper measurement of all tree stems in the sample plots was carried out and the percentage of trees with more than one stem was determined. The diameter of each stem (D1.30) was determined by measuring two perpendicular diameters at a height of 1.30 m with an accuracy of 1 cm., and the average diameter (Dav) of the experimental area was calculated by the arithmetic average of the basal area according to formula (1):

$$\mathbf{Dav}=\sqrt{\mathbf{1.274*Gav}}: \quad (1),$$

where **Dav –** average tree diameter (cm)
Gav= Gtotal/N – average tree basal area (m^2);
Gtotal – total basal area (m^2);
N – total number of the trees .

The stem volumes of the Black locust trees and the growing stock of the sample plots were calculated through volume-class tables for the Black locust. (Krastanov et al., 2004).

The data were statistically processed. Considering the best approach, the Shapiro-Wilk test was used to check the normality of distribution of trees by thickness (Snedecor, Cochran, 1989), the analysis of variance components (One-way ANOVA) and Duncan's multiple range test for comparison between means.

Results

An analytical comparison of the normality of distribution of trees by thickness and the percentage distribution of trees by degrees of thickness (DT) of the half-sib progenies of 12 Bulgarian and 6 foreign selected clones of *Robinia pseudoacacia* L. was performed.

The indicators obtained by a Shapiro-Wilk (W) test were statistically significant (with cut-off significance levels p >0.05) for almost all progenies except Obretenik-1 and Italica (Table 1). Normally, the maximum number of trees should be concentrated around the central degree of thickness (*m) in which the average diameter falls. In some of the progenies this maximum is drawn to the left or right of the central degree (*c). The concentration of a larger number of trees in the lower degrees of thickness affects the total percentage to the central degree, which should be around 60%, and in

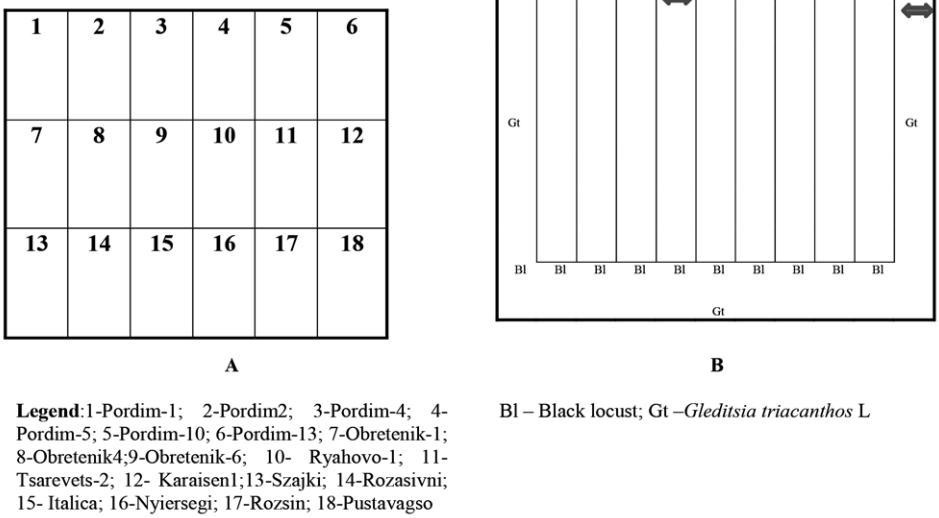

Figure 1. Design of the experimental plantation (**A**) Arrangement of the progenies/families (**B**) Plot scheme for one progeny/family.

progenies such as Pordim-5, Obretenik-6, Tsarevets-2 it is over 60%. The percentage distribution of trees by degrees of thickness varies among the different progenies and thus affects the values of mean diameter and growing stock.

Table 2 presents the dendrobiometric characteristics of the plantations from half-sib progenies of the 18 selected Black locust clones. The number of trees per hectare varies from 1167 for the Pustavagso clone to 1888 for the Nyirsegi clone, the two clones being represented mostly by single stems. For the progenies of Obretenik-6 and Rozsin clones the number of multi stemmed trees varies respectively from 1.2% to 14.2%. For the studied period, the percentage of surviving individuals varied from 35% for the Pustavagso progeny to 57% for the Pordim-2 and Nyirsegi progenies, and for other 11 progenies it was 50-57%.

A one-way Analysis of variance for the height and diameter shows a statistically significant difference among the progenies regarding the average indicator diameter ($F=2.550$, $df=17$ и $p = 0.001$) and height ($F=1.735$, $df=17$ и $p = 0.034$).

The applied Duncan's multi-rank criterion identified differences between the progenies of the studied clones, the progenies of the Szajki, Rozsin, Obretenik-1 and Obretenik-4 clones having the best growth in diameter, while the progeny of the Pustavagso clone shows the lowest values for this indicator. In terms of average height, the progenies of the Bulgarian clones Obretenik-1 and Obretenik-4 have the best growth in height, followed by those of the clones Pordim-4, Ryahovo-1 and Nyirsegi. The indicator Dav is the average square diameter, which determines the central degree of thickness

Table 1. Percentage distribution of the number of trees by degrees of thickness (DT) and normality of the distribution

Black locust clone	Degrees of thickness (cm)													Shapiro-Wilk test	Significance level
	4	6	8	10	12	14	16	18	20	22	24	26		W	p
	Number of trees (%)												Number of trees		
Pordim-1	3.3	5.0	12.5	7.5	19.2^{m}	13.3^{c}	15.1	13.3	6.7	2.5	0.8	0.8	120	0.9245	0.3269
Pordim-2	4.4	12.6	11.1	17.8^{m}	11.1^{c}	10.5	12.6	6.5	7.4	5.2	-	0.8	135	0.9638	0.8357
Pordim-4	4.1	5.2	17.5^{m}	11.3	9.3	14.4^{c}	13.4	7.2	7.2	5.2	3.1	2.1	97	0.9409	0.5094
Pordim-5	0.8	4.0	8.1	12.1	20.1^{m}	19.4^{c}	16.1	10.5	7.3	1.6			124	0.9410	0.5638
Pordim-10	1.5	3.8	11,9	15.0	19.6	12.0^{c}	20.3^{m}	9.0	3.8	2.3	0.8		133	0.8985	0.1771
Pordim-13	0.8	3.6	8.2	17.2	9.7	20.9^{c}	23.1^{m}	10.5	4.5	1.5			134	0.9138	0.3082
Obretenik-1		2.8	4.7	12.8	20.2^{m}	18.4^{c}	17.4	12.8	5.6	1.8	1.8	1.8	109	0.8434	**0.0350**
Obretenik-4	2.5	3.3	7.4	10.7	12.3	21.3^{c}	13.1	11.5	12.3	4.1	1.5		122	0.9166	0.2913
Obretenik-6	0.8	2.5	11.7	14.2	15.0	20.0^{c}	16.7	11,5	4.2	1.7	1.7		120	0.8811	0.1074
Ryahovo-1		2.2	16.0	13.0	11.5	19.9^{c}	13.7	11.5	7.6	1.5	3.1		131	0.9355	0.5040
Tsarevets-2	5.1	5.9	12.7	11	16.1	16.9^{c}	13.6	5.1	5.1	4.2	3.5	0.8	118	0.8964	0.1425
Karaisen-1	2.7	9.0	13.5	9.0	14.4	13.5^{c}	16.2^{m}	9.9	5.4	4.5	0.9	0.9	111	0.9265	0,3442
Szajki	0.8	6.7	5.0	14.2	10.8	16.7^{c}	14.1	9.2	8.3	6.7	3.3	4.2	120	0.9642	0.8410
Rozasivni	0.8	6.8	9.3	14.4	11.8	16.2^{c}	16.1	11.0	11.1	1.7	-	0.8	118	0.8883	0.1324
Italica	2.3	10.6	10.6	12.9	14.4	14.4^{c}	14.4	10.6	3.8	4.5	-	1.5	132	0.8506	**0.0435**
Nyirsegi	2.9	3.0	18.6^{m}	15.7	17.7	14.7^{c}	8.8	6.9	5.8	5.9			102	0.8804	0.1317
Rozsin	1.0	11.3	7.2	13.4	8.2	15.5^{c}	14.4	9.3	5.2	9.3	3.1	2.1	97	0.9551	0.7118
Pustavagso	6.3	17.4	11.1	15.9	19.0^{c}	9.5	7.9	9.5	3.2				63	0.9492	0.6809

*c – central degree of thickness *m – maximum number of trees outside central degree of thickness (%)

Table 2. Dendrobiometrical characteristics of the black locust trees in the sample plots

Sample plot	Black locust clone	Height (m)		Diameter (cm)			Basal area (m^2)		Density No//ha	Volume (m^3/ha)
		Mean± Std.deviation	Coefficient of variation (%)	Mean± Std.deviation	Coefficient of variation (%)	Dav	Gtotal	Gav		
1	Pordim-1	14.4643±4.0959 **bc**	28	13.4500±4.6524 **bc**	34	14.3	1.9176	0.0160	1667	200.4444
2	Pordim-2	13.0000±5.0728 **a**	39	12.4412±5.0988 **ab**	41	13.4	4.2012	0.0307	1875	185.7778
3	Pordim-4	15.8276±4.2516 **cd**	27	13.4433±5.4371 **bc**	40	14.5	1.6704	0.0170	1347	175.7083
4	Pordim-5	13.4667±3.2348 **ab**	24	13.5323±3.8602 **bc**	28	14.1	4.1721	0.0336	1722	185.7222
5	Pordim-10	15.1212±3.6806 **bc**	24	13.0827±4.0640 **bc**	31	13.7	1.9740	0.0148	1847	223.1389
6	Pordim-13	14.6667±2.9046 **bc**	20	13.5224±3.7771 **bc**	28	14.0	2.0504	0.0153	1861	218.1389
7	Obretenik-1	16.3548±2.8112 **d**	17	14.4821±4.1351 **cd**	28	14.9	1.9776	0.0177	1513	226.6389
8	Obretenik-4	16.3429±3.7958 **d**	23	14.4839±4.6565 **cd**	32	15.0	2.2232	0.0179	1694	207.8472
9	Obretenik-6	15.5172±2.8362 **bc**	18	13.5000±4.0189 **bc**	30	14.1	1.8586	0.0155	1667	212.6944
10	Ryahovo-1	15.9706±3.7212 **cd**	23	13.7252±4.3589 **bc**	32	14.4	2.1149	0.0161	1819	242.5417
11	Tsarevets-2	14.7188±4.4810 **bc**	30	13.0508±5.0685 **bc**	39	14.0	1.8071	0.0153	1638	190.7222
12	Karaisen-1	14.6250±4.2710 **bc**	29	13.1532±4.9105 **bc**	37	14.0	1.6992	0.0153	1542	180.4027
13	Szajki	15.3636±4.8850**bc**	32	14.8167±5.2724 **d**	35	15.5	2.3203	0.0193	1667	244.3888
14	Rozasivni	14.8788±4.1137 **bc**	27	13.6610±4.4783 **bc**	33	14.4	1.9191	0.0163	1638	201.1944
15	Italica	13.5588±5.0464 **ab**	37	12.9697±4.8330 **ab**	37	13.8	1.9769	0.0150	1833	203.0833
16	Nyirségi	15.7576±4.3014**cd**	27	12.6471±4.5220 **ab**	36	13.4	1.4506	0.0142	1888	219.1111
17	Rozsin	15.0000±4.6368 **bc**	31	14.1237±5.4346 **cd**	38	15.1	1.7133	0.0177	1347	182.9444
18	Pustavagso	14.1818±4.6651 **bc**	33	12.0377±3.9123 **a**	35	12.0	0.6539	0.0123	1167	151.8333

and with the average height of the experimental plot is used to calculate the growing stock through the developed volume-class tables for Black locust (Krastanov et al. 2004).

Given that Black locust plantations in Bulgaria have been managed for 20-25 years, and the studied progenies are 20 years old and have not been tendered, special attention was paid to those with the highest productivity. The comparison of the progenies in terms of total growing stock shows the superiority of the Hungarian clone Szajki and the Bulgarian clone Ryahovo-1, whose productivity is over 240,000 m3/ha. Among the other clones Obretenik-1, Obretenik-6, Pordim-10, Pordim13 and Nyirseji, whose total stock is between 210,000 and 226,000 m3/ha, are of interest.

Discussion

The growth and productivity of the Black locust depends on a number of factors such as habitat conditions, density, qualities of reproductive materials, cultivation of the plantations in the first years and tending activities. Bulgarian clones are more resistant on sites with deeper groundwater, and Hungarian ones to sites with higher groundwater and lighter in mechanical composition soils (Kalmukov, 2014).

Although the experiment was not replicated, after two decades of growth, the effect of initial planting density was more pronounced on diameter growth than on height growth. The intensity of diameter growth has higher values when the competition between saplings is less pronounced. For the Black locust it influences strength after the 5-6th year and clearly manifests itself at larger growing space, as the intensity of self-pruning decreases with age (Kalmukov, 2009). The results of the present study confirm this tendency for the progenies with the best diameter growth Szajki and Obretenik-4 at densities of 1667 and 1694 pcs/ha, respectively.

The number of trees of the studied progenies per hectare has decreased intensively as a result of self-pruning and poaching. Good growing stock is observed at different densities from 1667 pcs/ha in the Szajki progeny to 1888 pcs/ha in the Nyirsegi progeny. The higher growing stock at a density of 1667 pcs/ha for the Szajki progeny is due to good growth in diameter and the bigger number of trees presenting 45.8% above the central degree of thickness (DT 14) and their distribution with smooth decrease in the number of trees in the interval from DT 16 to DT 26. For the progeny of the Obretenik-6 clone at the same density, the growing stock decreased due to the lower values of the average diameter, as result of the greater number of trees -64%, from the lower to the central degree of thickness. At the lower densities above 1,800 pcs/ha, the better growing stock of the Pordim-13 progeny is due to the higher percentage – 54%, of trees in the average thickness grades. The Ryahovo -1 progeny, which has the same growth in diameter, has a higher growing stock, which is calculated at a larger height range with a larger stem volume at different degrees of thickness (table 2). Although all progenies had a normal distribution of trees by thickness according to the Shapiro-Wilk test, variation in their percentage distribution by thickness grades of the different progenies to the left or right of the central grade affects the stock accumulation. The medium degrees of thickness, represented by the largest number of stems,

increase the amount of large and medium assortments in the plantations (Ferezliev et al. 2018). In order to achieve such structure of the plantations, which guarantees a good growth in diameter and/or productivity, it is necessary to carry out tending activities. Usually, in the case of Black locust plantations, this is done 6-8 years after forming the canopy, with the intensity of thinning not exceeding 45-50% of the trees and keeping no less than 1500-1800 pcs/ha (Kalmukov et al 1999).

The vegetative progenies of seven of the clones are included in the network for cultivar testing established in Northern Bulgaria by Tsanov et al. in 1992. An assessment of the growth and productivity of 5 of them over a period of 20 years was made by Broshtilov (2009).

Tsanov et al. (1992), recommended a differentiated use of some of the clones depending on the type of habitat (chernozem, alluvial and gray forest soils), the progeny of Obretenik-6 clone being distinguished by the highest indicators of average height and average diameter at the age of 4 on gray forest soil. The vegetative progeny of Obretenik-4 was cited as an example of successful selection with the best growth, productivity and stem quality on medium-productive sites with cinnamon forest soil (Broshtilov, 2009). Generally, the progenies of the Ryahovo-1 and Nyirseji clones showed lower values of the inventory indicators diameter, mean height and total growing stock compared to the half-sib progenies of the same clones in the present study at the same age.

Studies on the growth and productivity of 7-year-old half-sib progenies of three Black locust clones on carbonate chernozem in the region of the Svishtov State Forest Enterprise show the superiority of the Karaisen clone (Dimitrova, 2017; Dimitrova & Kalmukov, 2019).

Half-sib Black locus progenies from the Bulgarian clones Pordim-10, Pordim-13, Obretenik-1, Obretenik-6 and Ryahovo-1 and from the foreign clones Szajki and Nyirseji show good growth and/or productivity on rich and dry gray soil. They can be used to establish plantations on such a type of habitat, with the same planting scheme and applying tending activities to increase growth and productivity.

The half-sib progenies of the selected *Robinia pseudoacacia* L. clones, included in the present study, are part of the genetic resources of the species available in Bulgaria. The results add to the existing information on the differentiated use of suitable clones and technologies to establish plantations with economic and ecological functions, depending on the habitat conditions.

Conclusion

The comparative analysis on half-sib progeny plantations from eighteen clones of Black locust (*Robinia pseudoacacia* L.) showed differentiation in growth and/or productivity between the progenies of the selected clones under the same habitat conditions.

The progenies of the Bulgarian clones Pordim-10, Pordim-13, Obretenik-1, Obretenik-6 and Ryahovo-1 and the Hungarian clones Szajki and Nyirseji have good productivity on rich and dry gray soil. This should be taken into account when choosing material for the establishment of industrial plantations and such for biomass production in different habitats, as well as when planning and conducting tending activities.

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References

Böhm C., Quinkenstein A., Freese D. 2011. Yield prediction of young black locust (*Robinia pseudoacacia* L.) plantations for woody biomass production using allometric relations. Annals of Forest Research 54 (2), 215–227.

Broshtilov K., Kalmukov K., Tsanov Ts., Naydenov Y. 1998. Vegetative propagation of black locust (*Robinia pseudoacacia* L.). In: Iliev I., Zhelev P., Tzvetkov I. (Eds.). International Plant Propagators Society. IPPS in Bulgaria, Third Scientific Conference Propagation of Ornamental Plants. University of Forestry, October 3-5, Sofia, 167–173.

Broshtilov K. 2009. Growth of white acacia (*Robinia pseudoacacia* L.) vegetative generation on habitat of average productivity where chromic luvisoils is available. Forestry Ideas 15 (1), 166–176. (In Bulgarian, English summary).

Brus R., Ficko A., Roženbergar D., Westergren M., Jarni K. 2016. Non-native tree species for European Forests: experiences, risks and opportunities. COST Action FP1403 NNEXT Country Reports, Joint Volume. University of Natural Resources and Life Sciences (BOKU), Vienna, pp 297–304.

Dimitrova P. 2017. Comparative analysis of growth structure and productivity in young age of half-sibs progenies from selected black locust (*Robinia pseudoacacia* L.) clones. Nauka za Gorata (Forest Science), 53 (2), 21–31. (in Bulgarian, English summary).

Dimitrova P., Kalmukov K. 2019. Dynamics of growth parameters of plantations from selected *Robinia pseudoacacia* L. clones in young age. Forest Science 55 (1), 41–52. (in Bulgarian, English summary).

Ferezliev A., Zafirov N., Karov, Kr. 2018. Comparative investigation on distribution by diameyter variation curves in Douglas-fir plantations in state forestry Alabak - Velingrad. Forest science 1, 39–53. (In Bulgarian, English summary).

Gyuleva V., Stankova T., Popov E. 2013. Establishment of plantations of fastgrowing tree species in Bulgaria with a short rotation for energetic purposes. Science & Technologies 3 (6), 96–100. (In Bulgarian, English summary).

Gyuleva V. 2014. Selection and testing of fast-growing tree species for accelerated production of wood raw material – preliminary results from sample plots in Zlatna Panega. In Zhiyanski M. et al. (Eds.). Proceedings of scientific publications of the Forest Research Institute, 145th anniversary of the Bulgarian Academy of Sciences, Sofia, 239–245. (In Bulgarian, English summary).

Kalmukov K., Naydenov Y., Todorov H. 1999. Influence of growth space on growth and productivity of young black locust plantations. Forestry Ideas 5, 3–12. (In Bulgarian, English summary).

Kalmukov K. 2009. Influence of the initial density on growth and productivity of some tree species in biomass plantations. In: L. Trichkov (Ed.). Wood and energy – new opportunities in crisis conditions. National conference, Sofia, Inter Expo Centre, 26.03.2009, 44–48. (In Bulgarian, English summary).

Kalmukov K. 2010. Growth and productivity of intensive forest plantations in the region of State Forest Enterprise V. Tarnovo. Svishtov, Executive Forest Agency, Report, 133. (In Bulgarian).

Kalmukov K. 2013. Influence of the initial density and site conditions on growth and productivity of short-rotation biomass black locust (*Robinia pseudoacacia* L.) plantations. Science & Technologies 3 (6), 47–51. (In Bulgarian, English summary).

Kalmukov K. 2014. Improving of black locust stands in Bulgaria. Gora 6/7, 24–26. (In Bulgarian).

Krastanov K., Tsakov H., Beljakov P., Stojkov H., Stojkov D., Dimitrov E.T. 2004. Volume and cross-cutting table for black locust. – In: Krastanov, K., Rajkov, R. 2004. Guidebook (Guide of Dendrobiometry) 237–245. (In Bulgarian).

Kraszkiewicz A. 2013. Evaluation of the Possibility of energy use black locust (*Robinia pseudoacacia* L.) dendromass acquired in forest stands growing on clay soils. Journal of Central European Agriculture 14 (1), 388–399.

Naydenov, Y., Broshtilov K., Kalmukov K. 1981. Opportunities for vegetative production of elite material from black locust (*Robinia pseudoacacia* L.), XI national review of technical-and-scientific creativity of youth. Biology, 249–258. (in Bulgarian).

Pyšek P., Lambdon P.W., Arianoutsou M., Kühn I., Pino J., Winter M. 2009. Alien vascular plants of Europe. In: Nentwig W. (Ed.). Handbook of Alien Species in Europe, DAISIE. Invading nature: Springer series in invasion ecology l3, 43–61.

Redei K., Viperdi I., Tome M., Soares P. 2010. Black Locust (*Robinia pseudoacacia* L.) Short-Rotation Crops in Hungary: A Review, Silva Lusitana 18 (2), 217–223.

Redei K., Csiha I. Keseru Zs. 2011. Black locust (*Robinia pseudoacacia* L.) Short-Rotation Crops under Marginal, Site Conditions. Acta Silvatica and Lignaria Hungarica 7, 125–132.

Snedecor W.G., Cochran W.G. 1989. Statistical Methods. Eight Edition. The Iowa State University Press, Ames, 503 pp.

Stankova T., Gyuleva V., Kalmukov K., Dimitrova P., Velizarova E., Dimitrov D. N., Hristova H., Andonova E., Kalaydzhiev I., Velinova K. 2016. Biometric models for the aboveground biomass of juvenile black locust trees. Silva Balcanica 17 (1), 21–30.

Stankova T., Gyuleva V., Kalmukov K., Dimitrov D. N., Popov E., Glushkova M., Dimitrova P., Hristova H. 2018. Woody biomass estimation of coppiced plants from open pollinated progenies of two selected black locust clones. In Zhiyanski, M. et al. (Edt.). Proceeding papers of the International Scientific Conference "90 years Forest Research Institute – for the society and nature", 24-26 October, Sofia, 251–266.

Stankova T., Gyuleva V., Kalmukov K., Popov E., Pérez-Cruzado C., Glushkova M., Dimitrov, D. N., Dimitrova P., Hristova H., Andonova E. 2020. Effect of spacing, parental genotype and harvesting cycle on biomass production in two half-sib progenies of *Robinia pseudoacacia* L. – Forestry: An International Journal of Forest Research 93 (4), 505–518.

Stolarski M. J., Krzyzaniak M., Szczukowski S., Tworkowski J., Bieniek Ar. 2013. Dendromass derived from agricultural land as energy Feedstock. Polish Journal of Environmental Studies 22 (2), 511–520.

Tsanov Ts., Naydenov Y., Kalmukov K., Broshtilov K. 1992. First results from testing of some black locust clones. Forest Science 4, 24-30. (In Bulgarian, Russian summary).

Vítková M., Müllerová J., Sádlo J. Pyšek P. 2017. Black locust (*Robinia pseudoacacia* L.) beloved and despised: a story of an invasive tree in Central Europe. Forest Ecology and Management 384, 287–302.

WRBSR. 2014. International soil classification system for naming soils and creating legends for soil maps. World soil resources reports, No. 106. FAO, Rome, 119 pp.