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RESEARCH ARTICLE

Studies on Manna ash (*Fraxinus ornus* L.) In Bulgaria

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Abstract

The purpose of this publication is to review and analyze the main studies of Manna ash in Bulgaria in order to present summarized information and acquire an objective view of the possibilities for proper perception of the importance of this local tree species and its use in various aspects of science and practice in our country. The study covers the period from the second half of the 1940s, when the first specialized journals in the field of forest science were published, until 2022. The focus of the study is on publications related directly or indirectly to various aspects of research on manna ash.

The tracking of the chronology of forestry studies in Bulgaria shows trends towards a change in the perception of Manna ash as an inferior species and the search for its benefits for forestry practice, including rethinking its role from one of a weed species into an adjustable competitor, stimulating the regeneration of oaks and others indigenous species in plantations.

The role of phytocoenological studies, which in relation to the Manna ash communities, both in natural and artificial forest plantations, with its participation have increased in recent years. With their help, it is possible to trace the stages of successions and fluctuations and behavior of Manna ash in xerothermic oak forests and austian pine crops – its ecological-coenotic strategy towards the main tree species.

The studies of Manna ash in Bulgaria in the field of special uses are close to their European analogues and in a number of cases overtake them with new data and discoveries, mostly in terms of biologically active products and antiallergic agents obtained from this plant species, among which we have world patents.

Keywords

forestry, manna ash, phytocoenology, review, special uses

Introduction

In our recent past, the forests of Manna ash and other tree species such as *Oriental hornbeam*, *Tatarian maple*, *Common hornbeam*, elm, etc. were considered a passing historical stage in the development of forestry and a bad legacy of previous political regimes (Georgiev et al., 1965). For this reason, a large part of them were planned for reconstruction. The main reasons for declaring species such as Manna ash to be of low value are: poor wood quality of these species or low demand in terms of consumption in industry and construction; portion of these plantations grow on rich habitats while showing low productivity; some of these forests are thinned and do not fully use the potential fertility of the soils they occupy; manna ash hinders regeneration processes of the main species in the plantation.

According to Erbakamov et al. (1996) in silvicultural practice, Manna ash is perceived as an undervalued species, which is primarily due to its low productivity despite its high natural regenerative capacity and its wide range associated with the ecological plasticity of the species. Manna ash is most often found as an undergrowth in oak forests, where it settles en masse and makes it difficult for the oaks to regenerate. For this reason, in the forestry activities planning, it is most often recommended to cut it during the main (renewal) felling. However, after the renewal cuttings, its participation in the composition of the undergrowth and the young tree stand is significant, which necessitates the removal of Manna ash during the first cultivation activities (thinning), in order to create a preponderance of the main tree species and limit its participation. This leads to the spread of crooked-stemmed, low-productive and low-quality individuals of this species in our forests.

Aleksandrov and Genov (1997) refer Manna ash to the group of 170 undervalued and neglected forest tree and shrub species, representing a genetic resource that, under certain circumstances, can contribute greatly to the conservation and restoration of forests subject to droughts, fires and diseases.

The aim of this publication is to carry out a review and analysis of the main studies of the Manna ash in Bulgaria with the aim of presenting generalized information and gaining an objective view on the possibilities for the correct perception of the importance of this local tree species and its use in various aspects of science and practice in our country.

Methods

The study covers the period from the second half of the 1940s, when the first specialized journals in the field of forest science were published, such as "Gorsko stopanstvo" etc. until 2022. The focus of the study is on publications related directly or indirectly to various aspects of Manna ash research.

A review of specialized periodical journals and magazines in the field of biological sciences and, in particular, forests, scientific and scientifically popular publications such as "Gorsko stopanstvo" (subsequently "Gorska promishlenost" and "Gora"),

"Bulletin de l'Institut Botanique", "Gorskostopanska nauka" (subsequently "Forest science"), "Forestry ideas", Sylva Balkanica, Phytologia Balkanica, etc. Collections of scientific forums, foreign periodicals, in which studies of Manna ash on the territory of the country were published, textbooks, scientific monographs, etc., were reviewed in parallel.

Results

The results of the research follow the chronology and are systematized depending on the directions of the studies carried out over the years concerning the species: "Forestry studies", "Floristic, phytocoenological and ecological studies", "Studies of the morphology and physiology of Manna ash", "Studies in the field of special uses of Manna ash products".

Forestry studies

According to Ivanov (1959), young oak plantations should be grown at short intervals. This is necessitated by the rapid growth of the shoots of undesirable species such as Manna ash, which quickly take over the protected species. This is especially necessary in better habitat conditions, where many species have settled on the same area. According to the same author, thinings in oak forests should take place immediately after the final cutting, when damage to the plantation is best seen and both unwanted tree species and damaged saplings are promptly removed.

Marinov (1960) is of the opinion that in mixed young oak plantations on wetter and richer habitats, where the seed specimens of oak grow together with the faster-growing ones at a young age Manna ash, hornbeam etc. species, the lighting phase of the thinnings must be carried out in time. Otherwise, the seed oak will be silenced and the future stand will be formed by low-value species.

Dakov at al. (1960) consider that Manna ash and other understory species can cause suppression of the oak undergrowth not only through shading but also through competition for soil moisture.

A study by Perzhina (1961) on the use of chemical agents for the destruction of Manna ash and others „low-yielding" broad-leaved tree and shrub species recommends spraying the stumps and foundamental spraying of the stems as the most suitable methods.

Bachvarov (1964) conducted a study on the location of the roots of the Austrian pine and the natural tree and shrub vegetation during reconstructions. The root system of the Austrian pine is mainly located in the soil layer under the roots of the naturally growing trees and shrubs (including Manna ash). The roots of Manna ash compete in the same soil horizon with the roots of *Oriental hornbeam*, elm, blackthorn, hawthorn and dogwood. The Dog rose, blackberry and juniper, as understory species with a shallower root system than that of Manna ash, absorb water more quickly from

the spring reserves and are the first to capture the moisture of the summer precipitation that falls on the surface.

A study by Vezev et al. (1968) on the soil-protective effect of some tree and shrub species in the lower forest vegetation zone of the Sandanski region showed that the soil-protective effect, expressed by the power of the soil layer preserved from washing, at a slope of the terrain of 20 to 30 degrees for the groups of Manna ash stems is from 5 to 25 cm.

According to Garelkov et al. (1969) Manna ash stands are part of the habitat types and reconstruction forest types in the oak zone (lower forest zone), but are not as abundant as the *Oriental hornbeam*.

Experiments by Nodenska (1971) prove that Austrian pine crops will have a greater anti-erosion effect and higher resistance to diseases and enemies, if suitable broad-leaved tree and shrub species such as Manna ash are introduced into them. Zhupov (1980) studied the coppice forests with the participation of Manna ash in the region of Pazardzhik, where measures are being taken to convert them into seed forests by two methods – extension of the felling cycle and reconstruction.

Dobrinov et al. (1982) mention that Manna ash is subject to severe destruction by goats and clear cuttings, that negative selection leads to the deterioration of the stand and to the proliferation of crooked-stemmed forms. Kochev and Penev (1982) proved the efficacy of the herbicide and arborecide "Roundup" (20% aqueous solution) against the stump shoots of the Manna ash in the reconstructions. The authors recommend as a result the greasing of the stumps in the period August-December, immediately after felling. According to them, sprinkling the stumps in spring does not give results, because the flow of juices is upward.

A study by Erbakamov at al. (1996) carried out in the area of the Nessebar proved that there are also straight-stemmed Manna ash trees with a height greater than that found for it and with a high average diameter. The stem section, suitable for construction timber, is 8-10 (12) m long and over 18 cm (even over 30 cm) in diameter. This shows that in some individuals it is possible to expect first-quality large construction wood from alder, which is not inferior in terms of technical parameters to that of ash in our country (Fraxinus excelsior L., F. oxycarpa M. Bieb. ex. Willd.). In biogroups with Oriental beech or Dalechamps oak, in most cases, Manna ash occupies a co-dominant position, which shows that, if the forestry measures are carried out correctly, it may not displace the valuable species, but grow in a group with them.

According to data of Vachovski, Dimitrov (2003) for the entire territory of the country in 1975 the area of *Oriental hornbeam* plantations planned for reconstruction was at least twice as large as that of the Manna ash plantations.

Zlatanov (2003) studied the appearance and development of Manna ash under the stand of 70-75 year old Autsrian pine artificial plantations on the southern slopes of Murgash Mountain. The author found that the establishment of the available Manna ash undergrowth started when the stands were 30-40 years old. In terms of growth in height and vitality, the individuals growing at the density 0.6-0.8 of the first Austrian pine layer are not significantly inferior to those growing at the much lower density

0.2-0.4. Presence of a larger number of suppressed individuals (up to 40-80 individuals per 1 are) is observed only in the dense groups of undergrowth.

Another study by Zlatanov (2006) on the influence of thinnings on the composition and structure of the undergrowth in *Pinus nigra* artificial stands aged 36-75 years, shows that in older plantations (age 69-75 years) the regular thinning with moderate to high intensity has favored the formation of places of a second broad-leaved floor with a number of up to 10,000 saplings/ha and a dominant height of up to 2.8m, and in this way the beginning of the replacement of the Austrian pine with broad-leaved species incl. Manna ash.

A study by Glogov et al. (2019) on the behavior and relationships between *Fraxinus ornus* and *Carpinus orientalis* on the territory of the Lozen Mountain shows that the two species settle preferentially in conifers than in coppice oak, hornbeam and beech plantations. In the study area, the *Oriental hornbeam* shows a tendency to displace Manna ash. The results of the dendrobiometric indicators of the Manna ash and the *Oriental hornbeam* on the territory of Lozen Mountain show a higher density of the first of these two species. *Oriental hornbeam* predominates over Manna ash by area range, including in stands where it occurs mixed with Manna ash.

The results of a study by Gyudorova et al. (2022) showed that sedge in Austrian pine crops fully recovered after a single application of mechanical control measures and grazing. Manna ash shoots form a characteristic "hydra effect", the regulation of which requires frequent interventions and a sufficient number of forest workers, which are currently lacking in the country. In this situation, according to the authors, the option of "silvicultural patience" is recommended in relation to Manna ash with the tendency that the oaks will gradually outgrow it. Forestry measures should be aimed not at the reduction of Manna ash at an early age, but at the care of regrowth by oak. After the ninth year, the oak understory strengthens, develops a deep root system, and becomes competitive with its companions, gradually outgrowing the Manna ash.

Studies on the Morphology and Physiology of the Manna ash

A study by Michev (1956) on the moisture content of seeds from native forest tree and shrub species showed that the average moisture content of Manna ash seeds was 11.4% (close to that of other ash trees). According to this indicator, Manna ash occupies an average position compared to species with high seed moisture (16-24%) such as sycamore, dogwood and fir and those with low seed moisture (6-8%) such as European smoketree, European nettle tree and Warted Spindle-Tree. A study by the same author (Michev, 1958) shows the following data on the sizes of the fruits and seeds of the Manna ash: Average length of the seed (including the wing) 27.4 mm, average length of the seed 9.3, average width of the seed (with the wing): 4.9 mm. According to these indicators, the species is inferior to the narrow-leaved ash and American ash.

Stefanov and Tsikova (1969) conducted experiments on rooting by cuttings of about 180 species of woody plants and shrubs, including Manna ash and other species from the genus Fraxinus. The results show that the cuttings of F. ornus are very sus-

ceptible to rooting. Cuttings form young stems that can be kept undamaged for up to 2 years due to ash's great resistance to decay. The cutting's water supply is maintained by direct suction of water from the substrate. But after this period, the stems begin to die due to the lack of developing roots.
According to data from a study by Kostov et al. (2005) in the forests of the „Beslet" State Forest Enterprise, the Garmen village, the average height of Manna ash in 3 subdivisions with an area of 4.14 ha is 4.67 m, with an average age in years of 33.3 years. and an average diameter of 6.67 cm.

According to Iliev et al. (2015) on the production of saplings of Manna ash, alternations of this species have a deep to moderate physiological dormancy, a germination rate of 60-80% and from 1 kg of seed material, an average of 26,400 one-year seedlings can be produced. According to the authors, depending ot the ecological requirements, the Manna ash resembles the European ash, but it is more thermophilic, drought-resistant and tolerates calcareous soils.

Floristic and phytocoenological studies

A fundamental study by Bondev (1991) presents a classification according to the dominant approach of the communities with the participation of *Fraxinus ornus* as part of the classification and mapping of the vegetation of the country. He established 5 formations and groups of formations of the type of mesophytic and xerophytic microthermal vegetation in the Hornbeam- Dalechamps oak forest belt and 7 formations of the type of xerophytic and mesoxerophytic, microthermal and mesothermal vegetation in the xerothermal oak belt and in the hilly plains. Subsequently, other authors (Biserkov et al., 2015, Glogov et al., 2020, Tzonev at al., 2006, 2018) updated and detailed Bondev's classification according to the Braun Blanquet system.

Marinov et al. (1995) made an ecological and phytocoenological characterization of oak woodlands in Bulgaria, including a classification of the communities, in which oak woodland is mentioned as a characteristic species of the understory in the group of dry hill-slope oak woodlands.

Gyudorova at al. (2020a,b) carried out floristic and phytocoenological studies in Austrian pine artificial atands with a predominant presence of Manna ash in the second floor, conducted on the territory of 4 mountains around the city of Sofia – Lozenska, Plana, Vitosha and Stara planina in the period June-August, 2020. High community similarity was found in Austrian pine stands with Manna ash understory in the four mountains. At the present stage, they are designated as serial and are classified to the highest syntaxonomic rank-order Quercetalia pubescentis Br.-Bl. (1931) 1932. The autochthonic vegetation, in whose habitats the studied phytocoenoses are located, belongs to the communities of the associations Quercion petraeae (Zolyomi et Jakucs in Soo, 1963) and Quercion confertae Horvat 1958 with the association Quercetum frainetto-cerridis Rudski 1949. Regarding the specificity of the floral composition, the authors found that determining the specific nature of this type of artificial coenoses are not so much specific taxa as their biological and ecological-phytogeographic features.

Studies in the field of special uses of Manna ash products

According to Petkov (1982), alcoholic extracts from the bark of Manna ash have a bacteriostatic effect against Staphylococus aureus, according to the same author, the yield of esculin from F. ornus amounts to 3.8%, which determines the plant as a raw material for its preparation.

Stoyanov and Dimitrova (1990) make a detailed description of the extraction and distribution of Manna ash bark as a valuable plant raw material, which is used in the pharmaceutical industry, as a dye for coloring woolen fabrics, etc.

A study by Stoyanova et al. (1994) on the biological composition of the leaves and bark of some species from the genus Fraxinus showed that, of the studied species, the leaves and bark of F. ornus were the richest in ascorbic acid. The leaves of the species also showed the highest content of chlorophyll A (89 to 383.8 mg%) and carotenoids (21.7 to 78.2 mg%). The results of the research of the same author (Stoyanova, 2009) on the natural complex of macro- and micro-elements in the leaves and bark of F. ornus, that when collecting the bark of this species, the months of June and July are the most suitable, and for the leaves – June, August.

Yotsova-Baurenska (1990) carried out research on the content of total and protein nitrogen in the leaves of Manna ash and others tree and shrub species in coppice Turkish oak-hornbeam communities in the Devnia region. The author found that Manna ash in conditions of industrial pollution contains less nitrogen than under normal conditions, i.e. pollution negatively affects the nitrogen exchange of the species.

Kostova (1992) made an in-depth phytochemical analysis of the synthesis of substances with biological activity from the bark of Manna ash and found many new compounds, among which coumarin derivatives.

Discussion

The chronology of the reviewed literature shows a certain uniformity and, at the same time, insufficiency of the studies of Manna ash, especially with regard to its forestry role. Although in the 1990s the concept of multifunctional forest management was adopted and concepts such as „reconstruction of low-value species“ were definitely left behind in time, still at this stage in forestry circles there is no unequivocal attitude towards the Manna ash.

The behavior of this understory element, considered both independently and in its close interrelationship with the main tree species in the plantation, has not yet been sufficiently precisely studied, and the methods for managing and regulating the number of its populations in the forests have not been definitively substantiated. In this regard, the role of phytocoenological studies is very important, which in relation to the Manna ash communities both in natural plantations and in artificial forest ctands with its participation have been increasing in recent years. With their help, it is possible to trace the stages of successions and fluctuations and the behavior of Manna ash

in xerothermic oak forests and Austrian pine artificial plantations including its ecological-coenotic strategy in relation to the main tree species. It is not clear at this stage whether the phytocoenoses established so far in conifers with a prevalance of Manna ash in the schrub layer are not an intermediate stage towards a climax community in which it gradually loses its dominance and gives way to oaks. From this point of view, the strategy of „silvicultural patience" towards Manna ash recommended in the most recent publications would be more successful compared to the measures mentioned in the publications from the beginning of the new century.

The studies of *Fraxinus ornus* in our country in the field of special uses are approaching their European counterparts and in a number of cases they are ahead of them with new data and discoveries, especially regarding biologically active products and anti-allergic agents obtained from Manna ash, among which we have world patents (Ivanov, 2005).

The study does not include the data on pests and pathogens found on *Fraxinus ornus* on the territory of the country, for which there are horological data on the pages of periodicals such as "Bulletin de l'Institut Botanique" etc., and whose review will be the subject of further study.

Conclusion

Tracing the chronology of forestry studies in our country shows trends towards a change in the perception of Manna ash as an undervalued species and a search for its benefits for forestry practice, including rethinking its role from that of a weed species to an adjustable competitor stimulating regeneration by oak, etc. native species in plantations.

The correct understanding of the characteristics, behavior and role of Manna ash requires a complex approach to its study and the relationship between the different levels of biodiversity – populational, coenotic and ecosystem – in which this species participates.

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References

Alexandrov A., Genov K. 1997. Undervalued forest tree genetic resources of landscape importance in Bulgaria. Forest science 1-2, 3–8. (In Bulgarian)..

Biserkov V., Gusev C., Popov V., Hibaum G., Rusakova V., Pandurski I., Uzunov Y., Dimitrov M., Tsonev R., Tsoneva S. (eds.) 2015. Red Book of the Republic Bulgaria, Volume 3, Natural Habitats, IBER-BAS & MOEW, Sofia, 458, http://e-ecodb.bas.bg/rdb/.

Bondev I. 1991. The vegetation of Bulgaria. Map in M 1:600,000 with explanatory text, Ed. SU 'Kliment Ohridski', Sofia, 183 p. (In Bulgarian).

Bachvarov D. 1964. On the arrangement of the roots of the Austrian pine and the natural tree and shrub vegetation during reconstructions. Gorskostopanska nauka 6, 11–18. (In Bulgarian).

Garelkov D., Kostov P., Vasilev V., Kostov K., Zhelev I.,. Tsanova P. In: Serafimov P. Petkov B. 1969. Reconstruction of low productivity broadleaf forests. BAS Publishing House. 151 p. (In Bulgarian).

Georgiev Z., Vassilev N., Naumov Z., Kostov P. 1965. Reconstruction of low-value coppice forests. Zemizdat. Sofia, 204 p. (In Bulgarian).

Glogov P., Markov I., Georgieva M.L., Zaemdzhikova G., Dodev Y., Pavlova D., Gyudorova S.. 2019. Study of the distribution and ecological features of the *Oriental hornbeam* (*Carpinus orientalis* Mill.) and Manna ash (*Fraxinus ornus* L.) in the territory of Lozen Mountain. Forest Science 55(2), 71–93. (In Bulgarian).

Glogov P., Gyudorova S., Georgieva M., Bozhilova M.. 2020. Updating the classification of the potential vegetation in the gorge of the Iskar River between Plana and Lozenska Planina, Collection of scientific works from the 29th International Scientific Conference 'Management and Quality' for young scientists, Sofia 11-12.06., 2020, 83–99. (In Bulgarian).

Gyudorova S., Glogov P., Georgieva M.L. 2020a. Characteristics of the floristic composition of Austrian pine (*Pinus nigra* Arn.) artificial stands with an understory of Manna ash (*Fraxinus ornus* L.) in the mountains around the city of Sofia. Collection of scientific papers from the 29th International Scientific Conference for Young Scientists, Blagoevgrad, 24-25.09.2020, 409–418. (In Bulgarian).

Gyudorova S., Glogov P., Georgieva M.L. 2020b. Phytocoenotic studies in Austrian pine (*Pinus nigra* Arn.) artificial stands with an understory of Manna ash (*Fraxinus ornus* L.) in the mountains around the city of Sofia. Collection of scientific works from the 29th International Scientific Conference for Young Scientists, Blagoevgrad, 24-25.09.2020, 398–409. (In Bulgarian).

Gyudorova S., Glogov P., Popov G. 2022. Study of the regenerative abilities of Manna ash in artificial Austrian pine plantations in the region of Sofia, Bulgaria. 2. Baskent International Conference on Multidisciplinary Studies, February 24-25, 2022, Ankara Turkey: 401-408. ISBN 978-625-8405-36-1

Dakov M.Y., Chalakov, Kostov K. 1960. Influence of some ecological factors on the growth of oak understory. Gorsko stopanstvo 5, 4–12. (In Bulgarian).

Damyanov A. 1971. Peculiarities of regeneration with oak under the assembly of coppice Turkish oak forests. Gorsko stopanstvo 12, 17–21. (In Bulgarian).

Dobrinov D., Doikov G., Gagov V. 1982. Forest Genetic Fund of the People's Republic of Bulgaria. S. Zemizdat. 258 p. (In Bulgarian).

Erbakamov, G., Hinkov G., Stiptsov V. 1996. An attempt to evaluate the Manna ash (*Fraxinus ornus* L.) as a valuable tree species. Forest science 2, 69–73. (In Bulgarian).

Ivanov D. 1959. First and Secon phases of thinnigs – a condition for increasing the productivity of young oak plantations. Gorsko stopanstvo 9, 6–10. (In Bulgarian).

Ivanov I. 2005. Review on the scientific works of Senior Associate Research Scientist II degree Ivanka Nikolova Kostova on the competition for Senior Associate Research Scientist I degree in the specialty 'Bioorganic Chemistry and Chemistry of Natural and Physiologically Active Substances'. Faculty of Pharmacy, Medical University, Sofia, 1–7. (In Bulgarian).

Ivanov I. 2005. Review on the scientific works of senior research fellow II degree Ivanka Nikolova Kostova in the competition for senior research fellow I degree in the specialty 'Bioorganic chemistry and chemistry of natural and physiologically active substances'. Faculty of Pharmacy, Medical University, Sofia, 1–7. (In Bulgarian).

Iliev N., Milev M., Alexandrov P., Petkova K. 2015. Production of saplings of tree and shrub species. Ed. house at University of forestry, 333 p. (In Bulgarian).

Kochev P., Penev G. 1982. The roundup herbicide against the weed and unwanted tree and shrub vegetation. Gorsko stopanstvo 9, 45–48. (In Bulgarian).

Kostov G., Paligorov I., Stiptsov V., Myashkov I. 2005. Multifunctional forestry planning. University of Forestry- Sofia. ISBN 954-332-009-8. 208 p. (In Bulgarian).

Kostova I. 1992. Hydroxycoumarins from *Fraxinus ornus* Bark 58(5) 484. Planta medica doi: 10.1055/s-2006-961529.

Marinov M. 1960. More attention to first and second phase of thinnings in young plantations. Gorsko stopanstvo 7, 1–9. (In Bulgarian).

Marinov, M.K. Kostadinov, G. Popov, V. Stiptsov, H. Bozhinov, D. Dinev, D. Denev, S. Khorozov. 1995. Oak forests in Bulgaria. Zemizdat. Sofia. 255 p. (In Bulgarian).

Michev B. 1958. Studies on the sizes of cones, fruits and seeds of our forest species. Gorsko stopanstvo 6, 26–30. (In Bulgarian).

Michev B. Studies on the humidity of our forest tree and shrub seeds. Gorsko stopanstvo 4, 156–161. (In Bulgarian).

Nodenska N. 1971. Soil erosion and health status of Austrian pine artificial stands in Kardzhali district. Gorsko stopanstvo 7, 36–38. (In Bulgarian).

Perzyna V. 1961. Use of herbicides to destroy undesirable tree and shrub species. Gorsko stopanstvo 11, 23–28. (In Bulgarian).

Petkov V. 1982. Modern phytotherapy. S. Medicina I fizkutura. 518 p. (In Bulgarian).

Stefanov B., Tsikova E. 1969. Toward the problem of vegetative propagation of tree species and shrubs by rooting cuttings. Gorskostopanska nauka 4, 9-29. (In Bulgarian).

Stoyanov D., Dimitrova G. 1990. Raw material characteristics of Manna ash. Gorsko stopanstvo 8, 13–14. (In Bulgarian).

Stoyanova M., Ionov N., Marinov I., Apostolova B. 1994. Studies on the biochemical composition of the leaves and bark of some species of the genus Fraxinus. Forest science 1, 38–44. (In Bulgarian).

Stoyanova M. 2009. Content of mineral elements in leaves and bark of European ash (Fraxinus excelsior L.) and Manna ash (*Fraxinus ornus* L.). Forest science 2, 65–72. (In Bulgarian).

Tzonev R., Dimitrov M., Chytry M., Roussakova V., Dimova D., Gussev C., Pavlov D., Vulchev V., Vitkova A., Gogoushev G., Nikolov I., Borisova D., Ganeva A. 2006, Beech forest communities in Bulgaria. Phytocoenologia 36, 247–279.

Tzonev R., Dimitrov M., Gussev C., Vulchev V., Nikolov I. 2018. Classification of the relict forest communities of Palla's Black Pine (*Pinus nigra* subsp. *pallasiana*) in Bulgaria. Hacquetia, 1–37. DOI: 10.1515/hacq-2017-0011.

Vachovski H., Dimitrov S. 2003. Forests and forestry of Bulgaria in the 20th century. 'Apricom' OOD. 350 p. (In Bulgarian).

Vezev L., Nikolov V., Mandev A. 1968. On the anti-erosion effect of some tree and shrub species in the lower forest vegetation zone of the Sandanski region. Gorskostopanska nauka, 31–40. (In Bulgarian).

Yotsova-Baurenska. 1990. Studies on the nitrogen content of some tree and shrub species in the Devnya region. Gorsko stopanstvo 10, 7–8. (In Bulgarian).

Zhupov K. 1980. Reconstruction of inferior coppice forests by afforestation. Gorsko stopanstvo 4, 51–53. (In Bulgarian).

Zlatanov, T. 2003. Accommodation and development of the Manna ash (*Fraxinus ornus* L.) under the canopy of Austrian pine (*Pinus nigra* Arn.) artificial stands on the southern slopes of the Murgash Mountains. In: Rosnev B. (Chief Ed.), International Scientific Conference '75 Years Forest Research Institute – Bulgarian Academy of Sciences', Sofia, 1–5 October 2003, Vol. I, 217–221. (In Bulgarian).

Zlatanov, T. 2006. Influence of thinnings on composition and structure of the understory in Austrian pine (*Pinus nigra* Arn.) artificial stands. Forest science 3, 35–45. (In Bulgarian).