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NUMBER AND QUALITY STRUCTURE OF NATURAL BEECH REGENERATION IN ROUND APERTURES ON BISTRA MOUNTAIN

¹ANDRIJESKI M., ²VELKOVSKI N., ²VASILEVSKI K., ³NAJDOVSKI B.

¹Public enterprise Makedonski sumi, Skopje, Macedonia

²Ss. Cyril and Methodius University in Skopje, Faculty of Forestry in Skopje, Skopje, Macedonia

³MSc student, Ss. Cyril and Methodius University in Skopje, Faculty of Forestry in Skopje, Skopje, Macedonia

Corresponding author e-mail address: milorad.andrijeski@gmail.com

ABSTRACT: This research is made on the number and quality structure of the natural regeneration of beech in round apertures on Bistra Mountain. It's conducted by direct scientific research activities, by gathering information from the field. This information was later classified and processed by mathematical-static methods, and appropriate analysis were made, which results are shown both tabular and graphically. The study was made in pure beech forests represented in the Bistra Mountain. The natural conditions of the researched area, as essential for the growth and the survival of the forest ecosystems, also take a place in this paper. It was found that they are favorable for the development of forest vegetation. This paper also provides an overview of forest management in the past, as well as an analysis of results of taken silvicultural and regeneration measures, and it was determined that the studied forests have been under anthropogenic and zoogenic impact deep in the past. The development and the regeneration processes in the studied forests stands were being researched in their early development stages. The research was made under natural regeneration in round apertures and including quality structure of the offspring, as an important indicator over the next regeneration processes. From the conducted research is concluded that the beech forests of Bistra Mountain have a strong regeneration potential which is mainly correlated with the size of the round apertures.

Keywords: beech, beech forests, natural regeneration.

1 INTRODUCTION

The beech is one of Macedonia's most valuable tree species that can be found on all of the mountains in the country. The wide area covered by this species, as well as large concentration of wood stock in its forests, makes this specific species very important. According to the data of the publication "Forestry", edited by State Statistical Office of the Republic of Macedonia, the clean beech forests in the Republic of Macedonia cover 232.243 ha, or 23.61% of the full area covered in forest. Beech also participates on a large scale in mixed forests with fir, oak, pine etc., which forests are provided in Macedonia on 270.525 ha or 27.5 % of total forest area.

The great significance of beech and beech forests are reflected not only on its importance as a commercial tree species, but this species is especially important from a bio-ecological aspect, because it builds communities with many different species of trees and plants that are characterized by considerable diversity.

For further survival and development of these forests, the natural regeneration processes are considered extremely important. That is why a large number of researchers have been dealing with the question of the beech forests in Macedonia and the regeneration processes in these forests.

At Bistra Mountain most prevalent are beech forests, then mixed beech – fir and oak forests.

As one of the most important forests in the country, beech forest communities have already been studied by many authors, from different aspects and in different areas.

Thus, the characteristic of crowns in some beech coppice forests is explored by Krstevski, K. (1975). The structure, growth and productivity of pure beech stands with virgin characteristics for Osogovski Mountains and Belasica were researched by Ivanovski C. (1971 and 1978). The form of the beech and oak trunks in Republic of Macedonia was studied by Gogushevski M. and Ivanov D. (1980 and 1981). The bio-structural relations

in the beech high forests were analyzed by Mirchevski S. (1978).

Beech forests in terms of their reconstruction and development in pure high forests, depending on the canopy on the massif of the Arbit Mountain are explored by Petrushevski, S. (1982).

The structural elements and the productivity of the beech stands on the Kozhuf Mountain were researched by Ristevski P. (1987). The structure, productivity, bio-ecological characteristics and natural renewal for Maleshevski Mountains are analyzed by Velkovski N. (1999 and 2007).

The mixed beech-fir forests are especially important because of their structure, productivity and other functions. The productivity of beech-fir forests in Forestry Unit "Doshnica" was studied of Gogushevski, M. (1970). Natural regeneration and development of beech and beech – fir forests, depending on management is researched by Mirchevski S. (1983).

The ecological characteristics of the beech-fir forests were researched by Koshanin (1925), Grebeshchnikov, (1938), Dzekov, (1962), Em, H. (1961, 1975), Nikolovski, T. (1968), Vilarov, L. (1970), Hadzigeorgiev, K. (1972) and others, and the wood production ability of oak and beech forests are researched by Ivanov D. (1971).

Previous researches showed that the development of beech forests and their regeneration processes largely depend on the site conditions and the adjustability of the beech to them, according to its bio-ecological and genetic predispositions.

In general, in Macedonia is present Balkan beech *Fagus moesiaca* (Domin, Maly) Czezcott. (*F. silvatica* ssp. *moesizaca* (Maly) Czezcott), which manifest some intermediary differences between the European beech (*Fagus silvatica* L.) and the Eastern beech (*Fagus orientalis* Lipsky) from morphological, biological and ecological characteristics. Optimal soil conditions for proper development of the Balkan beech are fresh, deep, well aerated and humic soils, with a mild acidic reaction and a pH of around 0,6. On such soil, regardless on the

subsoil, beech forms a thick and branched root system, which effectively uses the nutrients from the soil. As a shade tolerant species, beech builds dense stands and produces large amount of timber. The ratio between total area of upper side of the leaves and the soil area in the mountain beech forests can be 8:1, which means that 1 ha of beech forest covers 8ha of land. Therefore, choosing the method of rejuvenation, concerning the appearance and silvicultural care of the new growth and avoidance of excessive shade are very important.

An important requisite for the appearance and silvicultural care of the young stands is the protection of the parent trees, because in the first years the new growth is very sensitive to extreme temperatures and drought. First, the regrowth's are lifting their cotyledons from the carpel above the ground. Soon after that, the carpel fall off, and the cotyledons remain on the young tree on a height of around 8 mm above the ground. The growth of the beech is slow, especially in the juvenile period, so beech trees at the age of 20 years reach about 3 m in height, but in unfavorable conditions, they grow even less. They tend to grow faster at later age, depending of the available amount of sunlight, and around the age of 100 years they reach maximal height, so at favorable site conditions the beech stands can have a wood mass of 800m³/ha. However, some environmental conditions or inadequate silvicultural practices can have a significant negative impact on the regeneration process of the beech forests, but also to the entire forest ecosystem. Special limitation role has temperature extremes and the availability of water, as a primary factor which limits the production of the natural ecosystems (Whittaker 1975). The drought periods in the last few decades are a key factor for the degradation of the beech and oak forests in Europe (Raftoyannis & Radoglou 2002).

Despite the considerable number of studies which researched the beech forests around the country, one can still say that the area of Bistra Mountain is not sufficiently studied. Therefore, research in this paper aimed at determining the number and quality structure of natural regeneration of beech in round apertures in the forests of Bistra Mountain.

2 METHOD AND RESEARCH OBJECT

The research on the number and quality structure of beech natural regeneration in round apertures is made on the massif of Bistra Mountain, which is situated in the western part of Macedonia, where different climate, soil, topographical and anthropogenic impacts encounter, providing conditions for prevalence of the beech forests.

The research was being pursued through direct measuring on the field and later office data analysis of the collected data. The data was collected through direct measuring on previously placed trial plots, chosen as authentic representative areas of the natural regeneration and its development stadium. Further, by mathematical calculations and methods, the results and values for fixed areal unit of 1ha has been obtained. The juvenile individuals are classified according to their development stadium, but also a valuation of their quality was made, as a basis for further determination of their potential for a proper natural regeneration. By processing and analyzing the data, obtained appropriate results, that are further compared with results from different researches on adequate type of forests and regeneration processes,

determined by other authors on other sites and extracted relevant conclusions.

In the process of the natural development, the stands follow different development stages, from the smallest, just sprouted offspring to trunks that, with further differentiation, take over the main part in the structure of the mature plantation. According to Bonushevac (1951), the forest in its development goes through the new growth, young stand, middle aged stand, non-grownup stand and grownup stand.

For examination of the natural regeneration of the forests on the Bistra Mountain, the research has been made on the first two development stadiums: new growth and young stand. These stadiums according to Šafar (1958) are:

- Regrowth – Plants at age of one year.
- New growth - From the stadium of regrowth to 1.30m height. Furthermore, the new growth stadium is separated as *non-grownup*, up to 0.30m and *grownup*, from 0.30 to 1.30m high.
- Young stand - over 1.30m in height, to 10cm in diameter at breast height. Further, the young stadium is separated as *non-grownup*, from 1.30m height to 3cm diameter at breast height, and *grownup*, 3-10cm diameter at breast height.

According to this classification, the term of natural regeneration comprises all the individuals at juvenile stands from the age of 1 year, to 10cm in diameter at breast height.

The subsoil at the researched area is mostly silicate and contains mainly shale; also quartzite is found on small areas. The slope of the terrain is mainly moderately steep to steep. The beech forests are mainly represented on acidic brown soils (distric cambisole), where in the upper part of the horizon, to 10 cm depth, high level of humus is notable, reach up to 10 %. The soil reaction is mild acidic. These soils are well provided with nitrogen, medium rich with potassium and almost always poor with phosphorus.

A very important hydrological object from an anthropogenic character - the Mavrovo Lake, is situated not far from the beech forests. The lake dominates the landscape by its coverage area and water reserves. The lake is formed by raising a dam on river Mavrovska Reka, but also many other rivers flow into it.

At the Bistra Mountain is prevailing highland climate, with great influence of the continental climate. According to data of the meteorological station in Mavrovi Anovi for the period 2001-2010 the mean annual air temperature is 7,6°C, the mean annual rainfall amount is 1.150 mm and is very favorable for growth and development of the forest vegetation. The increased air humidity affects the air temperature positively. The increasing of the humidity soothes the temperature variations and the extremes occur rarely. At the area most often are the northeast winds, with frequency of 212 ‰ and an average speed of about 6 m/s.

The undertaken silvicultural measures mainly positively affected the development of juvenile stands. However, on certain locations are notable effects of improperly selected and undertaken silvicultural and managing measures, which left traces that are noticeable even after several decades. Examples include the effects of belt type clear cuts in the eastern parts of the researched area.

The most represented forest communities on the northern slopes of Bistra Mountain are beech forest and

mixed forest of beech and fir, which accounted for 84.2% of the researched area. As a result of the favorable ecological conditions on these sites, there are mainly high, productive forests, with high standing timber and high growth. Timber in studied stands ranged from 175 to 370 m³/ha. Occasionally, individually or in groups, can be found mixtures of other species such as maple, alder, willow, oak, rowan etc. On smaller locations, on the peripheral parts of the researched area, mostly in lower altitudes and specific site conditions, encountered forests of Sessile oak and various modifications of the forest of Hop hornbeam, with hints of Manna ash, Pubescent oak, linden, etc., but still, the beech is the dominant tree species of the entire mountain range.

3 RESULTS AND DISCUSSION

The studies of natural regeneration in round apertures, was done in beech forest stands with different sizes of the apertures.

Analysis on the number and structure of natural regeneration of beech in development stages, depending on the aperture size was made.

The number of the natural regeneration, as an important indicator for the regeneration potential of the stand, for area of 1 ha is calculated using the following formula:

$$N = \frac{n \times 10.000}{P}$$

N = number of individuals on area of 1 ha
 n = number of individuals on measured area
 P = measured area (ha)

Table I: Representation of natural regeneration of beech in different development stages and different sized apertures

Number of individuals/ha in development phases	Aperture area (m ²)						Total	
	440	%	1.600	%	2.500	%		
non-grownup new growth	2.500	4,0	1.400	3,5	1.213	4,2	5.113	3,9
grownup new growth	22.500	36,0	5.480	13,7	2.380	8,3	30.360	23,1
non-grownup young stand	25.000	40,0	13.080	32,7	7.187	25,0	45.267	34,5
grownup young stand	12.500	20,0	20.040	50,1	17.970	62,5	50.510	38,5
Total	62.500	100,0	40.000	100,0	28.750	100,0	131.250	100,0

The data presented in Table I and Figure 1 shows that in all round apertures are registered individuals from all development stages, which means that regeneration process runs continuously. The largest amount of individuals per 1 ha area is at the round apertures of 440m² (62.500 individuals/ha), and lowest amount at the largest round apertures of 2.500 m² (28.750 individuals/ha).

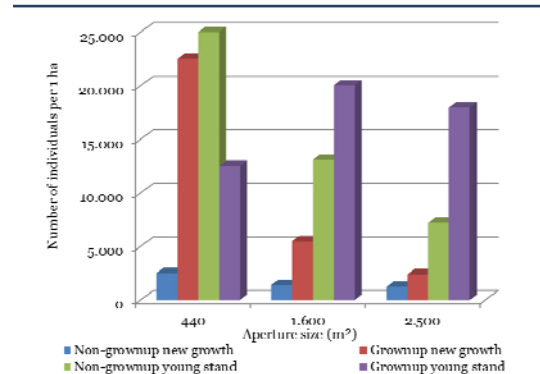


Figure 1: Representation of natural regeneration of beech in different development stages and different sized apertures



Figure 2: Regeneration in round apertures of 440 m²



Figure 3: Regeneration in round apertures of 440 m²



Figure 4: Grass emersion in round apertures of 1.600 m²



Figure 5: Regeneration in round apertures of 2.500 m²



Figure 6: Weed emersion in apertures larger than 2.500 m²

It is notable that in the larger apertures (1.600 and 2.500 m²), the participation of individuals from the development phase grownup young stand is higher. It is an outcome of greater free space in these apertures, so the natural regeneration grows faster and convert to the next development stage.

Such dependence between the size of the apertures in the forests and the amount of the natural regeneration was concluded on other localities too. Thus in the Maleshevski Mountains, amount of the natural regeneration individuals of beech in the apertures to 500m², varies between 77.500 individuals/ha on the eastern exposure to 144.500 individuals/ha in the northern exposure; in the apertures from 500 to 1000m² from 46.500 individuals/ha on the eastern exposure to 80.000 individuals/ha in the north and in the apertures from 1000 to 1500m² from 16.500 individuals/ha on the eastern exposure and 25.000 individuals/ha on the northern exposure (Velkovski, 2007).

Certain correlation between the size of the apertures in the forests and the amount of the natural regeneration is found in other species of trees. Thus, in the fir forests in Macedonia it was determined that, on the northern exposures, the amount of the natural regeneration in the apertures of 400 m² is 46.800 individuals/ha, in the apertures from 401 to 800 m² equals 34.500 individuals/ha, in the apertures from 801 to 1200 m² equals to 25.500 individuals/ha and in the apertures from 1.201 to 1.600m² amounted to 21.700 individuals/ha

(Mirčevski 1976). In the southern exposures determined the following values: in the apertures up to 400 m² the amount equals 45.400 individuals/ha, in the apertures from 401 to 800 m² equals 26.700 individuals/ha, in the apertures from 801 to 1200 m² amounts to 17.700 individuals/ha, and in the apertures from 1.201 to 1.600 m² equals 13.200 individuals/ha (Mirčevski 1976). In Scots pine forests on the mountain massif Nidže on northern exposures is determined that the abundance of the natural regeneration individuals in the apertures up to 500 m² amounted to 10.000 individuals/ha, in the apertures from 500 to 1.000 m² amounted to 8.700 individuals/ha; while on the western exposure in the apertures up to 500 m² determined to 42.050 individuals/ha, and in the apertures from 500 to 1.000 m² specified 8.700 individuals/ha (Batkoski, 1977).

The greater abundance of the natural regeneration of shade-tolerant tree species, such as beech and fir, compared to Scots pine is expected because they can develop in low amount of light, as according to their bio ecological characteristics are more adaptable of such natural conditions such as are created in round apertures in the forest.

The qualitative structure of the natural regeneration individuals of the stands on the northern slopes of the Bistra Mountain has been studied so that all individuals of the researched plots were evaluated individually, the data are calculated and reduced per 1 ha area and shown in Table II and Figures 7, 8 and 9.

The grouping was done in three quality groups:

- *Individuals of good quality* - a group that includes all those who stand out for their quality and good health,
- *Individuals with medium quality* - a group that includes all individuals who are behind the individuals of good quality, but they are still in a good health condition and good vigor,
- *Individuals with poor quality* - those who left behind in its development, with bad phenotypic and genotypic characteristics, dry branches or tops and incorrectly developed, branched canopy.

Table II: Quality structure of beech renewal in different sizes of circular apertures

Aperture area (m ²)	Quality in %			Total
	good	average	bad	
440	52	29	19	100
1.600	23	52	25	100
2.500	15	36	49	100

The data presented in Table II and Figures 7, 8 and 9 shows that by increasing the size of the round apertures in the forest the number of individuals with good quality decreases from 52% at the apertures sized 440 m², 23 % in apertures sized 1.600 m², to 15% apertures sized 2.500 m². At same aperture size, the number of individuals of poor quality increases from 19% at the apertures sized 440 m² to 49% at the apertures sized 2.500m². These data suggest that the best conditions for quality natural regeneration of beech exist in the round apertures of 440 m².

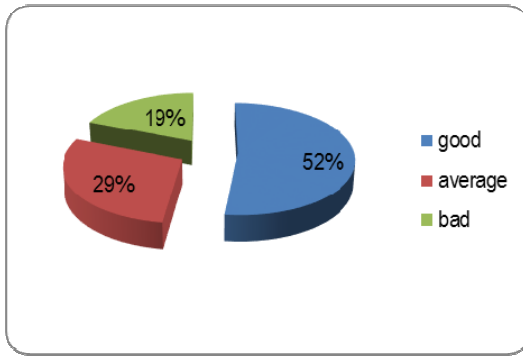


Figure 7: Quality structure of beech regeneration in round apertures of 440 m²

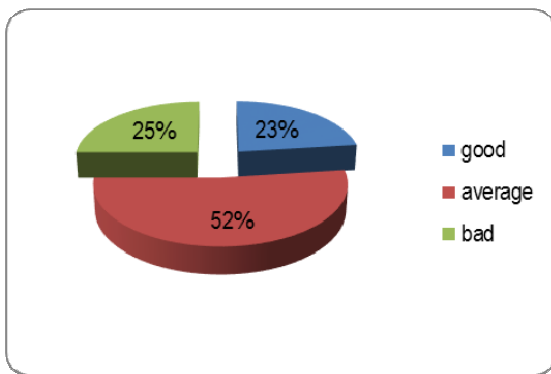


Figure 8: Quality structure of beech regeneration in round apertures of 1.600 m²

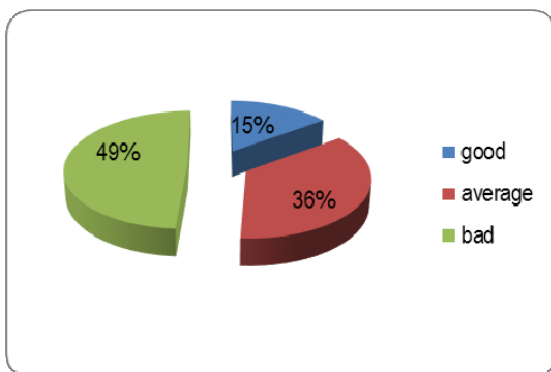


Figure 9: Quality structure of beech regeneration in round apertures of 2.500 m²

Large apertures of 1.600 m², and even more of 2.500 m², are not favorable for quality natural regeneration of the beech. In these large apertures, beside the decreased quality and abundance of beech natural regeneration individuals, are featured processes of grass overgrowing, which further complicates the regeneration process. Therefore, the application of future silvicultural measures in beech forest stands should be aimed to avoid creating large apertures, because apertures about 440 m² are the most suitable for quality natural regeneration.

Little better quality structures on the regeneration of the beech was concluded on Maleshevski Mountains, where in the apertures of 500 m² the number of individuals of good quality was 57 %, and the number of individuals with poor quality of 15 %. In apertures with a

size of 500 to 1.000 m², number of individuals of good quality was 41 %, and the individuals of bad quality 21 %. In apertures with a size between 1.000 and 1.500 m² number of individuals of good quality was 20 % and those with poor quality of 47 % (Velkovski, 2007).

Economic activities affected the natural rejuvenating processes on many localities in the investigated area. So, in the past, after the cuttings in beech forest stands, seedlings of spruce or seeds of fir were introduced. This practice continues today too, although in many places, after the 15th year regenerated individuals' dieback due to lack of light. Regarding the rejuvenation of stands, can be concluded that at the stands where silvicultural measures are taken, occurs quality offspring.

In the stands of the researched area, following silvicultural measures were taken: protection of the young stands, filling of the non-regenerated areas, thinning, pruning and seedling.

Protection of the young stands is a measure that is continuously implemented in the investigated area. Moreover, it is aimed primarily at protecting the grazing of domestic animals (sheep and goats), which in some cases can completely destroy the young forest, and prevention of illegal logging. Special measures for protection from wild animals were not been taken, but also not recorded any serious damage, because the wildlife population of this area is not too high.

Filling of the non-regenerated areas after the cuttings is a measure that is often applied. Filling is performed by applying seeds of fir or spruce in square areas or by seedlings of the same species. This measure initially has delivered some results, with the good advancement of fir and spruce, but later absence of silvicultural measures result in dieback after the tenth year. The reason for this is that these conifer species were suppressed by the natural regeneration of beech, which develop intensely and with good quality in the apertures area.

In other parts of stands, mostly used silvicultural measure is thinning. It is performed in coppice and high forests, with intensity between 15 and 20%. This intensity proved to be insufficient. The site conditions of the area are suitable for the development of forest stands with good quality structure, which can provide better, faster and more optimal development, applying thinning with intensity of 25 % and at better site conditions up to 30%.

4 CONCLUSIONS

- 1) The natural conditions of the Bistra Mountain together with anthropogenic and zoogenic factors contributed for prevalence of pure beech forests at this mountain range.
- 2) The most used measure in previous management of the stands is thinning. It is performed in coppice and high forests, with intensity between 15 and 20%. This intensity proved to be insufficient, because the natural conditions of the area are suitable for development of forest stands with good quality structure and which can provide better, faster and more optimal development if applied thinning intensity of 25% and in better site conditions even up to 30%.
- 3) In the researched area, mostly applied regeneration measure is group selective cutting. In small areas, round or belt type, in coppice plantations, clean cutting is applied. As a result of the regeneration measures in the beech forests, in many places is appeared quality natural regeneration of beech.

4) In certain parts, in order to improve regeneration process and enrich the forests with conifer tree species is performed fir seed dispersal and spruce afforestation. However, due to absence of further silvicultural measures, the offspring of these conifer species is with bad quality, because there is rarely occurrence of it, in the form of small groups, or on many parts dieback. There is particular poor success in spruce seed dispersal and seedlings planting. The reason of this is because for advancement in the beech forests, spruce individuals need properly enforced silvicultural measures, as well as assistance in the competitive struggle with the natural regeneration of beech, which varies in quality and density.

5) Natural regeneration in round apertures of 440m² is most favorable for regeneration of beech forests, because it brings together individuals from all stages of development, with a high percentage of individuals with good quality (52%), meaning that regeneration process runs continuously and with quality.

6) Increase of the apertures over 500m², reduce the number and quality structure of natural regeneration, and over 1.600 m² occur processes of grass overgrowing. Apertures over 2 500 m² are least favorable because good quality natural regeneration is estimating as low as 15% and overall regeneration process in these apertures is low. Apertures of this size should be avoided in management of the beech forests.

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М-р Дејан Манџуковски

Корица и насловна фотографија

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