CLIMATIC AND ECOLOGICAL CONSTRAINTS IN THE DISTRIBUTION OF EUROPEAN BEECH (*FAGUS SYLVATICA*) AT THE EASTERN LIMIT (SCIENTIFIC RESERVE "PLAIUL FAGULUI")

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Abstract. For the Republic of Moldova, the European beech forests (*Fagus sylvatica* specie) represent their most eastern areal in the spatial distribution, in Europe. During the last century there have been unfavorable changes in the climate conditions for the development of beech forests in Moldova. The summer mean temperature has increased, while the annual rainfall showed a decreasing trend. Therefore, on the basis of the beech climate tolerance index (Q_{BTI}), it was determined that the limit of drought tolerance, in temporal and spatial aspect, clarify beech death phenomena. The data obtained were compared with the state of vitality of the beech crowns within "Plaiul Fagului Reserve", which in the last years is unsatisfactory, largely due to this phenomenon.

Introduction

The beech (*Fagus* L., Fagaceae) species are representative trees of temperate deciduous broadleaf forests in the northern hemisphere (Fang, Lechowicz, 2006).

The European beech (*Fagus sylvatica* specie) is one of the most important and diversely used tree in Europe. It is an European species, emblem of Europe, spread only in Europe, mainly in central, western and secondary, southern parts of the continent, occupying the plains and hills in north-western Europe, and in the southern part - advancing to the mountains - over 1500 m. The forest massifs reach in the north, in the plain areas of southern Norway and Sweden, at 59° northern latitude, in the south, in northern Sicily, at 38° northern latitude, in

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the west, in the Bretagne Peninsula and in the east, in Podolia and in the Republic of Moldovia. In the eastern Podolia (Ukraine), the forests of *Fagus Sylvatica* are only insular, on small areas (www.euforgen.eu), (Fig. 1). In altitude, *Fagus sylvatica* rises from the plains, from the northern latitude of about 50°, to the mountains, at about 1600 m to its southern latitudinal limit, of about 40° northern latitude (Hacked-Pain et al, 2016).

On smaller areas, in south-eastern Europe and in Asia Minor there are two species of beech, *Oriental beech* and *Fagus taurica*. *Oriental beech* is located in the northern part of the Mediterranean climate, especially in Turkey (European Turkey, the Black Sea coast and the coast of the Gulf of Adana), southern Bulgaria and Crimea. The species *Fagus taurica*, a hybrid between *Fagus sylvatica* and *Fagus orientalis* is located in a single, restricted region, in the south of the Yaila Mountains, in Crimea (www.euforgen.eu).

Fig. 1. The natural distribution area of *Fagus sylvatica* in Europe (www.euroforigen.org).

Fagus sylvatica is a late-successional forest tree with a life span of about 300 years, and a very late reproduction age (40-50 years old). The seed production is characterized by irregular mast years.

In the Republic of Moldova beech grows at the *eastern border of its natural area*, spreading in the north-west of Codrii region (Ungheni, Nisporeni, Calarasi, Straseneni administrative districts), altitude 215-400 m. The beech stands in Moldova occupy about 400 ha.

In „Plaiul Fagului” Reserve, beech occupies an area of about 265.9 ha, spreading at higher altitudes (250-370 m), in the upper and middle part of slopes, with north and north-east exposure. The beech stands are represented by small areas, more often in the form of narrow strips near the breaks caused by landslides, along the ravines and small rivers. Coverage of the canopy crown is 0.8-0.9; in the upper layer dominates the beech, and in the arboretum - oak, linden, ash, maple and cherry. Herbaceous layer is poorly developed, with predominance of mesophilic species (Natura Rezervației ”Plaiul Fagului”, 2005).

Ecological and climatical conditions

The spread of *Fagus sylvatica* from its glacial refugia started during the late-glacial and has been continuous and irreversible until the present, without important retreats and re-advances, so that the modern distribution of beech in central and northern Europe corresponds to its maximum post-glacial extension (Magri, 2008).

The climatic restriction are due by the lowest temperatures of the winter, toward north (minimum < 30° C and sensitivity at late spring frost, in May), (Peters, 1992, Mihăilă et al, 2019) and by the higher temperatures in summer and especially the reduced quantity of precipitations in late spring and summer forward south, especially in Spain and the continental climate to the eastward, with too cold winters and too hot summers and low quantities of precipitations.

Practically, the spread of *Fagus sylvatica* includes almost entirely temperate oceanic and transitional temperate climates and the areas between 500 m and 1500 m altitude, of the Mediterranean climate.

Bioclimatic, according to Metzger et al, (2013) and in the *High resolution bioclimate map of the world*, *Fagus sylvatica* is present in Europe in broad biomes ”Boreal/Alpin” and ”Cool-temperate”. In the biome ”Boreal/Alpin”, *Fagus Sylvatica* is present in the ”Global environmental zones”, ”Extremely cold and mesic - F” and ”Cold and mesic - G” and in the ”Cool temperate biome”, in the ”Global environmental zones”, ”Cool temperate and dry - H” and ”Cool temperate and moist - J” (Fig. 2).

European beech is a strong competitor with high shadow tolerance as seedling and sapling. Beech is therefore able to get to dominance on sites with a relatively broad spectrum of nutrient and hydrological regimes, from highly acidic to basic soils (Leuschner Ch. et al., 2006) and from dry to moist conditions.

In the southern part of its range, and at low elevations, the competitiveness of beech is limited by increasing water stress, until finally it is replaced by forests consist of more drought-tolerant species (Peters R., 1997), mainly *Quercus* and *Pinus*. Although *Fagus sylvatica* is one of the dominant tree species' in central European temperate forests with high physiological tolerance and competitiveness, drought sensitivity is assumed to be a key factor limiting growth and distribution of beech near to its lower distributional limit (xeric limit) in southern and south-eastern Europe. Several studies suggest a decline in beech regeneration or extensive beech dieback with worsening climatic conditions (Rasztovits E., 2011).

Materials and methods

To determine the complex relationship between climate conditions of study area and distribution of beech in "Plaiul Fagului" Reserve, study was based on **Beech tolerance index Q_{BTI}** . A climate index (Q_{BTI}) for beech was introduced based on the weighted spring and summer precipitation and mean summer temperatures (Rasztovits E., 2011):

$$Q_{BTI} = \frac{0.2 * P_{III} + 0.5 * P_{IV} + P_V + P_{VI} + P_{VII} + 0.8 * P_{VIII}}{(T_{VI} + T_{VII} + T_{VIII})/3}$$

where: PIII: precipitation in March

PIV: precipitation in April

PV: precipitation in May

PVI: precipitation in June

PVII: precipitation in July

PVIII: precipitation in August

TVI: mean temperature in June

TVII: mean temperature in July

TVIII: mean temperature in August

Temporal change of the tolerance index of beech (Q_{BTI}) between 1981-2017 in Republic of Moldova, was calculated based on 17 meteorological station data, through Statgraphics Centurion XVI Programme.

Figure 2. Environmental zoning of Europe (Sven et al, apud Metzger *et al.*, 2013).

Results and discussions

It can be stated that drought in R. Moldavia is not an accidentally occurring natural phenomenon, but is a frequent one and its manifestation has a permanent character. The phenomenon has been amplifying in recent decades due to climate change (Putuntică, Sofroni, 2011; Nedelcov et al, 2019).

In the spatial distribution of Q_{BTI} is important to know the absolute altitude of areas occupied by beech, therefore the digital map with the absolute altitudes within the “Plaiul Fagului” Reserve has been obtained. It was determined that absolute altitudes of research area vary within 129-407 m, while the beech areas include the territory between 242-336 m (Fig. 3).

After calculating the Q_{BTI} for the researched surface, it was identified that, although the area is limited / reduced, the spatial differentiation of Q_{BTI} can vary, and in our case is 4.5- value which can be quite important and be as stress indicator in some extremely dry years in the region (Fig. 4).

The Q_{BTI} value in the areas occupied by beech (NV and SE of the Reserve) is higher than in the rest of the territory, and varies within 15.2 ... 17.2 (compared to 12.7 ... 13.7 for areas with lower altitudes - less than 200 m).

The Q_{BTI} estimation in temporal aspect, according to data from Cornești meteorological station, located further North of the "Plaiul Fagului" Reserve, demonstrates that the beech on the researched territory develops in climatic conditions expressed by the *multiannual average of this index equal to 14,9 units*. Values below 10.8 - rendered with a red line on the graph, corresponding to the climatic tolerance of beech to drought conditions, according to the literature; in our research there are some cases with values under this limit, that corresponds with so called "dry years" - years 2000, 2003, 2007, 2009, 2012, 2015 (Fig. 5).

In this regard, we mention national studies on the state of health of the main tree species/vitality of species from national forest fund (Raport privind activitatea tehnico-științifică..., 2017), where in 2015, of 37 individually

researched species, the highest intensity of injuries (grades 2-4, according ICP Forests methodology) is recorded for beech (35% of total species); for 2016 year - also for beech (41%).

Fig. 5. Dynamics of beech tolerance index Q_{BTI} (1981-2017), according to data from Cornești meteorological station (North of the “Plaiul Fagului” Reserve).

In these conditions, we believe that further in-depth studies are needed to explain the “death of beech” process, also in the context of climate change (Nedealcov et al., 2017).

Conclusions

Beech climate tolerance index Q_{BTI} for researched area, in temporal aspect (1981-2017) has a multiannual average value equal to 14,9 units. The lowest values of this index reflect the climatic conditions of the dry years. The Q_{BTI} value in the areas occupied by beech (NV and SE of the “Plaiul Fagului” Reserve) is higher than in the rest of the territory, and varies within 15.2 ... 17.2 (compared to 12.7 ... 13.7 for areas with lower altitudes - less than 200m), which confirms that beech is a moisture-loving species. Studies related to adaptation of tree native species to the future climatic conditions are recommended, with inclusion of forestry problems in future environmental, national strategies.

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