Ecological and coenotic characteristics of Vaccinium myrtillus L. in southern taiga forest communities

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Abstract. Materials in the paper characterize ecological range of bilberry (Vaccinium myrtillus L.) in southern taiga forests of Kirov region. It is significantly influenced by illumination, soil humidity, richness and acidity. Parameters of bilberry contribution to lower forest synfolium, structural and morphological peculiarities of the species were defined, as well as productivity.

1. Introduction

Intensification of human impact on populations of resort plant species lead to necessity of applied measures for sustainable utilization of their use based on knowledge of the species ecology and biology, productivity, spacial and temporal distribution, stock value and dynamics.

Bilberry (Vaccinium myrtillus L.) family Ericaceae occupies a leading position by its area and stocks among wild growing berry plants in Kirov region and makes a significant component of forest communities, often determining the lower forest synfolium. The share of bilberry types of forests reaches 30.9% of total forest-covered lands [1]. Among those birch forests prevail (12.7%), followed by spruce (11.4%), aspen (4.6%) and pine forests. Bilberry is a mycorrhizal plant [2] and positively affects nutrition of all synfolia, including trees, intensifies natural reforestation by spruce and pine, prevents wind and water soil erosion. Well-humous soils are being formed under bilberry bushes. It also serves as a fodder for many game animals, which use buds, leaves, sprouts or berries depending on a season [3]. For instance, moose uses up to 2.7 t/ha of bilberry sprouts that makes about 45% of total growth.

Main berry-bearing areas of bilberry are concentrated in southern taiga sub zone [4] and reach 39.4 thousand ha (42% of total area in the region). First data on bilberry productivity in southern taiga in Kirov region were presented in a paper by A A Skryabina and G G Kotozhkova [5], who studied Kotelnich area of the region. Maximum productivity of V. myrtillus in bilberry forest types of North-Eastern European Russia reaches 52.6-86.0 g/m² [6]. According to different researchers [4,7], average long-term productivity of bilberry in southern taiga sub zone of Kirov region is maximum in bilberry spruce forests (41.5±4.1 g/m²) and minimum in bilberry aspen forests (21.5±2.6 g/m²).

Bilberry is demanding to the factor of soil humidity, reaching the largest abundance at 66 to 90% soil humidity steps, according to L G Ramensky [8]. It usually grows on nitrogen-poor soils and is classified as an oligotrophic species. L A Zhukova’s scale [9] defines V. myrtillus as an euryvalent by light scale, hemi-eury-valent by cryoclimatic scale, meso-valent by thermoclimatic scale, and hemi-steno-valent by ombroclimatic scale.
The study of *V. myrtillus* population parameters that define the principles of resources’ sustainable use, are fragmented in both geographical and ecological-coenotic aspects [3].

Aim of the study was to reveal ecological, biological and productivity parameters of *V. myrtillus* in southern taiga sub zone of Kirov region, and to define ecological preferences of bilberry in southern taiga forest communities; estimate the species contribution to the composition of lower forest synfolium of southern taiga forest communities; define structural and morphometric parameters of *V. myrtillus* plant communities (PCs) in southern taiga forests; and to determine the value and dynamics of bilberry fruits productivity.

2. Materials and methods

Productivity and population parameters of *V. myrtillus* were studied in Kotelnich area of Kirov region (southern taiga sub zone) in 2013-2019, vegetation periods differed between the years (figure 1). Data on productivity published by other researchers for the period of 1984-2014 and archival records from the Plant Ecology and Resources Dept. of Russian Research Institute of Game Management and Fur Farming (VNIIIOZ, Kirov) were also analyzed. Investigation based on common methods of constant sample plots (CSP) [10]. Productivity census was accomplished in 10 plant communities (table 1) on 1 m² sample plots. Geobotanical descriptions were made with common methodic approaches. Partial shrubs (PS) were chosen as accounting units.

![Figure 1](image_url)

**Figure 1.** Basic meteorological parameters in the area of investigation for studied vegetation periods of 2012-2019 (a - total precipitation; b - average monthly air temperature).

Ecological and biological preferences of *V. myrtillus* were estimated with use of Ellenberg’s scales [11] which consider the influence of various ecological factors such as light, soil humidity, richness and acidity. Hemeroby of the communities with bilberry was determined by the species composition with each species having individual tolerance spectrum towards human impact factors [12].

| # PC | Plant community type       | Tree stand composition* | Crown density | Lower forest synfolium (dominating species)                      |
|------|---------------------------|-------------------------|---------------|------------------------------------------------------------------|
| 1    | Cowberry-bilberry pine forest | 8P2S+B                  | 0.7           | *Vaccinium vitis-idaea* L., *Rubus saxatilis* L.,  
|      |                           |                         |               | *Calamagrostis arundinacea* (L.) Roth.,  
|      |                           |                         |               | *Vaccinium myrtillus* L., *Fragaria vesca* L.                     |
| 2    | Calamagrostis-bilberry spruce-pine forest | 5P5S+B                  | 0.8           | *Vaccinium vitis-idaea* L., *Rubus saxatilis* L.,  
|      |                           |                         |               | *Vaccinium myrtillus* L., *Calamagrostis arundinacea* (L.) Roth. |
| 3    | Bilberry-green-moss pine forest | 7P3S                    | 0.4           | *Vaccinium vitis-idaea* L., *Linnaea borealis* L.,  
|      |                           |                         |               | *Vaccinium myrtillus* L.                                          |
4 Clear-cut of bilberry-sphagnum pine forest - - Vaccinium vitis-idaea L., Vaccinium myrtillus L., Linnaea borealis L.
5 Bilberry spruce-pine forest 7P3S+B 0.7 Vaccinium vitis-idaea L., Rubus saxatilis L., Vaccinium myrtillus L., Calamagrostis arundinacea (L.) Roth.
6 Bilberry-green-moss spruce-pine forest 6P4S+B 0.9 Vaccinium vitis-idaea L., Vaccinium myrtillus L., Calamagrostis arundinacea (L.) Roth.
7 Bilberry aspen-pine forest 6P4As+B+S 0.8 Vaccinium myrtillus L., Calamagrostis arundinacea (L.) Roth., Rubus saxatilis L., Oxalis acetosella L., Vaccinium vitis-idaea L.
8 Bilberry birch forest with pine 6B4P+As 0.7 Vaccinium vitis-idaea L., Vaccinium myrtillus L., Pteridium aquilinum (L.) Kuhn.
9 Sphagnum-bilberry spruce-pine forest 5P4S1B 0.6 Vaccinium myrtillus L., Vaccinium vitis-idaea L., Carex limosa L.
10 Oxalis-bilberry-green-moss spruce forest 10S+P 0.9 Vaccinium myrtillus L., Oxalis acetosella L., Calamagrostis arundinacea (L.) Roth., Dryopteris carthusiana (Vill.) H. P. Fuchs

As - aspen; B - birch, P - pine, S - spruce.

The study was based on 4-point hemeroby scale by Jalas: 1) the highest sensitivity (a, o - hemerobs prevail); 2) high sensitivity (o, m hemerobs); 3) medium sensitivity (m, b hemerobs); 4) low sensitivity (b, c, p, t hemerobs). The ratio of 2 groups out of the hemeroby spectrum revealed the conditions and the resilience of plant communities to complex human intervention. The first group included a-o-m section of the spectrum (species non-tolerating human impact to those which are resilient to sporadic insignificant disturbances), the second included b-c-p-t section of the spectrum (species of intensively used communities to species of fully destroyed ecosystems). Ecological parameters of the habitats were estimated with D N Tsyganov’s amplitude scales [13]. Samples of soils and litter were collected to estimate acidity [14]. Ecological valence and trophic niche were specified with L A Zhukova methodic approach [9].

Statistics were made according to common methods. Levels of features’ variability were defined according to G N Zaitsev [15]: CV > 20 % – high; CV = 11-20 % – medium; CV < 10 % – low. Correlation analyses was used to estimate interconnection of morphological features. Correlation strength was estimated as follows [16]: r < 0.34 – low; r = 0.34–0.69 – medium; r > 0.7 – high.

3. Results
In the area of studies V. myrtillus grows in semi-shady to shady conditions (5th step of the Ellenberg’s scale), and is rarely found in conditions of full illumination (figure 2). The results are close to ecological preferences of bilberry defined for different areas of its range. For example, in the Ukrainian Polesye optimum conditions for bilberry are found in forest stands that pass 15-35% of solar energy. In conditions of forest zone of the European Russia the species is characterised by high plasticity and can survive in conditions of direct light. In southern taiga sub zone bilberry is an indicator of medium humid soils (5th step of the Ellenberg’s scale), being absent in wet and dry habitats. It prefers nutrient-poor soils, rarely - nutrient-rich ones (3rd step of the Ellenberg’s scale), acidic or medium-acidic with average pH 3.6 (4th step of the scale). Litter acidity was a little lower (pH = 3.9). Bilberry ecological preferences defined with Ellenberg’s scales are close to the data.
received in previous studies. Illumination, soil richness and urbanity values were close to the ones for Central Europe, but soil and litter acidity parameter was twice higher than the one for Central Europe.

Figure 2. Ecological parameters of bilberry habitats according to Ellenberg’s scales (1974).

Hemeroby is a marker that indicate the species’ and communities’ resilience to human impact. PCs with V. myrtillus in southern taiga are mostly presented by o-oligo-hemerobs and m-meso-hemerobs (39% and 40% correspondingly from the total species number), i.e. by the species highly sensitive to anthropogenic factors. These include Maianthemum bifolium (L.) F W Schmidt, Vaccinium vitis-idaea L., and etc. The share of b-eu-hemerobs in the communities (species of intensively used natural communities, that experience use of fertilisers, biocides, soil liming, etc.) is 17%: Hieracium umbellatum L., Orthilia secunda (L.) House, Pyrola rotundifolia L. and etc. Share of a-a-hemerobs, i.e. highly sensitive species (Lycopodium annotinum L., Lycopodium complanatum L.), in communities with bilberry is only 3%, and a-eu-hemerobs (ruderal species) like Galium mollugo L., occupy less than 1%. The level of t-hemerobs was absent in all studied PCs. The a-o-m section of the spectrum dominates over b-c-p-t section. Plant communities with V. myrtillus are mostly composed by species not tolerating human impact, like Solidago virgaurea L., Vaccinium vitis-idaea L., Arctostaphylos uva-ursi (L.) Spreng., Maianthemum bifolium (L.) F W Schmidt. This makes V. myrtillus a moderate urban-phobic growing outside human settlements.

Figure 3. Graphic description of bilberry’s ecological niche fragment by D N Tsyganov’s scales (1983) in southern taiga in Kirov region.

Tm-Thermo-climatic, Kn-climate continentality, Om-ombro-climatic, Cr-cryoclimatic, Hd-soil humidity, Tr-soil salts regime, Re-soil acidity, Nt-soil nitrogen richness, fH-humidity variation, Lc-light-shading; PEV – Potential ecological valence, REV – actual ecological valence
Phytoindication ecological scales of D N Tsyganov [13] reveal the border of bilberry’s ecological niche in studied communities. Populations of \( V. \) myrtillus are found in a narrow range of edaphic factors. Ecological efficacy coefficient \( (K_{ec \cdot eff}) \) shows that major ecological possibilities are already executed for edaphic factors (soil acidity \( (K_{ec \cdot eff}=122\%) \), soil humidity variation \( (K_{ec \cdot eff}=100\%) \); for climatic \( (ombroclimatic \ (K_{ec \cdot eff}=105\%) \) and thermo-climatic \( (K_{ec \cdot eff}=106\%) \) factors), being the lowest for illumination factor \( (K_{ec \cdot eff}=71\%) \). Climatic tolerance index of \( V. \) myrtillus is \( I_{clim}=0.58 \), thus the species is a hemi-eurybiont; soil tolerance index \( I_{soil}=0.45 \) – a hemi-stenobiont, \( I_{light-shade}=0.89 \) – eurybiont. These data correspond with previously published [17] characteristics of the species, which ecological range within southern taiga sub zone of Kirov region is shown on figure 3.

In studied plant communities (PCs) bilberry is a dominant or co-dominant of lower forest synfolium (figure 4). Projective cover varied from 23.2±2.5% (clear-cut of bilberry-sphagnum pine forest - PC4) to 80.1±3.2% (bilberry birch forest with pine - PC8), and did not change significantly over the years. Average number of PS varied from 40.3±1.5 per m\(^2\) (PC7 – bilberry aspen-spruce forest) to 198.9±4.9 and 198.8±5.7 per m\(^2\) (bilberry-green-moss pine forest - PC3 and sphagnum-bilberry spruce-pine forest – PC9 correspondingly), average height of yielding PS – from 14.4±1.1 cm (PC4) to 37.1±0.6 cm (PC7). Correlation between crown density and bilberry projective cover in 2014 was high and reversed \((r=-0.79)\). Less strong influence of crown density was marked on average number of PS \((r=-0.70)\). Correlation between average number of PS and their height is medium and reversed \((r=-0.53)\).

![Figure 4. Dynamics of bilberry projective cover in different plant communities in 2013-2019, %](image1)

Vegetative PS prevailed in the structure of all studied PCs (figure 5). Their share was the highest in PC4 (100 %). Number of yielding and not-yielding PSs was highly variable \((CV=29\% \) and \(CV=80\%\) correspondingly). It’s worth mentioning that all studied plant communities with bilberry had higher numbers of PSs compared to the published data from bordering regions [7].

![Figure 5. Dynamics of number of bilberry yielding sprouts in different plant communities in 2013-2019, per m\(^2\)](image2)
Minimum yields were marked in 2017 and 2019 — from 1.7±0.2 g/m² to 4.4±0.8 g/m². Such low yields were only marked 5 times during the previous observation period (in 1978, 1981, 1983, 1986 and 2010). In 2014 average productivity of bilberry in all PCs was maximal — 26.1±2.2 g/m², reaching 44.2±3.9 g/m² in PC №3 (figure 6). Yield value depended mainly on two factors: number of yielding PSs (r = 0.94) and crown density (r = -0.77). Influence of meteorological conditions during the vegetation period was established: medium correlation between average bilberry productivity and air temperatures in May (r = 0.5); high – and with total precipitation in June (r = 0.7). High level of correlation was marked between average diameter and average weight of a berry (r = 0.9), influence of July’s temperature on berry size was also defined (r = 0.7).

Figure 6. Dynamics of bilberry (Vaccinium myrtillus L.) fructification in different plant communities in 2013-2019. X-axis - berry weight, g/m²; Y-axis - plant community number

Main factors influencing V. myrtillus productivity, are meteorological parameters of the vegetation period [18, 19]. Thus, dry conditions of 2013 lead to sharp decrease of bilberry productivity in southern taiga of Kirov region, and meteorological conditions of 2014, on the contrary, resulted in its increase. Productivity of all PCs (excluding PC №6) was higher than average long-term level and was close to the values of highly-productive years. Generally, bilberry in studied areas is yielding almost evenly: average long-term point of fructification for 50-years period was 3.0, reaching 4-5 points in optimum habitats 3 times (1964, 1976, 2000) [4].

4. Conclusion
The study allowed to define edaphic characteristics of V. myrtillus plant communities for many ecological parameters. In the area of studies bilberry grows in conditions of semi-shade to shade, preferring medium-moist medium-acidic to acidic, nitrogen-poor (rarely nitrogen-rich) soils, and is acidophile and urban-phobic.

In studied PCs bilberry is a dominant or co-dominant of lower forest synfolium with projective cover of 23.2±2.5 to 82.0±3.1 %.

Vegetative partial sprouts prevail in the structure of studied communities.

Average productivity varied from 1.7±0.2 g/m² (2019) to 26.1±2.2 g/m² (2014) and depended on several factors: crown density, number of yielding sprouts and meteorological conditions of the vegetation period.

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