Resources potential of family Vacciniaceae in Russia

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Abstract. The study determines productivity, biological and explotation stocks of the most common wild growing plants from Vacciniaceae family in Russia: lingonberry (Vaccinium vitis-idaea L.), blueberry (V. uliginosum L.), cranberry (V. oxyccocos L.), and bilberry species. These species have significant stocks in natural habitats in Russia and are being collected for industrial purposes and personal consumption. The largest volumes of raw material (fruits and also leaves in case of lingonberry) were being collected in 1985-1989, but they sharply decreased at the end of 20th century. Productivity of berry thickets differs within Federal Districts, administrative regions and plant communities.

1. Introduction
Plants are rich sources of various medicinal substances, and more than 30% of all medications on world market have vegetative origins [1]. Majority of nutraceuticals include (or declare to include) botanical compounds. Up until this time significant volumes of raw material are being collected in natural habitats. And it is important to have data on resources potential of the species in order to make a decision on producing certain vegetative medications. This study aimed at estimation of resources potential and usage volumes of the most common food and medicinal plants from Vacciniaceae family.

2. Methods and Materials
Methodic approach to the problem was published earlier [2]. It was based on key habitats study and further extrapolation of data to same-type plant communities.

3. Results and discussion
3.1. Lingonberry
Lingonberry (Vaccinium vitis-idaea L.) within Russian Federation occurs in forest and arctic zones, in mountains it goes up to goltsy altitudinal belt. The species is the most productive in sparse and medium thick pine and abies lingonberry forests and clearings of these types, on open edges of swamps. Maximum yields of lingonberry in these habitats reach 1000-3754 kg/ha [3-6]. At conditions of 0.6 – 0.8 crown density in pine, abies and mixed forests lingonberry forms dense but mostly barren thickets with leaves productivity of up to 600 kg/ha; these types of habitats are reasonable for collection of lingonberry leaves and shoots.

Maximum productivity of lingonberry berries in Kirov region was defined in lingonberry-blueberry pine forests (21.7 ± 3.0 g/m²), on overgrowing clearings (20.3 ± 2.7 g/m²) in middle taiga zone, and in thinned bilberry pine forests with 0.3-0.4 crown density (20.1 ± 3.0 g/m²) (table 1).
Relatively high productivity of lingonberry is marked in low-density lingonberry, Majanthemum-lingonberry, mossy pine forests and clearing of these types. Average berry productivity in these communities is 15.0 ± 1.9 g/m², high reaching 30.0 ± 3.7 g/m² – 38.0 ± 4.2 g/m². In lingonberry pine forests of 0.5-0.6 crown density lingonberry is spread evenly. In low-density lingonberry and Majanthemum-lingonberry pine forests with selective cutting lingonberry forms thickets and it more productive than in other habitats; average productivity - 25.0 ± 2.9 g/m², high – from 52.0 ± 6.2 g/m² to 103.0 ± 12.9 g/m². In mossy pine forests lingonberry is more productive on low crown density spots (16.0 ± 1.2 g/m² to 43.0 ± 3.9 g/m²). On overgrowing 8-12 years old clearings lingonberry occurs in spots around stubs and cutting remains (19.6 ± 2.2 g/m²).

Table 1. Average long-term productivity of *Vaccinium vitis-idaea* berries in different forest types in Kirov region (1961-2004) (stationary study).

| Forest type                     | Number of plots | Productivity, g/m², M ± m/limits |
|---------------------------------|-----------------|----------------------------------|
| **Middle taiga**                |                 |                                  |
| Lingonberry pine                | 1685            | 12.4 ± 1.5 2.0 – 22.0            |
| Lingonberry-heather pine        | 560             | 14.6 ± 1.9 6.0 – 24.0            |
| Lingonberry-blueberry pine      | 620             | 21.7 ± 3.0 1.0 – 40.0            |
| Overgrowing clearing            | 1348            | 20.3 ± 2.7 0.5 – 28.0            |
| **Southern taiga**              |                 |                                  |
| Lingonberry pine                | 1359            | 9.6 ± 1.1 3.0 – 31.0             |
| Bilberry pine (crown density 0.3 -0.4) | 1300            | 20.1 ± 3.0 0.2 – 113.0          |
| Mossy pine                      | 1500            | 10.6 ± 1.4 1.5 – 23.0            |
| Overgrowing clearing            | 1265            | 14.0 ± 1.9 5.0 – 23.5            |

Productivity of lingonberry within Kirov region declines southwards. The highest berry productivity is common for 5-10 years old overgrowing clearings in middle taiga (28.0 ± 1.9 g/m²); the level is a little lower in southern taiga – from 13.0 ± 1.0 to 24.0 ± 1.5 g/m². The lowest berry productivity is typical for coniferous-broadleaf forest subzone - 10.0 ± 2.0 to 17.0 ± 8.0 g/m².

Biological stock (BS) of lingonberry fruits (table 2) in Russia in medium fruitful year reaches 480.7 thousands of tons, exploitation stock (ES) – 157.2 thousands of tons. The largest resources of lingonberry are concentrated in North-Western (35% BS and 20% ES), Far Eastern (27% BS and 31% ES) and Ural (20% BS and 26% ES) Federal Districts. Among separate regions the highest stock is located in the Sakha Republic (BS – 100.0; ES – 35.0 thousands of tons), Khanty-Mansy Autonomous District (BS – 78.1; ES – 32.2 thousands of tons), Komi Republic (BS – 59.6; ES – 8.9 thousands of tons), Karelia (BS – 44.0; ES – 4.4 thousands of tons), Arkhangelsk region (BS – 35.8; ES – 8.9 thousands of tons), and Khabarovsky Krai (BS – 25.0; ES – 12.0 thousands of tons). Average long-term score of fructification in these regions is 3.5-3.7. Minimal stock of lingonberry fruits is marked in Privolzhskiy and Central Federal Districts. The highest density of raw material BS (more than 100 t/thous.km²) is marked in the Komi Republic and Karelia, Arkhangelsk and Murmansk regions, and Khanty-Mansy Autonomous District.

Maximum industrial collection of lingonberry fruits in Russia in 1985-1989 were 10.7 thousands of tons, average long-term – 5.2 thousands of tons. Statistics on collection of fruits is absent for further
time periods. Expert estimations of usage volumes of lingonberry fruits demonstrate that industrial collection level which has declined 50-80% in 1980-90’s, is now increasing and reached the level of 1985-1989 in European part of Russia and Far East. In Siberia the level is still low and barely reaches 10-15% of 1985-1989 level. Raw material collection for personal consumption increased 20-40%, lingonberry habitats familiarization level varies depending on a Federal Districts and is 5-10% in Siberia, up to 98% in densely populated areas of the European part of Russia.

Till 1990’s industrial collection of lingonberry leaves in Russia have been 15.5-37.8 thousands of tons annually. Use of raw material stock in different regions varied from 0.004 to 1.0% of BS. Actual volume of collection decreased 5 times nowadays. In most Russian regions raw material is only being collected for personal consumption. In 2002-2003 we marked a trend on the increase of lingonberry leaves collection in some European regions of Russia. For example, OOO “Severnaya Yagoda” (Northern Berry) collected 3 t of raw material in Arkhangelsk region. The value is close to average long-term organized collection of lingonberry leaves by all collectors in Arkhangelsk region in 1985-1989. Kirov Oblpotrebsoyuz (Consumers Union) collected a bit more than 1 t annually in 2002, which is close to average long-term collection of lingonberry leaves raw material in the end of 20th century. During the last 5-6 years annual collection of the raw material was only 0.3 t in Kirov region. Familiarization of lingonberry leaves resources in most Russian regions does not exceed 1-2% of BS.

Table 2. Biological stock of raw material of Vacciniaceae plants in Russia (thousands of tons).

| Federal District      | Lingonberry | Blueberry | Cranberry | Bilberry |
|-----------------------|-------------|-----------|-----------|----------|
|                       | fruits      | leaves    | fruits    | fruits   |
| North-Western         | 168.7       | 244.6     | 38.6      | 279.6    | 385.8    |
| Central               | 4.4         | 28.4      | 1.3       | 1.4      | 11.3     |
| Privolzhskyi          | 12.4        | 36.0      | 4.8       | 18.6     | 47.6     |
| Ural                 | 97.5        | 73.8      | 245.1     | 67.4     | 503.0    |
| Siberian              | 69.0        | 118.1     | 647.5     | 30.8     | 953.6    |
| Far Eastern           | 128.7       | 107.6     | 324.6     | 41.2     | 30.1     |
| Total                 | 480.7       | 608.5     | 1261.9    | 439.0    | 1931.4   |

3.2. Blueberry

Blueberry (V. uliginosum L.) is found all over taiga zone in pine, spruce and abies forests of mossy, green-moss, dwarf shrubs-sphagnum types, on sphagnum swamps, often dominating and forming blueberry-green moss, blueberry-mossy, blueberry-sphagnum vegetation types. It dominates herbaceous-shrub layer of shrubs and dwarf shrubs tundra. In the lower part of goltsy belt it is often found in mountainous-tundra spruce forests. Maximum productivity of blueberry in these habitats in European part of Russia reaches 505 kg/ha [7], in Siberia - 620 kg/ha [8-10], and Far East - 530 – 1300 kg/ha [11, 12].

Productivity of blueberry varies depending on plant community type and vegetation subzone. In Kirov region the most productive populations of blueberry are marked in low-density sedge-sphagnum swamps of the far north of the region, where average long-term productivity reaches 200 ± 28 kg/ha, ranging in different years from 60 ± 8.4 kg/ha (low fruitful years) to 260 ± 32.0 kg/ha (highly fruitful years) (table 3). Total average long-term productivity of blueberry in middle taiga is 128.3 ± 18.0, ranging from 30 ± 3.8 to 260 ± 32.0 kg/ha; in southern taiga – 107.1 ± 16.0 kg/ha (from 20 ± 3.1 kg/ha to 200 ± 19.6 kg/ha); in coniferous-broadleaf forest subzone – 62.5 ± 9.1 kg/ha (from 40 ± 5.3 kg/ha to 110 ± 13.8 kg/ha).
Table 3. Productivity of *Vaccinium uliginosum* L. berries in different vegetation subzone of Kirov region, kg/ha (min – max / average).

| Subzone                     | Productivity       |
|-----------------------------|--------------------|
| Middle taiga                | 30 – 260           |
|                             | 128.3 ± 18.0       |
| Southern taiga              | 20 – 200           |
|                             | 107.1 ± 16.0       |
| Coniferous-broadleaf forests| 40 – 110           |
|                             | 62.5 ± 9.1         |

BS of blueberry fruits (table 3) in Russia in medium fruitful years is 1261.9 thousands of tons, ES – 354.7 thousands of tons. More than half of resources is concentrated in Siberian (51% BS and 44% ES) and one quarter in Far Eastern (26% BS and 18% ES) Federal Districts. Among separate regions the highest stock of blueberry is found in Krasnoyarsk Krai (BS – 370 thousands of tons, ES – 74 thousands of tons), Khabarovskiy Krai (BS – 190 thousands of tons, ES – 38 thousands of tons), Irkutsk region (BS – 180 thousands of tons, ES – 40 thousands of tons), Khanty-Mansy AD (BS – 120 thousands of tons, ES – 60 thousands of tons), and Yamal-Nenets AD (BS – 100 thousands of tons, ES – 50 thousands of tons). Minimal stock of blueberry fruits is registered in Central (Yaroslavl, Smolensk, and Moscow regions) and Privolzhskiy (Tatarstan Republic) Federal Districts.

Distribution of relative density of blueberry fruits BS in Russia is uneven. Maximum density of raw material (more than 200 t/thous. km²) is found in Irkutsk regions, Khabarovskiy Krai, Khanty-Mansy AD, and Tomsk region.

Maximum volume of collection of blueberry fruits in the end of 20th century was common in Khabarovskiy Krai, where more than 1 thousands of tons of raw material was collected in fruitful years. Average long-term collection volume in the country during that period didn’t exceed 2 thousands of tons. Currently organized collection of blueberry fruits became rare; e.g., in 2000 in Karelia collection volume was 2.3 t, in 2002 – 1.4 t. Blueberry fruits collection for personal consumption in most regions is insignificant, volumes reaching 1.2-1.4 t only in Khabarovskiy Krai. Level of familiarization of blueberry habitats varies significantly from 10-20 % in Siberia and Far East to 75% in densely populated European regions of Russia.

3.3. Cranberry
Cranberry (*V. oxycoccos* L.) productivity varies in different subzones and plant communities even within the same region. Thus, in Kirov region the most productive habitats (350±50 kg/ha) are low-density cotton-grass-sphagnum and oligotrophic open swamps (table 4). Lower productivity is common for sphagnum, sedge-sphagnum pine forests and mesotrophic open swamps (300±50 kg/ha). Cranberry productivity ranges from 80 to 700 kg/ha, but in the subzones of middle and southern taiga it always stays higher than profitable for collection. Low productivity of cranberry is marked in low density dwarf shrubs pine, sedge-sphagnum birch, sedge-sphagnum pine-birch forests (100±20 kg/ha – 120±20 kg/ha) and high density (0.7-0.8) forest stands - 50±20 kg/ha. Collection of berries in these habitats is profitable only in years of high and medium productivity.

Table 4. Productivity of *V. oxycoccos* L. berries in different vegetation subzone of Kirov region, kg/ha (min – max / average).

| Plant community                        | Middle taiga | Southern taiga | Coniferous-broadleaf forests | Average for the region |
|----------------------------------------|--------------|----------------|-------------------------------|------------------------|
| Sphagnum pine<sup>a</sup> forest       | 150 – 600    | 120 – 560      | -<sup>a</sup>                 | 300 ± 50               |
|                                        | 280±30       | 350±50         |                               |                        |
| Sedge-sphagnum pine<sup>a</sup> forests| 150 – 700    | 160 – 500      | 80 – 500                      | 300 ± 50               |
| mesotrophic open swamp                 | 300 ± 50     | 300 ± 50       | 200± 30                       | 300 ± 50               |
Cotton-grass-sphagnum pine\textsuperscript{b} & 170 – 800 & 170 – 700 & 80 – 500 & 350 ± 50 \\
forest, oligotrophic open swamp & 350 ± 50 & 350 ± 50 & 250 ± 35 & 350 ± 50 \\
Dwarf shrub cotton-grass-

| Productivity in birch forest stands (g/m²) |
|-----------------------------------------|
| **V. myrtillus** & 20 – 280 & 20 – 220 & -a & 100 ± 20 \\
| Sphagnum pine* forest & 100 ± 20 & 100 ± 15 & -a & 100 ± 20 \\
| Sphagnum birch\textsuperscript{b} & 40 ± 210 & 100 ± 20 & a & 100 ± 20 \\
| Sedge-sphagnum birch* forest, & -a & 50 – 180 & 120 ± 30 & 120 ± 30 \\
| dense-sphagnum pine-birch* & & & & \\
| forest & & & & \\
| Dense forest stands (0.7 – 0.8) & 50 ± 20 & & & \\

\textsuperscript{a} cranberry thickets not marked in these communities, 
\textsuperscript{b} low density (0.2 – 0.6) forest stands.

Productivity of cranberry on oligotrophic and meso-oligotrophic swamps of the European part of Russia (Republic of Karelia, Mary-El, Urmurtia; Leningrad and Pskov regions) can reach 2000 kg/ha, while in similar habitats in Siberia (Omsk region, Khanty-Mansy AD) it’s about 1200 kg/ha. BS of cranberry fruits in Russia in medium fruitful year is 451.5 thousands of tons, ES – 116.9 thousands of tons. Maximum resources of cranberry are concentrated in North-Western (62% BS and 54% ES) and Ural (15% BS and 23% ES) Federal. Among separate regions the highest resources are in Komi Republic (BS – 85.0 thousands of tons, ES – 8.5 thousands of tons), Khanty-Mansy AD (BS – 46.8 thousands of tons, ES – 19.5 thousands of tons), and Arkhangelsk region (BS – 43.5 thousands of tons, ES – 14.6 thousands of tons). Leningrad region is leading by relative cranberry fruits stock density (401 to 500 t/thous.km²). In Murmansk, Vologda and Novgorod regions, and Komi Republic relative density of raw material stock ranges from 150 to 300 t/thous.km². These regions, along with Tver region and the Republic of Karelia (which have 101-200 t/thous.km² stock density), are traditional suppliers of cranberry fruits.

Maximum industrial collection of cranberry in 1985-1989 in Russia was 19.3 thousands of tons, average long-term – 8.4 thousands of tons. Actual volume of industrial collection is now increasing after sharp decrease 70-50% in the end of 20\textsuperscript{th} century. In some regions of the European part of Russia it has almost reached average long-term volume of collection in 1985-1989. Collection for personal consumption has also increased 20-40%.

### 3.4. Bilberry species

Six species of bilberry are found in Russia: *Vaccinium arctostaphylos* L., *V. axillare* Nakai, *V. yatabei* Makino, *V. hirtum* Thunb., *V. ovalifolium* Smith, and *V. myrtillus* L. But only 3 of these species are collected industrially: *V. hirtum*, *V. ovalifolium*, and *V. myrtillus*, the latter dominating. *V. myrtillus* occurs in Russia from high mountains of Caucasus to forest-steppe areas, extreme north tundra and tundra, in forest zone – from Kaliningrad region to Khabarovskiy Krai. Maximum productivity of *V. myrtillus* in bilberry types of forest in the European Russia reaches 526 – 860 kg/ha [11, 13], in Western Siberia - 1026 - 1096 kg/ha [14].

*V. myrtillus* productivity varies depending on plant community type. Maximum productivity of the species in Kirov region is defined in bilberry spruce forests (41.5 ± 4.1 g/m²) (table 5), and the value is the most stable, varying within years from 27.1 ± 2 to 72.4 ± 5 g/m². A bit less productive are populations is bilberry birch forests – 37.7 ± 4.9 g/m², ranging from 8.9 ± 0.9 to 86.0 ± 12 g/m². Productivity in bilberry pine forests is 24.1 ± 2.0 g/m² (from 8.9 ± 1 to 80.6 ± 9.6 g/m²). The least productive are bilberry aspen forests – 21.5 ± 2.6 g/m².

Bilberry productivity is relatively stable. During 40 years of observation in Russia medium and highly fruitful years prevailed. BS of industrial bilberry species in Russia in medium fruitful years is 1931.4 thousands of tons, ES – 710.5 thousands of tons. More than 99% of BS and ES is provided by *V. myrtillus*. BS of *V. hirtum* and *V. ovalifolium* doesn’t exceed 500 t. About half of resources is concentrated in Siberian Federal District (49% BS and 41 % ES), quarter – in Ural (26% BS and 34%
ES), and a bit less in North-Western (20% BS and 20% ES) Federal Districts. Among separate territories the highest stocks of bilberry are marked in Krasnoyarsk Krai (BS - 400 thousands of tons, ES – 80 thousands of tons), Novosibirsk (BS - 200 thousands of tons, ES 60 – thousands of tons) and Irkutsk (BS – 200 thousands of tons, ES – 70 thousands of tons) regions, Khanty-Mansi AD (BS – 200 thousands of tons, ES, ES – 100 thousands of tons), Komi Republic (BS – 132.9 thousands of tons, ES – 39.9 thousands of tons.), Arkhangelsk region (BS - 98.8 thousands of tons, ES – 40.5 thousands of tons), and the Republic of Karelia (BS – 70.0 thousands of tons, ES – 28.7 thousands of tons). Average long-term productivity score in these regions is 3.5-3.7. Maximum raw material stock density (no less than 300 t/thous. km$^2$) is defined for Novosibirsk region, Khanty-Mansi AD, Republics of Karelia and Komi, and Vologda region.

Table 5. Average long-term productivity of Vaccinium myrtillus L. berries in different forest types in Kirov region (1961 – 2004).

| Forest type      | Number of plots | Productivity, g/m², M ± m / limit | Weight of 1 berry, g., M ± m / limit | Number of berries, per m², M ± m / limit |
|------------------|-----------------|-----------------------------------|--------------------------------------|------------------------------------------|
| Bilberry spruce  | 1281            | 41.5 ± 4.1                        | 0.31 ± 0.019                         | 133.9 ± 14.8                             |
| Bilberry pine    | 952             | 27.1 – 72.4                       | 0.23 – 0.42                          | 19 – 342                                 |
|                  |                 | 24.1 ± 2.0                         | 0.29 ± 0.024                         | 79.7 ± 7.2                               |
|                  |                 | 10.7 – 80.6                        | 0.21 – 0.41                          | 8 – 246                                  |
| Bilberry birch   | 1026            | 37.7 ± 4.9                        | 0.31 ± 0.019                         | 130.0 ± 12.7                             |
|                  |                 | 8.9 – 86.0                         | 0.23 – 0.42                          | 15 – 321                                 |
| Bilberry aspen   | 929             | 21.5 ± 2.6                        | 0.28 ± 0.022                         | 67.9 ± 8.4                               |
|                  |                 | 5.3 – 39.8                         | 0.20 – 0.9                            | 5 – 211                                  |

Statistics on collection volumes of bilberry fruits in the end of 20th century are absent. Bilberry was mostly stocked dry. Volumes of organized collection in most regions did not exceed 100-1000 kg of dry weight, 20-35 t of dry raw material in total in Russia. In 2000’s there was increased interest in quick-frozen berries for export, and nowadays bilberry collection is being conducted in almost every region of its range. The leaders (Karelia and Arkhangelsk region) annually supply 600-1550 t of bilberry each.

BS of raw material of studied plants of Vacciniaceae family in Russia in medium fruitful year reaches 4733.9 thousands of tons. Maximum stocks are typical for Krasnoyarsk Krai (BS 810.5 thousands of tons), Khanty-Mansi AD (BS 477.3 thousands of tons), Komi Republic (BS 473.8 thousands of tons), and Irkutsk region (BS 423.1 thousands of tons).

4. Conclusion
Total maximum industrial collection of Vacciniaceae raw material in 1985-1989 was 50 thousands of tons, average long-term – about 20 thousands of tons; dominated by lingonberry (14.9 thousands of tons) and cranberry (27.3 thousands of tons). Today’s volume of industrial collection decreased 30-80% in remote areas and increased twice in bordering regions. Resource potential allows increasing collection volumes without causing any harm to population, but collection should be organized according to the data on resource potential for certain territories and withdrawal norms. Sustainable use of resources implies territorial optimization, differentiation of collection volumes, suitable criteria and rules for collection.

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